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APPLICATION OF ARTIFICIAL NEURAL NETWORKS TO ANALYZE THE EMERGENCE OF SOYBEAN SEEDS AFTER APPLYING HERBAL TREATMENTS

Summary

The aim of the following work is to indicate factors which significantly affect the emergence of selected soybean varieties after application of natural herbal extracts based on - Levisticum officinale L., *Ribes nigrum* L., *Matricaria chamomilla* L., *as wet seed treatments using two methods of treatment. The research material included seeds treated for 24 hours in macerats, decoctions and infusions made from the above herb species as well as untreated seeds, seeded together with preparations in point application. Untreated seeds were used as the control group. The experiment was being conducted for 16 days in a greenhouse facility belonging to the COBORU Experimental Station for Variety Testing in Karzniczka. The assessed parameter referred to the percentage of soybean seedlings emergence ability determined based on the number of emerged plants. Indication of the importance of factors in shaping soybean emergence and considering their rank was possible due to the sensitivity analysis of the generated neural network with the MLP architecture 4:4-13-5-1:1 with two hidden layers. All analyzed factors of the experiment significantly shaped the ability of soybean emergence, with the following order: cultivar, application method, herb species from which the extract was made, form of preparation.*
***Key words**: soybean, natural seed treatments, neural networks, sensitivity analysis, MLP*

ZASTOSOWANIE SZTUCZNYCH SIECI NEURONOWYCH DO ANALIZY WSCHODÓW NASION SOI PO ZASTOSOWANIU ZAPRAW ZIOŁOWYCH

Streszczenie

Celem pracy było wskazanie czynników istotnie wpływających na wschody wybranych odmian soi po zastosowaniu naturalnych ekstraktów wodnych na bazie ziół - Levisticum officinale L., *Ribes nigrum* L., *Matricaria chamomilla* L., *jako zapraw nasiennych na mokro z wykorzystaniem dwóch sposobów zaprawiania. Materiał badawczy stanowiły nasiona zaprawiane przez dobę w maceratach, wywarach i naparach sporządzonych z powyższych gatunków ziół oraz nasiona niezaprawiane, wysiewane łącznie z aplikacją punktową preparatów. Za obiekt kontrolny przyjęto nasiona niezaprawiane. Eksperyment prowadzono przez 16 dni w obiekcie szklarniowych należącym do Stacji Doświadczalnej Oceny Odmian COBORU w Karzniczce. Parametrem poddanym ocenie była procentowa zdolność wschodów siewek soi określana na podstawie liczby wzeszłych roślin. Wskazanie istotności czynników w kształtowaniu zdolności wschodów soi oraz uwzględnienie ich rangi było możliwe dzięki analizie wrażliwości wytworzonej sieci neuronowej o architekturze MLP 4:4-13-5-1:1 z dwoma ukrytymi warstwami. Wszystkie analizowane czynniki doświadczenia znacząco kształtowały zdolność wschodów soi, a ich waga miała następującą kolejność: odmiana, sposób aplikacji preparatu, gatunek zioła, z którego sporządzono ekstrakt, forma preparatu.*
***Słowa kluczowe**: soja, naturalne zaprawy nasienne, sieci neuronowe, analiza wrażliwości, MLP*

1. Introduction

In recent years, an increasing number of consumers are turning to organic food [8, 30]. In order to meet the needs of the market, food manufacturers look for ways of effective crop cultivation in the organic system in terms of quantity and quality of crops. Each plantation, regardless of the production system, should be protected and nurtured from the very beginning. An important criterion determining the success of cultivation, especially organic, is the quality of seeds. One of the basic methods of seed refinement is treatment which can be a way to obtain high quality seeds. The advantage of such process consists in effective protection of seeds against soil pathogens after their emergence. In addition, seed treatment improves the vigor of seedlings, which translates into achieving the optimal planting density in the field [25]. Due to the complete ban on synthetic chemical seed treatments in organic crops, different natural preparations are used to refine the seeds. This may include plant substances: essential oils [5, 28] powdered herbs [19] or plant extracts [10]. The efficiency and effectiveness of natural decoctions is much poorer than chemicals. What's more, the germination capacity of seeds treated with natural substances may be different, because each variant can react differently to the same treatments [20]. Other factors, i.e. the concentration of substances contained in the preparations, time of soaking seeds, storage conditions of seed are also important in the course of emergence[1].

In recent years, there has been an increase in the use of artificial neural networks in agriculture, where often better results of analyzes are obtained comparing to classical statistical methods [7, 12-13, 16-18, 27].

The aim of the following work is to analyze the factors responsible for the course of soybean emergence after applying aqueous herbal extracts as "wet" seed treatments by means of different application method. Utilization of the sensitivity analysis on the created neural network allowed for the weight classification of factors affecting the germination of selected soybean varieties.

2. Materials and methods

The experiment was conducted in July in a greenhouse facility belonging to the COBORU Experimental Station for Variety Testing in Karzniczka located in the Pomeranian Voivodeship (φ = 54o29', λ = 17o14', H = 80 m above sea level). During 16 days of the experiment, the temperature and humidity conditions were controlled. The previously untreated seeds of three soybean varieties were used for the test: Abelina, Augusta and Merlin. The seeds were treated with water extracts prepared from the following herbs: *Levisticum officinale* L. roots, *Ribes nigrum* L. leaves, *Matricaria chamomilla* L. anthodium. Three forms of water extract were prepared for each herb species - macerate, infusion and decoction, according to the recipe given by Sas-Piotrowska and Piotrowski [22], Sas-Piotrowska et al. [20]. The soil used in the experiment was collected in June from the arable layer (0-20 cm) of organic oat field. The forecrop was organic narrow-leafed lupine. Soil samples were sieved through 4 and 2 mm mesh. In order to restore the lumpy structure, the soil was moistened with a small amount of water. Then it was mixed with the garden peat (pH 6,5) in a ratio of 1:2 (peat: soil). The experiment was performed in a completely random system, in 86 plastic multi-pots with 110 cuvettes for seeding at 5.5 cm depth. A single experimental combination consisted of 50 seeds sown at a depth of 3 cm, and each combination was prepared in triplicate. For each multi-pot stand, twelve hours before sowing, 400 ml of distilled water was added. In the experiment, the aqueous extracts were applied in two ways, i.e. the seeds were soaked for 24 hours in prepared extracts, dried in room conditions and then seeded into multi-pots. In the second variant, 24-hour soaking of seeds in distilled water, drying in room conditions and sowing with simultaneous application of aqueous extract (3 ml per 1 hole) was applied.

Source: own work / Źródło: opracowanie własne

Fig. 1. The emerging soybean seedlings during the experiment

Rys. 1. Wschodzące siewki soi w trakcie prowadzenia eksperymentu

The control group consisted of untreated seeds soaked for 24 h in distilled water. For 15 days (day 1- first day of seedling), seedlings were counted at eight-hour intervals (Fig. 1).

2.1. Method of building neural models

The selection of independent variables for the construction of the neural model was made in such a way to allow the neural network function on the basis of input variables of linguistic character [14, 23]. On the other hand, the output of the network presents a dependent variable - the percentage ability of emergence. All data are presented in Table 1.

When choosing a network topology and learning method, its ability to approximate and generalize was taken into account, basing on measures of their quality. The application of the Statistica v13.1 software allowed to test a network with two architectures - MLP and RBF. For the presented neural model, the number of tested networks was 10000 using the Automatic Network Designer. The selection of the network was based on the best parameters which determined the quality of the network.

The empirical data set was randomly divided into a learning, validation and test set. The number of sets was as follows: learning - 121 cases, validation - 25 cases, testing - 25 cases. The division of the set was made randomly in the proportion of 70 - 15 - 15%.

Table 1. Data structure in neural model

Tab. 1. Struktura danych w modelu neuronowym

Symbol	Variable name	Data range	Input/ Input of ANN
Z_in	Herb species/control	Control *Levisticum officinale* L. *Ribes nigrum* L. *Matricaria chamomilla* L.	Input
W_in	In-soil spot application	Yes No	Input
O_in	Variety	Abelina Augusta Merlin	Input
P_in	Type of preparation	None macerate infusion decoction	Input
K_out	Ability of emergence	44-100 %	Output

Source: own work / Źródło: opracowanie własne

2.2 Sensitivity analysis of the neural network

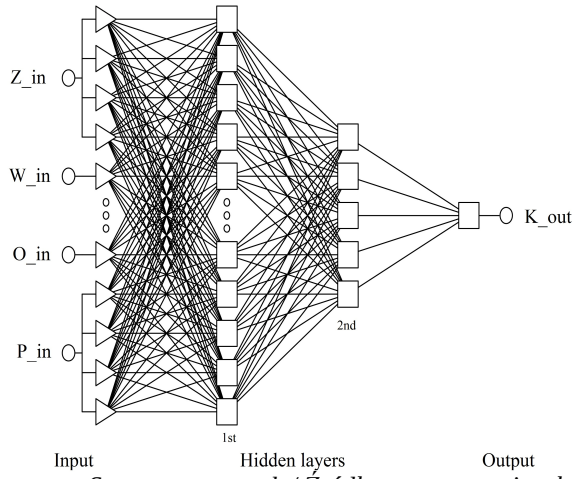
In order to check which of the tested independent features have the greatest influence on the soybean emergence ability, a sensitivity analysis of the created neural network is carried out. Once the input variable is removed (independent feature) from the model, its impact on the cumulative error of the neural network can be observed, thanks to which the significance (influencing the result - soybean emergence abilities) of individual independent features is determined. There are two indicators that deal with it:

- error quotient - is the error ratio, to the error obtained using all independent features, the larger it is, the greater the significance of a given feature. If it takes a value below 1, you can remove a given feature from the model to improve its quality, but it is not mandatory,
- rank - shows in the numerical manner the features according to decreasing error, the rank with the value of 1 is the most important for the network.

3. Results and discussion

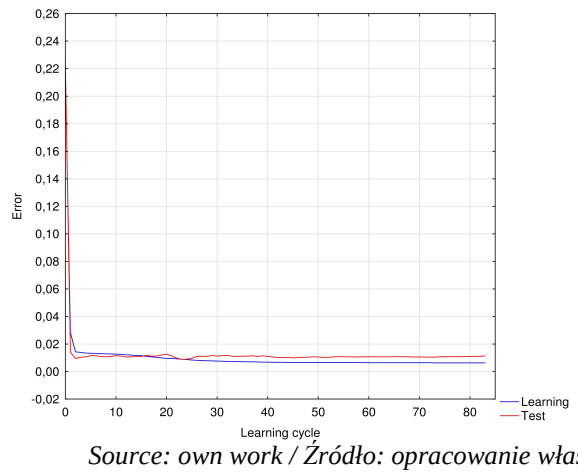
The generated neural model based on the MLP network has 4 neurons at the network input, 13 neurons in the first hidden layer, 5 neurons in the second hidden layer and one neuron at the network output (Fig. 2). The applied method of learning the network was single-stage. The network was trained using the Broyden-Fletcher-Goldfarb-Shanno gradient method (BFGS) which achieved the optimal result in the 23rd epoch (Fig. 3).

The Broyden-Fletcher-Goldfarb-Shanno algorithm belongs to the class of quasi-Newtonian methods, also known as variable metrics methods. It is characterized by high stability and low sensitivity to directional minimization errors and does not use the Hesse matrix [2].



Source: own work / Źródło: opracowanie własne

Fig. 2. General structure of the MLP artificial neural network
Rys. 2. Struktura sztucznej sieci neuronowej o topologii MLP



Source: own work / Źródło: opracowanie własne

Fig. 3. Neural network learning chart
Rys. 3. Wykres uczenia sieci neuronowej

The obtained parameters of the created neural model should be considered as satisfactory. The training, validation and test errors were around 0,01, and the correlation coefficient was 0,617. Basic information on the quality of the created neural model is included in Table 2.

Table 2. The quality and structure of the neural model
Tab. 2. Struktura i wskaźniki jakościowe modelu neuronowego

Neural Network structure	MLP 4:4-13-5-1:1
Learning Error	0,01390
Validation Error	0,01181
Test Error	0,01695
Mean	77,47368
Standard Deviation	12,98236
Average Error	0,07746
Deviation Error	10,23441
Mean Absolute Error	8,05278
Quotient Deviations	0,78833
Correlation	0,61740

Source: own work / Źródło: opracowanie własne

Sensitivity analysis of the neural network showed a significant impact (the error quotient greater than 1) of all the analyzed features on the percentage ability of soybean emergence. The most influential was the (O_in) variety, which reached the quotient of 4,31. Another factor with the quotient of 3,45 referred to the water extract application method (W_in). The third concerned the type of herb used (Z_in). The last, fourth position, with the ratio of 2,28 considered the type of preparation (P_in). The results are summarized in Table 3.

Table 3. Sensitivity analysis of neural network
Tab. 3. Analiza wrażliwości sieci neuronowej

Variable	Quotient	Rank
Z_in	2,810339	3
W_in	**3,459628**	**2**
O_in	**4,314393**	**1**
P_in	2,283215	4

Source: own work / Źródło: opracowanie własne

Over the last years, a tendency of using modern information technologies more widely is observed in order to better understand relationship between many processes occurring in nature, including germination of seeds. Mladenov and Denanov [15] used neural modeling for detailed image segmentation of seed emergence, using texture and color models. The image of germinating seeds was divided into background, roots, seeds and seedlings. Using a modified neural network with radial basal function network (RBFN) as a tool supporting image processing to assess germination of seeds was found as having high efficiency. Neural networks are also used to identify varieties of cultivated species based on color, morphological traits [29] or in addition the texture of seeds [24]. In the automatic assessment of tomato emergence rate, artificial neural networks were used to correctly identify emerging seeds. After correct identification of the object in the ready image, the task of perceptron network (MLP), an artificial neural network model, was to accurately classify the emerging seeds. The results showed very high accuracy of predictions (95,44%) of the applied neural network [26].

In the independent research, artificial neural networks were used to analyze factors responsible for germination and

emergence of selected soybean varieties after application of aqueous herbal extracts as "wet" seed treatments using two treatment techniques. Additionally, the performed sensitivity analysis of the created neural network allowed weighting the experiment factors. The soy variety i.e. genotype was the highest-rank factor. It is known that genetic differences between varieties of a given species determine the rate of aging and degradation of seeds [3] to [9]. Other genetic traits, such as the size of the seeds, the color of the seed coat, their chemical composition, shape the expression of the seed vigor. Inheritance of genes responsible for the vigor of soybeans has also been partially recognized [4]. Genetic compounds regulating the ability of emergence and rising of soybeans were not the subject of extensive research due to the greater interest in the influence of environmental factors [3]. The second important factor included the method of application of seed treatments, divided into 24-hour seed soaking in water extracts (point seeding to soil - NO), and 24-hour soaking in distilled water (point seeding to soil - YES) and treatment application together with seeding to soil. In research by Czerwińska et al. [6] the emergence ability of yellow lupine and pea was improved for untreated seeds, when infusion preparations were given during sowing. According to other authors, long-term soaking of seeds before sowing in "wet" treatments is effective because it decontaminates the seed properly [11]. Another important factor, the herb species, takes into consideration the active substances that affect the emergence ability of seeds and emergence of soybean seedlings. Improving germination of seeds is often closely correlated with improving the healthiness of seed [21]. The authors above presented a significant relationship between emergence ability of barley and the method of preparing water extracts. From all extracts made from 40 plant species, 30% of infusions and 27.5% of macerates showed a beneficial effect on the discussed parameter. In an independent research, the significance of the form of preparation in shaping the soybean's emergence ability was also confirmed, but on the basis of the conducted sensitivity analysis of the network, this factor obtained the lowest rank possible.

4. Conclusions

1. The created artificial neural network with 4:4-13-5-1:1 MLP architecture allows for gravimetric analysis of factors affecting the ability of emergence.

2. The sensitivity analysis of the neural network showed a significant impact of all analyzed features on the percentage of soybean emergence (K_out).

3. The variety (O_in) was the most influential on the soybean emergence, while the type of the preparation (P_in) was the least.

4. Further research should be carried out to increase the accuracy of the calculation while expanding the scope of the material examined.

5. Further research should be carried out on the chemical composition analysis of the water extracts used, as well as verification of the obtained results of the greenhouse test in field conditions.

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