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SUMMARY

Evaluation of manures, composts and growing media quality should include enough properties to enable an optimal use from productivity and environmental points of view. The aim of this paper is to describe basic structure of organic fertilizer (and growing media) evaluation model to present the model example by comparison of different manures as well as example of using plant growth experiment for calculating impact of pH and EC of growing media on lettuce plant growth. The basic structure of the model includes selection of quality indicators, interpretations of indicators value, and integration of interpreted values into new indexes. The first step includes data input and selection of available data as a basic or additional indicators depending on possible use as fertilizer or growing media. The second part of the model uses inputs for calculation of derived quality indicators. The third step integrates values into three new indexes: fertilizer, growing media, and environmental index. All three indexes are calculated on the basis of three different groups of indicators: basic value indicators, additional value indicators and limiting factors. The possible range of indexes values is 0-10, where range 0-3 means low, 3-7 medium and 7-10 high quality. Comparing fresh and composted manures, higher fertilizer and environmental indexes were determined for composted manures, and the highest fertilizer index was determined for composted pig manure (9.6) whereas the lowest for fresh cattle manure (3.2). Composted manures had high environmental index (6.0-10) for conventional agriculture, but some had no value (environmental index = 0) for organic agriculture because of too high zinc, copper or cadmium concentrations. Growing media indexes were determined according to their impact on lettuce growth. Growing media with different pH and EC resulted in very significant impacts on height, dry matter mass and leaf area of lettuce seedlings. The highest lettuce seedlings with highest mass and leaf area are produced using growing media with pH close to 6 and with EC lower than 2 dSm^{-1}. It could be concluded that conductivity approx. 3 dSm^{-1} has inhibitory effect on lettuce if pH is about 7 or higher. The computer model shows that raising pH and EC resulted in decreasing growth which could be expressed as increasing stress index. The lettuce height as a function of pH and EC is incorporated into the model as stress function showing increase of lettuce height by lowering EC from 4 to 1 dSm^{-1}or pH from 7.4 to 6. The highest growing media index (8.1) was determined for mixture of composted pig manure and peat (1:1), and lowest (2.3) for composted horse manure and peat (1:2.)

Key-words: composts quality, manures, fertilizer index, environmental index, growth media index, lettuce

INTRODUCTION

Parameters for evaluation quality of organic materials were investigated by numerous researchers in fields of composts maturity and stability (Vukobratović, 2008; Matteson and Sullivan, 2006; Wu and Ma, 2001), commercial quality (Tomati et al., 2002), toxicity (Vukobratović, 2008; Wong et al., 2001), etc. Numerous scientists published integrated chemical, physical and biological approach to compost quality evaluation (Mondini et al., 2003; Campitelli and Ceppi, 2007) and increasing number of authors developed computer models (Nemati and Fortin, 2008) for parameter prediction or as decision support systems (Horn et al., 2003). Simultaneously, many composted manures have been

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studied for their potential as constituents of growing media (Carlile, 2008). Different analytical methods have been used for the characterization of compost-based substrates and their ability to predict nutritional disorders during plant cultivation (Frangi et al., 2008; Baumgarten, 2008).

At the moment, there isn't any generally accepted system for organic fertilizer quality evaluation in Croatia although some results about organic fertilizer analyses and quality (Vukobratović, 2008; Vukobratović at al., 2009; Lončarić et al., 2005.) have been recently published. Moreover, Lončarić et al. (2009.) published the general description of model proposed for evaluation of fertilization quality of organic fertilizer. Authors included some aspects of environmental suitability of organic fertilizers too. However, model has recently been upgraded, expanded and corrected. The aim of this paper is to describe the basic structure of the model for organic fertilizer (and growing media) quality evaluation; to present upgraded approach for calculation of fertilization quality and environmental suitability and to present examples by comparison of quality of different fresh and composted manures. However, there are some parts of the model still not developed in a field of environmental suitability evaluation. Also, a new part of the model is evaluation of suitability of organic fertilizer or mixtures as growing media. The aim of the paper was to present example of plant growth experiment used for calculating impact of pH and EC of growing media on lettuce plant growth and for calculation of growth media suitability.

MATERIAL AND METHODS

The computer model has been developed respecting different importance of physical, chemical and biological quality indicators considering fertilization, growing media and environment points of view. Four different manures (cattle manure, horse manure, separated pig manure and chicken manure) were analyzed for contents of macronutrients (N, P, K), Na, micronutrients (Fe, Mn, Zn, Cu, Mo, Ni, Cl), and Cd, Co, Cr, Pb in a fresh and composted manures. In addition to that, C/N and NH_4-N/NO_3-N ratios were also analysed. The mentioned properties were already published by Vukobratović (2008), Vukobratović et al. (2008), Lončarić et al. (2005). The published data were used as examples for the model for calculating indexes (Fertilizer, Environment and Grown Media Index). The indexes present evaluation of organic fertilizer quality, where value 10 present the highest qualities and value 0 the lowest ones. Properties of organic fertilizer used for calculation of Fertilizer Index are N, P, K, Na, Cl content and CN and NH_4-N/NO_3-N ratios (Table 1). Also, a plant growth experiment with lettuce (*Lactuca sativa* L.) grown in different growing media was conducted. Different mixtures of composted cattle, pig, horse and chicken manures were prepared for lettuce sowing as 15 growing media with pH in water suspension (1:10 w/v) ranged from 5.89 to 8.17 and electrical conductivity (EC, 1:5 w/v) from 0.93 to 5.54 dSm^{-1}. The lettuce was sowed in containers with 80 ml volume and 5.5 cm diameter of space for each plant root in 6 replicates. The lettuce was not additionally fertilized and 35 days old plants (6 lettuce plants for each growing media) were collected and measured as follows: plant height (cm) was measured as height from plant base excluding root to the top, aboveground mass was dried on 70°C before measuring dry matter (mg) and leaf area (cm^2) was measured as a sum of area of all leaves per plant. The plant growth data were used for creating regression model of pH and EC impact on lettuce growth. The all statistic analyses were made by PC applications SAS for Windows (SAS Institute Inc., Cary, NC, USA), and Excel.

RESULTS AND DISCUSSION

Basics of model for organic fertilizer evaluation

The concept of organic fertilizer and growing media quality interpretations, which has already been developing in Croatia, is in the stage of integration as a computer model for determination of indexes in organic fertilizers evaluation. The first part of the model contains the list of basic physical, chemical and biological indicators and derived quality indicators (Thompson, 2001). It enables input of available results of analyzes. The basic indicators that could be used in the model are physical: air capacity, water holding capacity, ash, particles size, bulk density; chemical: organic carbon, N-P-K content, NH_4-N, NO_3-N, secondary and micro nutrients, heavy metals and harmful elements, CEC, pH, EC and biological: results of plant growth experiments, respirometry, color, odor, viable weed seed.

The second part of the model uses inputs for calculation of derived quality indicators: C/N, C/P, NH_4-N/NO_3-N, stability and maturity.
The third part of the model is part for integration of available indicators into new indexes. Three different indexes have been developing for organic fertilizers and growth media quality evaluation:
1. Fertilizer Index [Fert In],
2. Environmental Index [Env In],
3. Growing Media Index [GrMe In].
Fertilizer, Environmental and Growing Media indexes are calculated by the same basic system transforming properties into the indexes with possible results within the range (presented in brackets):

[Index (0-10)] = {[Basic Value(0-5)]+[Additional Value(0-5)]}/[Limiting Factors(1-2)] (1)

The possible range of indexes values is 0-10, where range 0-3 means low, 3-7 medium and 7-10 high quality (fertilizer quality, environmental quality or quality as growing media).
Basic value of Fertilizer Index is N-P-K concentrations considering ratio of these nutrients. Additional values are low C/N and NH_4-N/NO_3-N ratios, higher contents of micronutrients, higher porosity and cation exchange capacity (CEC). Limiting factors are harmful elements, inert, synthetic organic chemicals and sodium and chlorine content. Within the following example most of the mentioned properties are used, but some had to be dropped because of data lack.

Examples of organic fertilizers' chemical properties transformed into the Fertilizer Index
Basic values of [Fert In] are concentrations and ratio of N-P-K (Table 1) and P-K content in fertilizer amounts that represent equivalent of 170 kg N (maximum allowed by Nitrate Directive, 91/676/EEC). Additional values are low C/N and NH_4-N/NO_3-N ratios, and higher contents of micronutrients. Limiting factors are contents of sodium, chloride and harmful elements.
Basic value of Fertilizer Index is a sum of N index and PK index (BV = N index + PK index). The maximum value of N index is 3 for all fertilizers with N concentrations 20 g kg^{-1} or higher:

N index (in a range 0-3) = 0.15 × N in fertilizer (in g kg^{-1}) (2)

PK index is calculated on the basis of sum of phosphorus and potassium content in amount of fertilizer that represent equivalent of 170 kg N. PK index have a maximum value 2 if sum of P and K is 400 kg or more, according to the formula:

PK index (range 0-2) = 0.005 × (170/N in fertilizer) × (P in fertilizer + K in fertilizer) (3)
N, P and K in fertilizer should be in g kg^{-1}.

The PK index results presented in this paper (Table 2) are calculated using modified formula published by Lončarić et al. (2009). The modification was that threshold for maximum value of PK index is 400 kg as a sum of P and K. This sum is suggested as the average amount of P and K removed by field crops during two seasons (80 kg/ha P and 320 kg/ha K).
Among the analyzed organic fertilizer the maximum N index have fresh and composted chicken manures and vermicompost, while fresh and separated pig manure have maximum PK index (Table 2), but just because of high P content (Table 1).

Table 1. Chemical properties of manures (Lončarić et al., 2009)
Tablica 1. Kemijska svojstva stajskih gnojiva (Lončarić et al., 2009)

Manures *Stajski gnoj*	N (g/kg)	P (kg/ha)	K (kg/ha)	CN	NH_4/NO_3	Na (kg/ha)	Cl (kg/ha)
Fresh cattle manure *Svježi goveđi*	10.2	167	93	36.6	18.7	33	113
Fresh horse manure *Svježi konjski*	11.3	144	125	25.3	5.9	28	189
Fresh pig manure *Svježi svinjski*	12.4	480	12	24.2	19.0	23	14
Fresh chicken manure *Svježi pileći*	29.9	85	24	13.5	20.4	17	47
Composted cattle *Kompostirani goveđi*	18.9	136	82	16.1	0.14	33	116
Composted horse *Kompostirani konjski*	17.9	113	100	14.7	0.05	21	132
Composted pig *Kompostirani svinjski*	18.1	441	12	11.9	0.64	23	18
Composted chicken *Kompostirani pileći*	31.3	139	40	11.6	14.8	28	77
Lumbripost *Vermikompost*	23.2	82	45	10.6	0.10	5	12

Additional value is a sum of CN index (C/N ratio), NHNO index (NH_4-N/NO_3-N ratio) and Micro index (concentration of 5 micronutrients: Fe, Mn, Zn, Cu, Mo). CN index and NHNO index as indicators of organic fertilizer maturity can earn maximum 1.5 points each. CN index at C/N level 10 or lower resulted in additional value 1.5 and higher C/N ratio up to 40 decreased score to zero, according to the formula:

$$\text{CN index (ranged 0-1.5)} = 2 - 0{,}05 \times \text{CN} \quad (4)$$

The model contains very similar evaluation of NH_4-N/NO_3-N ratio, ratio 0.15 or lower resulted in maximum score 1.5 and ratio 15 or higher decreased score to zero:

$$\text{NHNO index (ranged 0-1.5)} = 1.52 - 0.1 \times NH_4\text{-N}/NO_3\text{-N} \quad (5)$$

All the composted manures, with chicken manure as exception, have maximum NHNO index at level 1.5 and among fresh manures only horse manure has additional value regarding to NH_4-N/NO_3-N ratio (Table 2).
Evaluated micronutrients are Fe, Mn, Zn, Cu, and Mo; each nutrient can score 0.5 points if concentrations are 10 g kg^{-1} Fe, 1 g kg^{-1} Mn or Zn, 0.5 g kg^{-1} Cu and 0.05 g kg^{-1} Mo. However, all 5 micronutrients together can score maximum 2 points of the additional value:

$$\text{Micro index (in range 0-2)} = 0.05 \times \text{Fe} + 0.5 \times \text{Mn} + 0.5 \times \text{Zn} + 1 \times \text{Cu} + 10 \times \text{Mo} \quad (6)$$

All the micronutrients concentrations should be expressed in g kg^{-1}. The highest Micro indexes have composted (2.0) and fresh pig manures (1.5) because of the highest content of all measured micronutrients.
Finally, additional value can be maximum 5 points, the highest additional value has composted pig manure (4.87), and lowest (0.59) fresh cattle manure (Table 2).
The model and examples presented in this paper include only two factors impacting LF (Limiting Factor): sodium and chloride contents (NaCl LF), and concentrations of harmful elements Cd, Cr, As, Hg, Pb (Harm LF). NaCl LF was evaluated like PK index on the basis of Na+ Cl amounts in a volume of organic fertilizer containing 170 kg N. If given fertilizer amount contains more than 400 kg Na+Cl, the limiting value considering Na and Cl content would reach 2 points as a maximum value (NaCl LF = 2). Otherwise, NaCl LF should be calculated using the formula:

NaCl LF (range 0-2) = 0.005 × (170/N in fertilizer) × (Na in fertilizer + Cl in fertilizer) (7)
Na and Cl in fertilizer should be in g kg^{-1}.

The maximum impact of Cd, Hg, As, Cr, Pb is at threshold levels for manure application in agriculture (5, 5, 100, 300, 500 mg kg^{-1}, respectively), and Harm LF can be calculated:

Harm LF (ranged 0-2) = Cd/5 + Hg/5 + As/100 + Cr/300 + Pb/500 (8)
All the harmful elements concentrations should be expressed in mg kg^{-1}.

Total limiting factor is a simple sum of the calculated limited factors:

Limiting Factor (LF) (in range 1-2) = NaCl LF + Harm LF (9)

The maximum of total limiting factors is set on 2, i.e. fertilization index of organic fertilizer can be reduced up to 50 % as a result of limiting factors. Simultaneously, the reason of maximum limiting factor can be just high concentrations of harmful elements with low Na and Cl concentrations, or vice versa (Lončarić, 2009). At the same time, minimum value of LF have to be 1 since absence of limiting factors shouldn't further increase basic or additional value of fertilizer.
All the [Fert In] values of composted manures (Table 2) were higher (5.28-9.59) than [Fert In] values of fresh manures (3.17-5.28) with fresh pig manure as an exception. The highest [Fert In] (9.59) was determined for the composted pig manure, and lowest for fresh cattle and horse manure (3.17 and 3.26).

Table 2. Basic values (BV), additional values (AV), limiting factors (LF) and Fertilizer Index of manures
Tablica 2. Osnovne vrijednosti (BV), dopunske vrijednosti (AV), limitirajući faktori (LF) i fertilizacijski indeks stajskih gnojiva

Manures *Stajski gnoj*	N index	PK index	**BV**	CN index	NHNO index	Micro index	**AV**	**LF**	**Fertilizer Index** ***Fert. indeks***
Fresh cattle manure *Svježi goveđi*	1.53	1.30	**2.83**	0.17	0.00	0.42	**0.59**	**1.08**	**3.17**
Fresh horse manure *Svježi konjski*	1.70	1.35	**3.05**	0.74	0.93	0.60	**2.27**	**1.63**	**3.26**
Fresh pig manure *Svježi svinjski*	1.86	2.00	**3.86**	0.79	0.00	1.50	**2.29**	**1.00**	**6.15**
Fresh chicken manure *Svježi pileći*	3.00	0.55	**3.55**	1.33	0.00	0.40	**1.73**	**1.00**	**5.28**
Composted cattle *Komp. goveđi*	2.84	1.09	**3.93**	1.20	1.50	0.77	**3.44**	**1.27**	**5.80**
Composted horse *Komp. konjski*	2.69	1.06	**3.75**	1.27	1.50	0.61	**3.38**	**1.35**	**5.28**
Composted pig *Komp. svinjski*	2.72	2.00	**4.72**	1.41	1.46	2.00	**4.87**	**1.00**	**9.59**
Composted chicken *Komp. Pileći*	3.00	0.90	**3.90**	1.42	0.04	0.66	**2.12**	**1.00**	**6.02**
Lumbripost *Vermikompost*	3.00	0.64	**3.64**	1.47	1.50	0.82	**3.79**	**1.00**	**7.43**

Examples of organic fertilizers' chemical properties transformed into the Environmetal Index
Basic value of Environmental Index in the model, according to the model general idea, should be all the properties with positive impact on increasing soil biodiversity and elasticity [ISBE]. There isn't any developed model for calculation [ISBE] at the moment. Therefore they are not presented in this paper. The same situation is with undeveloped model for additional values which should include importance of waste-to-fertilizer conversion, soil pH regulation, heavy metals chelating and decreasing of leaching. Limiting factors as a part of Environmental index are contents of toxic elements, persistent synthetic organic compounds and other contaminants. Since parts for calculating

basic and additional values of Environmental Index haven't been developed yet, the [Env In] in this example described only the impact of contents of potentially toxic elements as limiting factors (PoTox LF), but different for conventional and organic agriculture. Therefore, the numbers in the following formulas represent the thresholds for heavy metals concentrations in organic fertilizers allowed by regulations for conventional and organic agriculture in Croatia:

$$\text{PoTox LF}_{\text{Conventional}} \text{ (in range 1-10)} = Zn/1000 + Pb/500 + Cu/300 + Cr/300 + Ni/250 + Co/250 + As/100 + Mo/50 + Hg/5 + Cd/5 \quad (10)$$

$$\text{PoTox LF}_{\text{Organic}} \text{ (in range 1-10)} = Zn/210 + Pb/70 + Cu/70 + Cr/70 + Co/50 + Ni/42 + As/10 + Mo/10 + Hg/0.7 + Cd/0.7 \quad (11)$$

The maximum PoTox LF value can be 10, because basic and additional values can be irrelevant if toxic elements concentrations are higher than threshold value, and minimum value is set on 1.
Environmental index in the presented model was calculated very simply:

$$\text{Env In (in range 0-10)} = 10 / \text{PoTox LF} \quad (12)$$

However, there is a possible exception if any of toxic elements divided by treshold level result in number 1 or higher, value of Env In is zero (0), and fertilizer should not be used in conventional or organic agriculture (Table 3).

Table 3. Examples of Environment Index [Env In] of fresh and composted manures
Tablica 3. Primjeri ekološkog indeksa [Env In] svježih i kompostiranih stajskih gnojiva

Manures *Stajski gnoj*	[Env In] in conventional agriculture *[Env In] za konvencionalnu poljoprivredu*	[Env In] in organic agriculture *[Env In] za ekološku poljoprivredu*
Fresh cattle manure *Svježi goveđi*	10	4.15
Fresh horse manure *Svježi konjski*	10	3.95
Fresh pig manure *Svježi svinjski*	7.11	$0_{Zn, Cu, Cd}$
Fresh chicken manure *Svježi pileći*	10	0_{Zn}
Composted cattle *Kompostirani goveđi*	9.2	0_{Zn}
Composted horse *Kompostirani konjski*	8.2	2.67
Composted pig *Kompostirani svinjski*	10	$0_{Zn, Cu, Cd, Cr}$
Composted chicken *Kompostirani pileći*	6.0	$0_{Zn, Cu}$

Generally, [Fert In] is higher for composted manures indicating higher nutrient concentrations and maturity. However, limiting factors as part of [Env In] are higher for composts indicating higher heavy metal concentrations in composted than in fresh manures. Considering heavy metal concentrations all the manures, fresh and composted, can be used in conventional agriculture since the highest limiting factor was 1.67 (composted pig manure). However, considering fertilization in organic agriculture, limiting factor reaches threshold value (environmental index = 0, indicate that use as fertilizer is not allowed) because of too high zinc, cooper, cadmium or chrome concentrations in composted cattle manure as well as fresh and composted pig and chicken manures (Table 3).
Described indexes could be helpful for organic manure analysts, results interpreters, evaluators and farmers because of integration of numerous analytical results into evaluation of organic matter as fertilizer, as possible growing media and in sense of environmental impact. Much more measurements, interpreting, scaling and indexing should be incorporated into the model.

Results of plant growth experiment transformed into the data for calculation of Growing Media Index

Basic value of Growing Media Index is Plant Growing Index [PGI] as a result of plant growth experiment and/or germination tests. Additional values are NPK content, maturity index (based on C/N and respiration), phytopathogen suppress and water holding capacity. Limiting factors are viable weed seed and toxic elements content.

Since organic fertilizers, especially composts could be used as growing media or as component for preparing it (Carlile, 2008), the Growing Media Index is a way to evaluate suitability of compost as growing media. Basic value of Growing Media Index is Plant Growing Index derived from plant growth experiment. The plant growth experiment conducted in this research is experiment with lettuce seedlings and impact of growing media pH and EC on lettuce growth. This impact was transformed into stress index (SI) with values ranged 0-1. The SI=0 represent EC and pH values without negative impact on lettuce growth, and SI=1 means that EC and/or pH totally inhibited growth. Beside SI considering pH and EC (SI_{pH-EC}), some other stress indexes can be useful for calculating Plant Growing Index, such as stress index considering N-P-K contents (SI_{N-P-K}) and NH_4-N/NO_3-N ratio ($SI_{NH4}/_{NO3}$). Finally, using all important and available stress indexes, Plant Growth Index could be calculated:

$$[PGI] = 5 \times (1 - \text{Stress Index}) \quad (13)$$

$$\text{Stress Index} = \{[SI_{pH-EC}] + [SI_{N-P-K}] + [SI_{NH4/NO3}] + \ldots + [SI_n]\}/n \quad (14)$$

However, transformation of plant growth experiment results into stress index considering pH and EC of growing media is presented in this paper.

Composts mixtures used as a growing media with different pH and EC resulted in very significant impacts on height, dry matter mass and leaf area of lettuce seedlings (Table 4). All three analyzed growth indicators have responded very similarly to pH and EC. It is obviously that growing media EC doesn't describe the amounts and ratio of nutrients and salts, and it can differ in many properties even if the EC is identical. However, EC was used as property for evaluating growing media quality since EC value is impacted by nutrient concentrations and because of rapid and simple determination.

Table 4. Height (H in cm), dry matter (DM in mg/plant) and leaf area (LA in cm^2) of lettuce seedling impacted by pH and EC (dSm^{-1}) of growing media

Tablica 4. Utjecaj pH i EC (dSm^{-1}) supstrata na visinu (H u cm), suhu tvar (DM u mg/biljci) i lisnu površinu (LA u cm^2) presadnica salate

Media		EC (dSm^{-1})	pH	H	DM	LA
1	EC~1	0.93	6.28	4.8 ab	63 a	22 ab
2		1.08	7.03	4.7 ab	48 ab	18 bc
3		1.17	8.10	3.0 e	24 cd	9 de
4	EC~2	1.81	6.18	5.7 a	64 a	27 a
5		2.17	7.06	4.3 bc	37 bc	16 bcd
6		2.25	8.12	2.9 e	13 de	5 ef
7	EC~3	2.84	5.89	3.6 cde	28 bcd	11 cde
8		2.96	7.21	0 f	0 e	0 f
9		3.20	7.93	0 f	0 e	0 f
10	EC~4	4.18	6.27	4.2 bcd	23 cd	11 cde
11		4.15	7.32	0 f	0 e	0 f
12		3.94	8.17	0 f	0 e	0 f
13	EC~5	5.54	6.51	3.2 de	22 cd	9 de
14		5.08	7.13	0 f	0 e	0 f
15		5.30	8.11	0 f	0 e	0 f

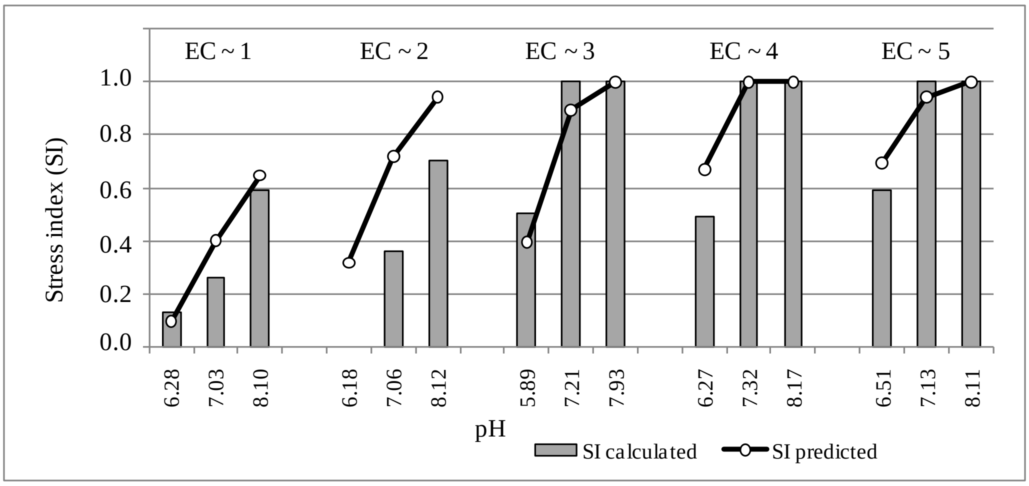
The differences between values with the same letters in a column are not significant

The highest lettuce seedlings with the highest mass and leaf area are produced on growth media with pH close to 6 and EC lower than 2 dSm^{-1}. Increasing pH to 7 reduced seedling growth, and increasing pH to 8 resulted in further growth decreasing (Table 4). Even stronger growth reduction was induced by increasing EC of growing media. Moreover, there wasn't any lettuce plant on growing media with EC close to 3 dSm^{-1} or higher with exception of media with pH about 6.

Therefore, it could be concluded that conductivity about 3 dSm^{-1} has growth inhibitory effect if pH is about 7 or higher. However, increasing EC from 1 to 2 dSm^{-1} has also growth reducing effect if pH increases to 7 or higher. Since seedling height, mass and leaf area have very significant multiple regression (0.80, 0.69 and 0.66, respectively) with pH and EC, the data were used for expressing pH and EC impact on lettuce growth. The unit for expression impact was a stress index. Stress index (SI_{pH-EC}) was calculated as a simple average of reducing height, mass and leaf area compared to maximum height (Hmax), leaf area (LFmax) and mass (DMmax) achieved on growing media with pH 6.2 and EC 1.8 dSm^{-1} (Table 4):

$$SI_{pH-EC}\ (0\text{-}1) = [(1-H/Hmax)+(1-LA/LAmax)+(1-DM/DMmax)]/3 \qquad (15)$$

The lowest SI_{pH-EC} (SI=0) was calculated on treatment with most intensive lettuce growth (used as a maximum). Other treatments with EC about 1 or 2 dSm^{-1} have SI 0.13-0.36 if pH is lower than or about 7 (Graph 1), and SI was 0.59 and 0.7 if pH was about 8. Rising EC to 3, 4 or 5 dSm^{-1} resulted in SI value 0.49-0.59 only if pH was about 6, and if pH was about 7 or higher, the SI_{pH-EC} was 1.00 indicating completely inhibited lettuce growth.

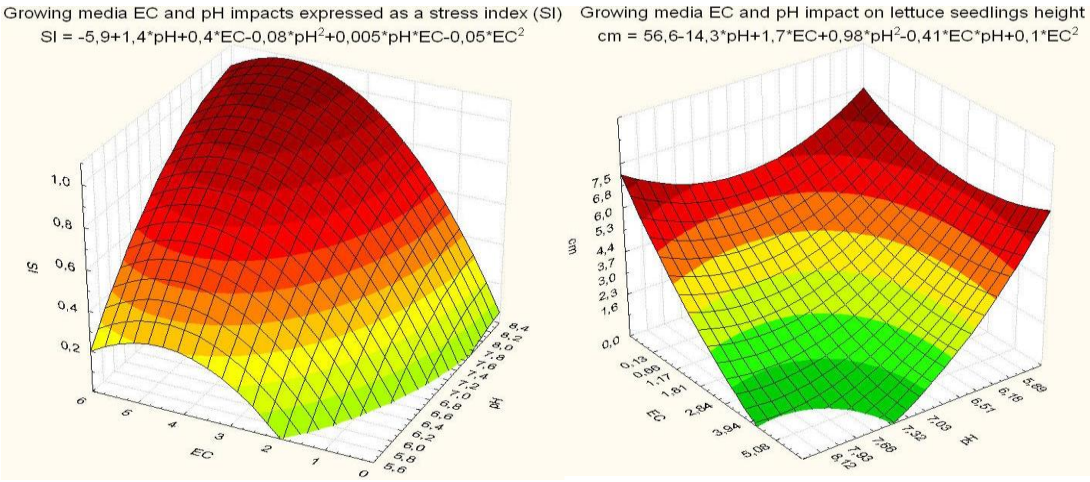


Graph 1. Calculated and predicted stress index (SI) of lettuce seedling impacted by pH and EC (dSm^{-1}) of growing media

Grafikon 1. Pokusom utvrđen i modelom predviđen utjecaj pH i EC (dSm^{-1}) supstrata na presadnice salate izražen kao stres indeks (SI)

Calculated stress index values are used for multiple regression model (Graph 2) which can be used for prediction of lettuce seedling growth impacted by pH and EC of growing media.

SI values (lines on Graph 1) predicted by stress function model are in significant correlation with calculated values, and the highest model error was detected at the conductivity level ~2 dSm^{-1}. However, the EC=2 dSm^{-1} or pH 7.5 are the highest values without impact on lettuce growth according to a model for SI prediction (Graph 2). The same model shows that raising pH and EC will result in decreasing growth which could be expressed as increasing stress index and could be predicted using pH and EC as input data. The seedlings height as a function of pH and EC changes was incorporated into the stress function model. The growth function (Graph 2) presents increasing of stress index as inversion of decreasing lettuce height by increasing EC above 4 dSm^{-1} or pH above 7.4. The presented system for creating stress function can be applied for any other growing media properties impact with any other seedling species.



Graph 2. Growth function of lettuce inversely expressed as a stress index (SI) and pH and EC impact on height
Grafikon 2. Funkcija rasta salate inverzno prikazana kao stres indeks (SI) i utjecaj pH i EC supstrata na visinu presadnica salate

Examples of substrates' Growing Media Index

Five different substrates were used for examples of integrating properties into Growing Media Index for lettuce: 1. mixture of composted horse manure and peat (ratio 1:2), 2. mixture of composted horse manure and soil (ratio 1:2), 3. mixture of composted horse manure and peat (ratio 1:3), 4. mixture of composted separated pig manure and peat (ratio 1:1), and 5. mixture of composted separated pig manure and soil (ratio 1:1). The properties of mixtures were already published (Vukobratović, 2008) and PGI were calculated according to the above described system regarding to supstrate pH and EC (Table 5).

Table 5. Examples of Plant Growth Index (PGI), Additional Values (AV), Limiting Factors (LF) and Growing Media Index [Gr Me In] for mixtures of composts, peat and soil
Tablica 5. Primjeri indeksa rasta biljke (PGI), dopunskih vrijednosti (AV), limitirajućih faktora (LF) i indeksa supstrata [Gr Me In] za mješavine komposta, treseta i tla

Growing media *(supstrat)*	pH	EC	PGI	AV	LF	Gr Me In
Composted horse:peat 1:2 *(kompostirani konjski:treset 1:2)*	7.0	4.0	0.40	1.9	1.00	2.30
Composted horse:soil 1:2 *(kompostirani konjski:tlo 1:2)*	8.0	0.9	2.35	4.0	1.00	6.35
Composted horse:peat 1:3 *(kompostirani konjski:treset 1:3)*	5.9	1.8	4.05	1.6	1.00	5.65
Composted pig:peat 1:1 *(kompostirani svinjski:treset 1:1)*	5.7	1.5	4.45	4.5	1.10	8.14
Composted pig:soil 1:1 *(kompostirani svinjski:tlo 1:1)*	6.2	1.0	4.55	5.0	1.30	7.35

CONCLUSION

Described concept of organic fertilizer evaluation by three indexes could be useful because of numerous data integration into few indexes and results are simple to rank and compare. Fertilizer index is sensitive to NPK concentration, manure stability and maturity, but also to potential decrease of soil quality by adding high amounts of sodium, chlorine or harmful elements. However, the model needs calibration and validation in all aspects like one made in pH and EC impact on Growing Media Index.

The optimum pH of growing media for lettuce was close to 6 and optimum EC was lower than 2 dSm^{-1}. Increasing pH and especially EC reduced growth, and conductivity about 3 dSm^{-1} or higher has growth inhibitory effect if pH is about 7 or higher. The impact of pH and EC on lettuce growth could be expressed simply as stress index ranged 0 to1 as inversion of lettuce growth, and regression model with incorporated stress index could be used for prediction of lettuce seedlings growth. The described modelling system can be applied for any other growing media properties impact with other seedling species by transforming plant growth experiment results.

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KOMPJUTORSKI MODEL OCJENJIVANJA KVALITETE ORGANSKIH GNOJIVA

SAŽETAK

Ocjena kvalitete organskih gnojiva (stajska gnojiva, komposti) i supstrata treba sadržavati dovoljno informacija da omogući izbor optimalne upotrebe s proizvodnog i ekološkog aspekta. Cilj je ovoga rada prikaz osnovne strukture modela za determinaciju indeksa ocjenjivanja kvalitete organskih gnojiva i supstrata. Osnovna struktura modela sadrži izbor i interpretaciju vrijednosti indikatora kvalitete te integraciju interpretiranih vrijednosti u nove indekse. Prvi korak uključuje unos podataka i izbor raspoloživih podataka za izračun osnovnih ili dopunskih indikatora, ovisno o indeksima i mogućim uporabama kao gnojivo ili supstrat. U drugom koraku raspoloživi podaci koriste se za izračun izvedenih indikatora kvalitete, a treći korak je integracija interpretiranih vrijednosti u tri nova indeksa: fertilizacijski indeks, indeks supstrata i ekološki indeks. Vrijednosti sva tri indeksa računaju se na temelju tri grupe indikatora: indikatori osnovne vrijednosti, indikatori dopunskih vrijednosti i limitirajući faktori. Raspon vrijednosti sva tri indeksa kreće se od 0-10, pri čemu raspon 0-3 znači nisku, 3-7 srednju, a 7-10 visoku kvalitetu. Usporedbom svježih i kompostiranih stajskih gnojiva, viši fertilizacijski i ekološki indeksi utvrđeni su za kompostirana gnojiva, najviši fertilizacijski indeks utvrđen je za kompostirani separat svinjske gnojovke (9,6), a najniži za svježi goveđi stajski gnoj (3,2). Kompostirana stajska gnojiva imaju visoki ekološki indeks (6,0-10) za konvencionalnu poljoprivredu, ali pojedini nemaju ekološku vrijednost (ekološki indeks = 0) za ekološku poljoprivredu zbog visoke koncentracije cinka, bakra ili kadmija. Indeksi supstrata utvrđeni su prema utjecaju supstrata na rast salate. Supstrati s različitim pH_{H2O} i EC vrijednostima rezultirali su vrlo značajnim utjecajem na visinu presadnica salate, produkciju suhe tvari i površinu lista. Najveće presadnice s najvećom masom i lisnom površinom proizvedene su uporabom supstrata s pH_{H2O} vrijednošću oko 6 i EC vrijednošću ispod 2 dSm^{-1}. Može se zaključiti da konduktivitet oko 3 dSm^{-1} ima inhibitorni učinak na salatu ukoliko je pH supstrata oko 7 ili viši. Kompjutorski je model pokazao da povećanje pH_{H2O} i EC rezultira smanjenim rastom salate, što se može izraziti kao porast stres indeksa. Visina salate kao funkcija pH_{H2O} i EC ugrađena je u model kao stres funkcija koja pokazuje povećanje salate smanjenjem EC vrijednosti od 4 do 1 dSm^{-1} ili pH_{H2O} vrijednosti od 7,4 do 6. Najveći indeks supstrata (8,1) utvrđen je za smjesu (1:1) kompostiranog separata svinjske gnojovke i treseta, a najniži (2,3) za smjesu (1:2) kompostiranog konjskog stajskog gnojiva i treseta.

Ključne riječi: kvaliteta komposta, stajska gnojiva, fertilizacijski indeks, ekološki indeks, indeks supstrata, salata

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