Studii şi Cercetări	Martie 2023	Biologie	32/1	37-41	Universitatea"Vasile Alecsandri" din Bacău

PHYTOTOXIC EFFECTS OF A COMMON LAUNDRY DETERGENT ON LETTUCE (*LACTUCA SATIVA* L.) USING THE MATHEMATICAL MODELLING OF FACTORIAL TYPE

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Key words: *phytotoxicity, lettuce, laundry detergent, mathematical modelling*

INTRODUCTION

The using of detergents for cleaning clothes is a common act of human existence today.The type of detergents (automatic/manual/powder/liquid) as well as the quantities used in each household, varies according to several factors: the socioeconomic status, the living of residential environment (urban / suburban / rural), number of family members, age and their purchases etc (Uzma S., et colab., 2018 ;Vassilenko E., et colab., 2021).

According to reports, at the level of 2021, in the EU, powder detergents generated a total retail sales value of 5.1 billion euros and an increase of almost 3.8% is estimated until 2028 (https://www.statista.com/statistics, Peruzzi D., 2022).

Powdered detergents as well as those in tablet or liquid form contain a varied range of compounds with the role of: surfactants, enzymes, bleaching agents, water softening agents, perfume, which can have negative repercussions on the ecosystem and ultimately on the human health. (Sobrino A., 2018; Finizio L., et al. 2020; Salvatori E.,2021).Ariel powder contains, according to the leaflet, approx. 44 chemical compounds (www.starlaundryaids.com) and the way in which it can affect the state of biocenoses depends on the way in which domestic wastewater is collected and cleaned. Detergents can negatively affect the state of the aquatic ecosystem, but also of the soil, especially in rural areas where household waste water is not collected in a centralized system, but is thrown on the ground, in one's own household, affecting the plants in the immediate vicinity (Salbatori E., et al . 2021).

There are relatively few studies regarding the optimization of the physiological processes of germination and growth of lettuce seedlings in laboratory conditions under the effect of detergents using a factorial experiment design procedure. Mathematical modeling through the factorial design procedure takes into account not only the individual (simple) effect of each parameter, but also their interaction and/or possible synergy effects. Such a convenient procedure requires a minimum number of experiments, through a suitable choice of parameter ranges, and can be easily generalized (Azzouz A., et al, 2002; Georgescu AM., et al. 2013; Georgescu AM., et al. 2017; Popa O., et al. 2022).

The aim of this paper is to establish an optimal domain for physiological processes of germination and growth of lettuce seedlings, using an experimental design study. Two factors were varied (imbibition time and detergent concentration) and evolution of root-shoots and cotyledon lengths were achieved as the response functions.

MATERIALS AND METHODS

The materials used in this study were: Ariel powder detergent with lavender (Ariel Lavander Freshness), purchased from the supermarket, lettuce (*Lactuca sativa* L.) variety MeravigliaD'Inverno purchased from the specialty store. Other materials used: universal soil, Floriol type, distilled water, compartmented pot, caliper, Petri dishes, Sanyo growth chamber, (fig.1). The concentrations of the detergent used in the experiment on the test plant were 0.5 g/L; 5.5 g/L and 10.5 g/L.

The working method for evaluating the growth and development of the test plant (fig.1) consisted in the preparation of 9 compartments in which soil and a quantity of 25 mL of solution. They were watered for the growth period only with distilled water. In each compartment, 5 seeds covered with a thin layer of soil were added. The duration of the experiment was 12 days, during which they were checked daily. Initially, they were kept in the dark, then with the 16/8 photoperiod in the Sanyo chamber.

The experimental part for the evaluation of germination (fig. 1) consisted in the following stages: Petri dishes were prepared; the seeds were initially left in contact with the tested substance in different ways. Work was done with 3 repetitions for each experimental variant and the imbibition time at which the seeds were placed was 1h, 6h and 11h for each concentration and for the control sample. The experimental variant of each tested detergent concentration contained a sample formed of 10 seeds. After soaking, the seeds were transferred to Petri

dishes on the basis of a layer of paper soaked in the appropriate detergent solution, the control sample being only distilled water. The duration of the experiment was 3 days, during which the Petri dishes kept in the dark, in the Sanyo room, were checked daily and watered where necessary.

The biometric measurements were made with the Powerfix-profi digital caliper.

Factorial design

The aim of this paper was the investigation of germination processes in the case of lettuce (*Lactuca sativa* L.) the MeraviglaD'Inverno variety. This investigation is realized by the influence of two parameters: imbibition time (X_1) and detergent concentration (X_2).The response functions analyzed were: root-shoot length (Y_1) and cotyledon length (Y_2). In Table 1 are presented the variation ranges of the investigated parameters.

RESULTS AND DISCUSSIONS

Design of experiments

In Table 2 are presented the analyzed response functions (root-shoot and cotyledon lengths), which reduced values are presented in parenthesis. Three other tests were also realized in the central point of the domain (0, 0) for the calculation of the significance of this program.

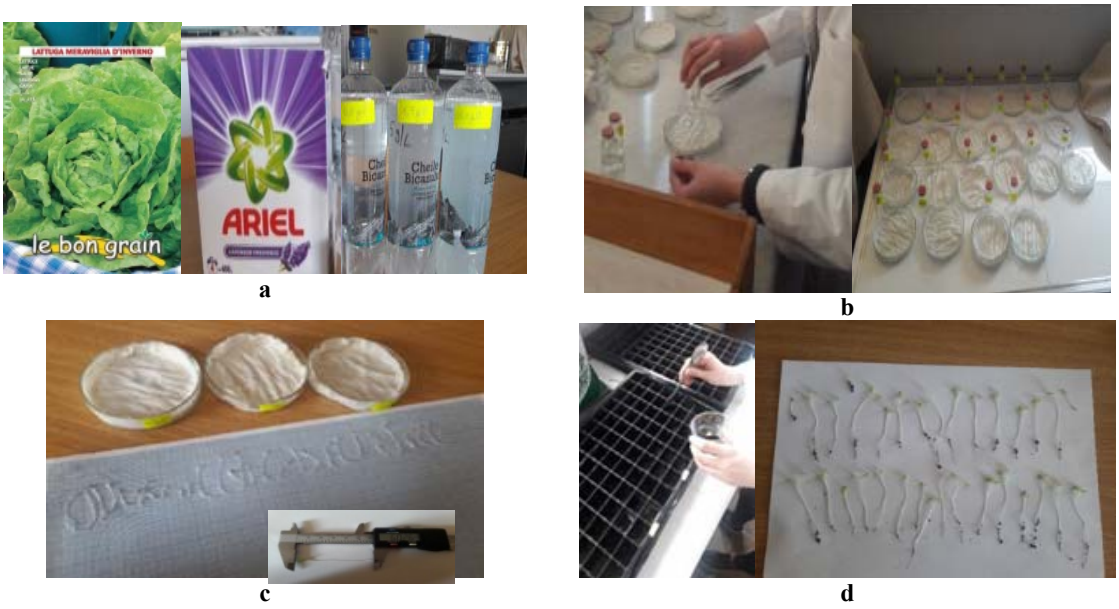

Fig. 1. Materials and results of biometric measurements on lettuce plants: a, b, c, d

Table 1. Parameters that influence germination process of lettuce (*Lactuca sativa* L.)

Parameters (x_i)	**Reduced variable**	**Minimal level(X_i^{min})**	**Median level (X_i^{med})**	**Maximal level(X_i^{max})**	**ΔX_i**
Imbibition time [h]	x_1	1	6	11	5
Detergent concentration [g/L]	x_2	0.5	5.5	10.5	5

Table 2. Varied parameters and response functions for root and cotyledon lengths of lettuce

Sample	**Imbibition time [h]**	**Detergent concentration [g/L]**	**Root-shoot length [mm]**	**Cotyledon length [mm]**
	x_1	**x_2**	**Y_1**	**Y_2**
1	1 (-1)	0.5 (-1)	6.63	19.87
2	1 (-1)	5.5 (0)	5.52	10.77
3	1 (-1)	10.5 (+1)	3.29	6.68
4	6 (0)	0.5 (-1)	6.95	21.56
5	6 (0)	5.5 (0)	6.45 (6.12; 6.84; 6.77)	10.98 (11.21; 10.31; 10.79)
6	6 (0)	10.5 (+1)	3.37	5.98
7	11 (+1)	0.5 (-1)	5.66	17.62
8	11 (+1)	5.5 (0)	5.22	8.19
9	11 (+1)	10.5 (+1)	2.96	4.62

Elaboration of the mathematical model

The response function for 3^2 type factorial program has the particular form (1).

The coefficients values of polynomial mathematical models (see Table 3), were calculated according to the literature (Lazic, 2004; Nistor et al., 2015).

Table 3. Values of the polynomial coefficients

Coefficients	Coefficient value for Y_1	Coefficient value for Y_2
a_0	6.20	11.01
a_1	-0.27	-1.14
a_2	-1.60	-6.96
a_{12}	0.10	0.03
a_{11}	-0.71	-1.54
a_{22}	-0.92	2.74

After the calculation of the polynomial coefficients, the mathematical models which describe the response functions(root-shoot and cotyledon lengths) are presented in equation (2).

Determination of the coefficients significance

The significance of the polynomial coefficients of the two response functions was realized with the *t - student* test, according to the algorithm presented in the literature (Nistor, I.D., et al. 2008; Lazic Z., 2004; Georgescu et al., 2013; Popa O. et al., 2022).In the case of both mathematical models, the *t-student* test results (see Table 4) indicate that interaction term (a_{12}) must be eliminated.

According to literature (Nistor, I.D., et al. 2008; Lazic Z., 2004; Georgescu et al., 2013; Popa O. et al., 2022), the absolute values and the signs of each coefficient separately will be discussed.

In the case of the first response function (root-shoot length), the a_o value indicates that the optimal root-shoot length is approximately equal to6.2mm. Because the individual coefficients (a_1 and a_2)are negative, the x_1 and x_2 variables have an unfavorable individual effect on the germination process. The response function is characterized by a maximum in relation to x_1 and x_2 variables, due to the negative signs of the quadratic term coefficients (a_{11} and a_{22}).

In the case of the second response function, the optimal cotyledon length value is close to 11.01 mm. The quadratic term coefficients ($a_{11}$and a_{22}) which values are negative, respectively positive, so the response function (Y_2) is characterized by a maximum in relation to variable x_1 and by a minimum in relation to variable x_2.

The partial derivatives of first order were calculated, in rapport with each variable. In the case of Y_1 response function, the optimal point was (-0.19; -0.87), represented in dimensionless coordinates. The optimal values for x_1 and x_2 are within the limits of the domain (-1, 1) which initially were supposed.

The real values of the optimal conditions for lettuce germination process were obtained for animbibition timeof 4.55 h and a detergent concentration of 1.65 g/L. In the case of the second response function (Y_2), the optimal point was (-0.37; 0.78).

The optimal values are within the limits of the domain (-1, 1) initially supposed. The real values of the optimal conditions for lettuce germination process were obtained for an imbibition timeof 3.65 h and a detergent concentration of 9.9 g/L.

In figures 2 and 3 are presented the dependences between imbibition time and detergent concentration on root-shoot and cotyledon lengths for the germination of lettuce (*Lactuca sativa* L.) the MeravigliaD'Inverno variety.

As long as both coefficients of quadratic terms have negative signs, the quadratic terms determine a maximum and the response surface (Fig. 2), which corresponds to the model is concave. The different signs of quadratic coefficients terms show a saddle-shape response surface (see Fig. 3).

$$Y = a_o + a_1 \cdot x_1 + a_2 \cdot x_2 + a_{12} \cdot x_1 \cdot x_2 + a_{11} \cdot x_1^2 + a_{22} \cdot x_2^2 \quad (1)$$

$$Y_1 = 6.2 - 0.27 \cdot x_1 - 1.6 \cdot x_2 + 0.1 \cdot x_1 \cdot x_2 - 0.71 \cdot x_1^2 - 0.92 \cdot x_2^2$$

$$Y_2 = 11.01 - 1.14 \cdot x_1 - 6.69 \cdot x_2 + 0.03 \cdot x_1 \cdot x_2 - 1.54 \cdot x_1^2 + 2.74 \cdot x_2^2 \quad (2)$$

Table 4. Results of the *t-student* test

t_j	t_0	t_1	t_2	t_{12}	t_{11}	t_{22}
Values for Y_1	95,43	4,10	24,67	1,64	10,92	14,15
Values for Y_2	157,31	16,40	99,45	0,45	22,12	39,17

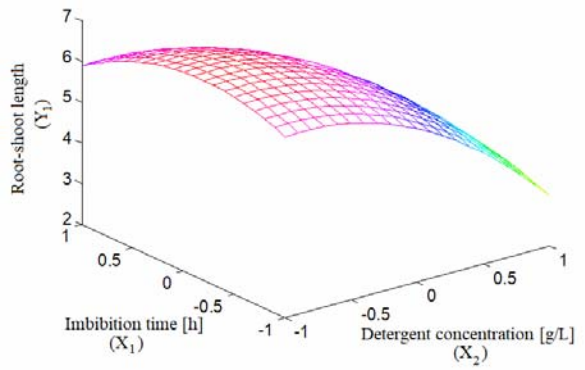

Fig. 2. Influence of imbibitions time (X_1) and of detergent concentration (X_2) on root-shoot length (Y_1)

$$Y_1 = 6.2 - 0.27 \cdot x_1 - 1.6 \cdot x_2 - 0.71 \cdot x_1^2 - 0.92 \cdot x_2^2$$

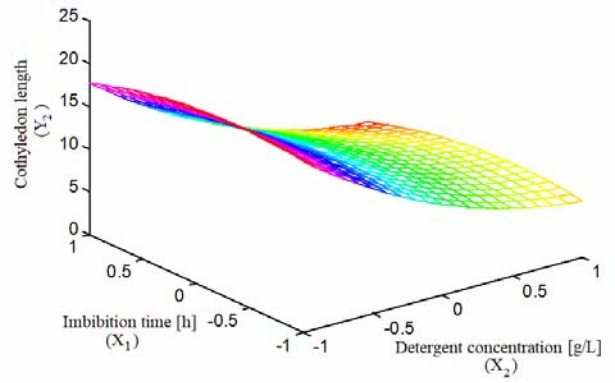

Fig. 3. Influence of imbibitions time (X_1) and of detergent concentration (X_2) on cotyledon length (Y_2)

$$Y_2 = 11.01 - 1.14 \cdot x_1 - 6.69 \cdot x_2 - 1.54 \cdot x_1^2 + 2.74 \cdot x_2^2$$

CONCLUSIONS

Tests performed on lettuce (*Lactuca sativa* L) as a test species (OECD 208) showed that Ariel detergent in the concentrations used did not significantly influence the growth and germination process.

Observations made on the germination process of lettuce (*Lactuca sativa* L.) revealed that all tested variants had germinated after 3 days of seeds germination, in the Sanyo growth chamber at 18° C. This result led to the conclusion that the effect of the detergent on germination was minimal.

The optimized values obtained from the experimental design are in agreement with the values of parameters initially explored.

The effect of the detergent tested in concentrations of 0.5 g/L, 5.5 g/L and 10.5 g/L was minimally affected on the lettuce germination process with the emergence percentage varying between 0.5 g/L and 10.5 g/L. Visible effects were highlighted by the biometric measurements of root-shoot length with a minimum of 2 mm and a maximum of 64.15 mm.

The impact of detergents on the environment must be continued by monitoring the influence of other concentrations on the plants and animal testing at the laboratory and the field level.

ABSTRACT

Laundry detergents are mixtures of chemical compounds commonly used as cleaning agents for clothes and various objects. Their different degree of decomposition and transformation make wastewater to contain a variable proportion of such contaminants. There is a possibility of contamination of the soil, but also of plant crops with detergents, if these insufficiently treated waters are used in irrigation.The aim of this study is to evaluate the degree of phytotoxicity of lavender powder detergent on lettuce (*Lactuca sativa* L.). The effect of the detergent was highlighted through the germination of seeds and the growth of lettuce seedlings.The use of lettuce as a test plant is recommended by OECD 208 and is a species that can be easily handled in pilot conditions but also in the field.

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