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Generative propagation in Geraniums in relation to different growth substrates

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Abstract
The study analysed the generative propagation of geraniums in different substrate conditions. The biological material was represented by *Pelargonium* × *zonale* "Orbit Rot" F1. Four types of growth substrate were used: clay balls (V1), perlite (V2), soil (V3) and hydroponic system (V4). A favourable effect in the germination process was recorded for the V2 variant. The height of the plants registered a differentiated evolution during the study period, March 16 - May 25, 2023. Variant V4 favourably influenced plant height (PH) during the study period, March 16 – May 25, 2023, PH = 31.5 cm. V2 (14.13 cm) and V3 (13.91 cm) variants followed with close values. High values for the number of leaves parameter (LN) were recorded for the V4 variant, also correlated with plant height. Close values for LN were recorded in the case of the other variants. Parameters at the root level (number of roots - RN, length of roots - RL) also showed a certain variation in relation to the experimental variants. High values for the length of the roots were recorded for the V4 variant, followed by V2.

Keywords: hydroponic system, models, ornamental plant, pelargonium, plant propagation

Introduction

Innovative ideas and technologies are promoted in the field of ornamental plants for the production of biological material, plant propagation, ensuring ornamental quality indices, plant protection, etc., in relation to market requirements and cultivation conditions [4]. For urban environments and ecosystems, the role and importance of ornamental plants was highlighted from the perspective of the ecosystem services they can provide [6]. Along with the functionality of ornamental plants in the context of urban ecosystems (ecosystemic, economic, cultural, social, etc.), the authors analysed the possibility of selecting and producing ideotypes of ornamental plants for ecosystem balance and functionality.

In the horticultural field, both sexuate reproduction (frequent under natural conditions) and asexuate reproduction were used for plant propagation. Over time, more and more methods of asexuate (vegetative) propagation of plants were developed as a result of the advantages they present [16]. The author considered the importance of propagation methods in the improvement programs of horticultural plants, as well as for the production of goods intended for the markets of horticultural material and highlighted modern propagation techniques and their importance for quality biological material.

Ornamental plants present a high variety of ornamental elements and parameters (shapes, colours, sizes, etc.), which are studied from the perspective of producing biological material with quality indices in line with market requirements [10]. The authors of the study highlighted the importance of propagation methods of horticultural biological material, and developed the importance of in vitro cultures. Vegetative propagation, by cuttings, is a frequently used method for the propagation of ornamental plants, as a result of the advantages it presents [27]. The authors tested different rooting substrates, made of accessible components (e.g. peat, sand, perlite) with good results for the tested species.

The methods of propagation of ornamental plants based on biotechnologies show an increasing interest in obtaining biological material of high biological and ornamental quality, with multiple functionalities [13]. The vegetative (clonal) propagation of plants was analysed in relation to the role of some bio stimulating substances, e.g. auxins, but also some co-factors of the rooting process [18]. The author comparatively analyzed different previous studies, and highlighted the direct influence and interaction of different substances

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in the rooting process, with practical importance for the vegetative propagation of plants.

Cultivation of ornamental plants is done in different conditions, from natural soil to substrates made by mixing mineral and organic components, but at the same time soilless cultivation methods are also studied [29]. The cultivation of ornamental plants often involves the use of growing substrates resulting from different mixtures of components, as a result of specific requirements of the plants, or the fact that the soil or the substrate in certain locations are not suitable in relation to the requirements of the plants. Therefore, studies of the analysis and behaviour of ornamental plants on different types of substrate are of interest [1]. The authors analysed the response of some plant cuttings on substrates made of components in different proportions (e.g. biochar, topsoil). The response of the plants to the growth substrate was recorded, based on some morphological parameters (number of roots, number of leaves, etc.) and the substrate that ensured the efficient vegetative propagation of the plants was identified.

Soilless plant culture systems were analysed from the perspective of economic advantages, yields, water use efficiency, reduced environmental impact, and production quality [14]. As a result of the advantages presented by the soilless culture systems of horticultural plants, different techniques for ensuring nutrient solutions, growth systems, and plant response to this culture system were analysed [26]. The advantages of soilless culture systems were analysed in relation to the availability of soil and water resources, but also from the perspective of openness and development towards urban areas [7]. Ornamental plants have been studied in relation to different habitats and growing conditions, in response to certain stress factors [25].

The propagation of ornamental plants is done through different methods and techniques, in relation to the appropriate response of the plants and the economic efficiency and ornamental attributes [12]. The root system is important in the reproduction process, for providing the plants with water and nutrients and supporting an adequate growth rate of the plants for efficient exploitation on the market.

The rooting of plants in the reproduction process was analysed in relation to different influencing factors, which are related to biological material, the growth substrate, bio stimulating substances applied, given also environmental factors such as light, temperature [21]. In relation to the light spectrum, the authors recorded a variable response of the plants regarding the rooting process, and formulated recommendations for ensuring light for optimal yield in the plant propagation process, for the species tested under the study conditions.

Geraniums are popular ornamental plants, with a wide variety of genotypes, cultivated in different indoor or outdoor environmental conditions, substrate and maintenance technologies [24]. The authors analysed different elements of plant growth, for crop technology recommendations. The feasibility of hydroponics was analysed for the growth of rooted geranium cuttings for the purpose of producing commercial plants [3]. The authors of the study analysed different morphological characters (e.g. number of leaves, number of branches, number of flowers, etc.) to evaluate the commercial quality of the plants obtained in relation to the growing technique. Based on the recorded results, the authors communicated the efficiency of water use, as well as obtaining plants with improved commercial characteristics.

The present study analysed the generative propagation of geranium, *Pelargonium* × *zonale* "Orbit Rot" F1, in the conditions of four growth substrates represented by clay balls, perlite, soil, and hydroponic system.

Material and Method

The study took place within the Floriculture Discipline of the University of Life Sciences "King Mihai I" from Timisoara, year 2023. The biological material was represented by the *Pelargonium* × *zonale* "Orbit Rot" F1 hybrid.

In relation to the purpose of the study, four variants of plant growth were considered: V1 – expanded clay balls; V2 – perlite; V3 – soil; V4 – hydroponic system, figure 1. The geranium seeds were germinated on March 9, 2023. Seed germination was recorded starting on March 13.

The study period was between March 13 (the date the seeds began to germinate) and May 25, 2023. Periodically, at seven-day intervals, observations were made regarding the evolution of plant dynamics. Within each variant, 10 plants were analysed.

Experimental data were recorded regarding the number of leaves (LN), plant height (PH). On May 25, the plants were extracted from the pots, the growth substrate was washed from the root level and the root system was evaluated, respectively the number of roots (RN) and the length of the roots (RL).

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Figure 1. The experimental variants regarding the propagation of geranium plants by generative means; aspects during the study period (original photos, photos of the authors)

The data regarding the number of leaves and the height of the plants (LN, PH) were recorded periodically, at intervals of seven days during the study period, starting from the emergence of the plants (March 13). The time (t, days) for the study period and determination intervals was calculated. The recorded experimental data were analysed statistically appropriately [8], [28].

Results and Discussion

The periodic recording of the values of geranium growth parameters led to series of data whose average values are presented in table 1. The number of roots (RN) presented values between RN = 11.44±0.47 for the V3 variant and RN = 13.60±0.47 in the case of the V2 variant. The length of the roots (RL) varied between RL = 8.08±2.62 in the case of the V1 variant and RL = 19.13±2.62 in the case of the V4 variant. The number of leaves (LN) presented values between LN = 7.60±3.09 for the V2 variant and LN = 20.00±3.09 in the case of the V4 variant. The height of the plants (PH) showed values between 9.49±4.87 cm in the case of the V1 variant and 31.50±4.87 cm in the case of the V4 variant. The data series showed normal distribution. As an example, the distributions for parametric LN and PH are presented graphically, figure 2.

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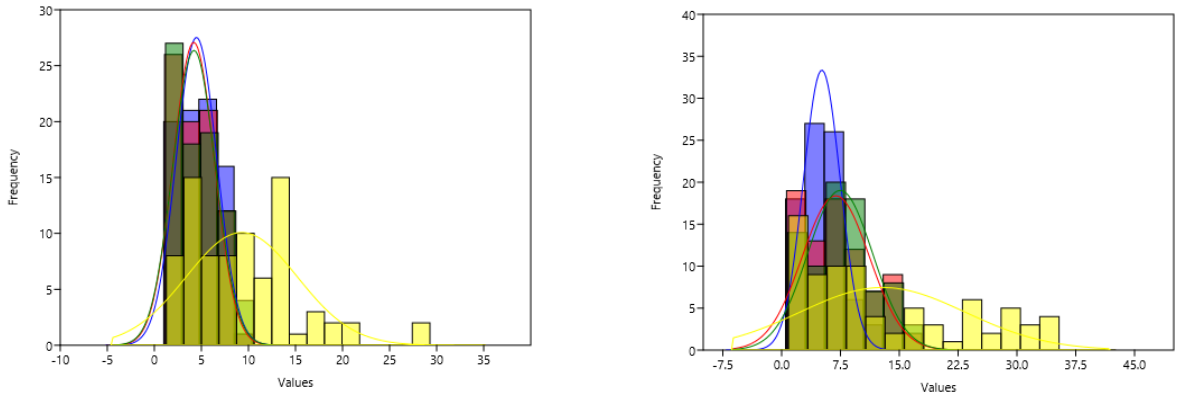
Table 1. The average values of the geranium parameters in relation to the growth substrate

Substrate	Experimental variant	RN	RL	LN	PH
		(No)	(cm)		
Expanded clay balls	V1	12.63	8.08	7.63	9.49
Perlite	V2	13.60	13.31	7.60	14.13
Soil	V3	11.44	8.20	7.67	13.91
Hydroponic system	V4	11.88	19.13	20.00	31.50
SE		±0.47	±2.62	±3.09	±4.87



(a) (b)

Figure 2. Distribution histograms of LN (a) and PH (b) parameter values on experimental variants

The correlation analysis led to the values presented in table 2. A very strong positive correlation was found between PH and RL (r = 0.920) and between PH and LN (r = 0.976). A strong, positive correlation was recorded between LN and RL (r = 0.883). Negative correlations, of weak intensity, were recorded between LN and RN (r = -0.362) and between PH and RN (r = -0.352).

From the analysis of the correlation coefficient values, it was found the very strong influence of the root length (RL) and the number of leaves (LN) on the growth and development of the plants, expressed by the PH parameter (***, p< 0.001). Also, the length of the root had a very strong influence on the number of leaves formed on the plants. The functional relationship between the root system and the growth, development and adaptation of plants is known [17], [15].

Table 2. The table of correlations between parametrically determined in *Pelargonium* × *zonale* "Orbit Rot" F1, in experimental conditions on differentiated growth substrate

	RN	RL	LN	PH
RN				
RL	0.042			
LN	-0.362	0.883***		
PH	-0.352	0.920***	0.976***	

According to PCA, the diagram in figure 3 resulted, in which the experimental variants were associated with parameters depending on their influence. Thus, the V4 variant was associated with plant height (PH, as biplot), and the V2 variant was associated with the root shoulder (RN, as biplot). The other two variants (V1 and V3) had an independent positioning. The first two principal components explain 99.08 % of the total variance, with 73.35% contribution for PC1 and 25.73 % for PC2, respectively.

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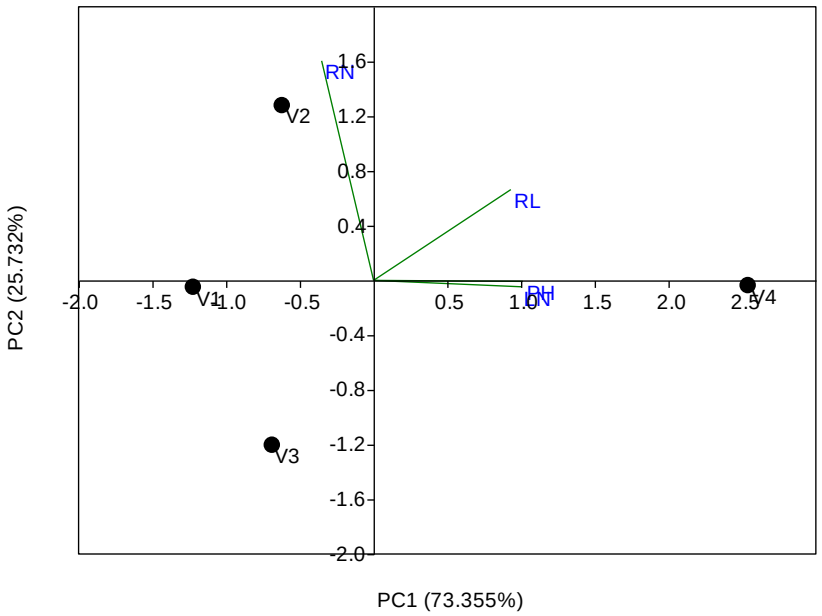

Figure 3. PCA diagram with the distribution of variants in relation to morphological parameters in geranium

The regression analysis was used to find out the variation of the determined parameters in relation to time during the study period.

The variation of LN_{V1} in relation to time (t, days) was described by equation (1), under conditions of $R^2 = 0.993$, $p<0.001$. The LN_{V2} variation was described by equation (2), under conditions of $R^2 = 0.992$, $p<0.001$. The LN_{V3} variation was described by equation (3), under conditions of $R^2 = 0.994$, $p<0.001$. The LN_{V4} variation was described by equation (4) under conditions of $R^2 = 0.980$, $p<0.001$

$$LN_{V1} = 0.00044\,x^2 + 0.0759\,x + 0.1338 \quad (1)$$

$$LN_{V2} = 0.00049\,x^2 + 0.070\,x + 0.1085 \quad (2)$$

$$LN_{V3} = 0.0006\,x^2 + 0.0623\,x + 0.1774 \quad (3)$$

$$LN_{V4} = 0.00239\,x^2 + 0.089\,x + 0.059 \quad (4)$$

where: x – time (t, days)

The variation of PH_{V1} in relation to time (t, days) was described by equation (5) under conditions of $R^2 = 0.976$, $p<0.001$. The PH_{V2} variation in function in relation to time (t) was described by equation (6) under conditions of $R^2 = 0.991$, $p<0.001$. The PH_{V3} variation in relation to time (t) was described by equation (7) under conditions of $R^2 = 0.988$, $p<0.001$. The variation of PH_{V4} in relation to time (t) was described by equation (8) under conditions of $R^2 = 0.991$, $p<0.001$.

$$PH_{V1} = 0.000352\,x^2 + 0.081\,x + 1.216 \quad (5)$$

$$PH_{V2} = 0.00171\,x^2 + 0.0586\,x + 1.091 \quad (6)$$

$$PH_{V3} = 0.00102\,x^2 + 0.1058\,x + 1.143 \quad (7)$$

$$PH_{V4} = 0.00757\,x^2 - 0.103\,x + 2.066 \quad (8)$$

where: x – time (t, days)

The PH variation was analysed in relation to the number of leaves (LN) and time (t) during the study period. The result was the general equation (9), with the presentation of the values of the coefficients in table 3, related to each variant (V1 to V4). In the case of the V4 variant, high values were recorded for the plant height parameter, and the graphic distribution of the PH variation in relation to LN and t is presented in figure 4 for the V2 variant, in figure 5 for V3 variant, and in figure 6 for V4 variant.

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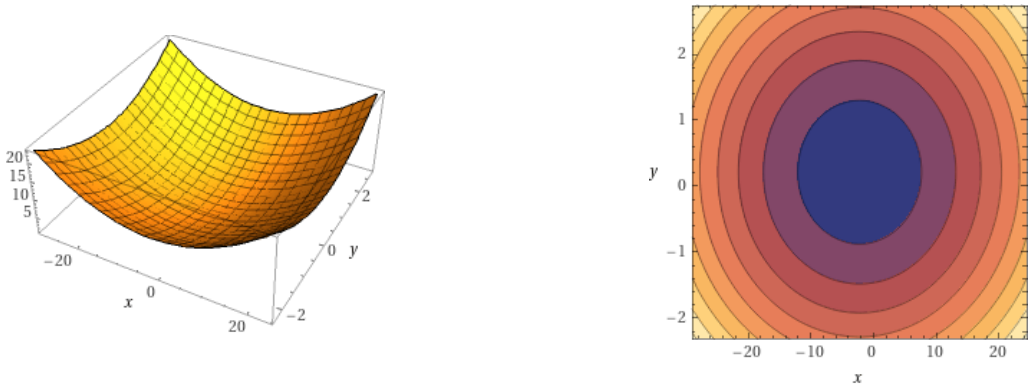
$$PH = ax^2 + by^2 + cx + dy + exy + f \quad (9)$$

where: PH – plant height (cm); x – leaf number (LN); y – time (t, days);
a, b, c, d, e, f – coefficients of the equation (9);

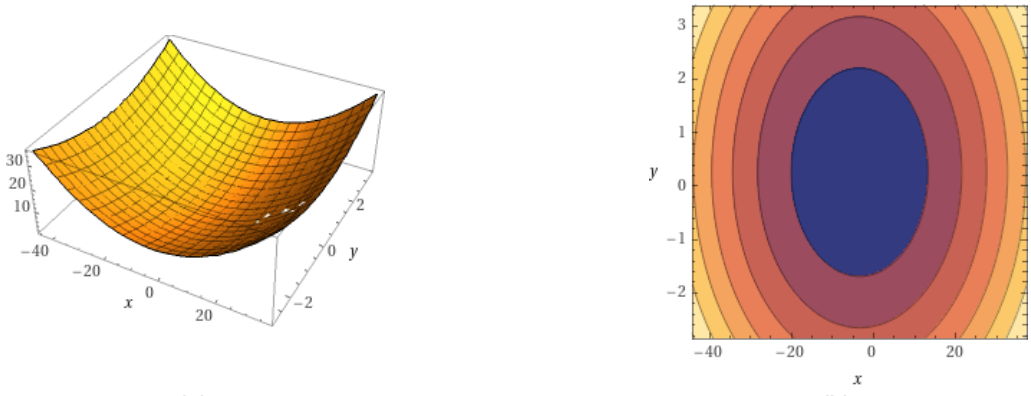
Table 3. The values of the coefficients of equation (9) and of the statistical safety parameters

Variants	Values of the coefficients of equation (9)						Statistical safety parameters		
	a	b	c	d	e	f	R^2	p	RMSE
V1	0.00157147	-0.58772380	-0.01807322	0.42961186	0.05841316	1.53448167	0.994	p<0.001	0.3032
V2	0.01812735	1.48631227	0.08035027	-0.62646740	-0.30635495	1.19664053	0.999	p<0.001	0.1377
V3	0.01470228	1.07078270	0.09958296	-0.55691685	-0.23403731	1.39916553	0.994	p<0.001	0.2935
V4	0.01074472	0.02451907	0.03712885	-1.26913365	-0.00819733	1.94403954	0.998	p<0.001	0.4357



(a) (b)

Figure 4. Graphical distribution of PH values in relation to LN (x axis) and t (y axis), V2 variant



(a) (b)

Figure 5. Graphical distribution of PH values in relation to LN (x axis) and t (y axis), V3 variant

Seed germination was between 80% for the V1 and V4 variants, 90% for the V3 variant and 100% for the V2 variant. Faster germination was recorded in the case of the V1 and V2 variants and slower in the case of the V4 variant. Differentiated values regarding the germination of seeds and the growth of geranium plants in relation to the rest period, the type of container and substrate were also communicated in other studies [11], [22].

The growth rate of geranium plants showed a certain variation in relation to the growth substrate conditions, during the study period. Variations in the rate of plant growth were analysed in relation to different growth methods and techniques and substances with a bio stimulating role on plants [19], [9].

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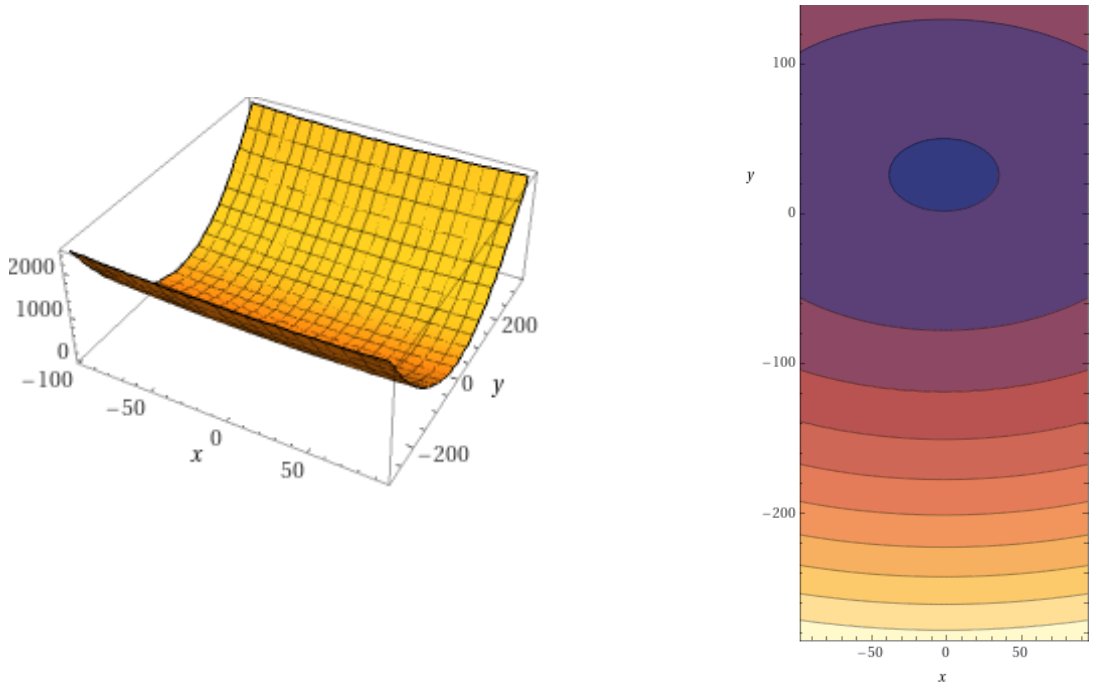
The height of geranium plants, at the end of the observation period, showed significant differences ($p<0.001$). In the case of the V4 variant, the highest values were recorded (PH = 31.50±4.87 cm), followed with similar values by the V2 variants (PH = 14.14±4.87 cm) and the V3 variant (PH = 13.91±4.87 cm).



(a) (b)

Figure 6. Graphical distribution of PH values in relation to LN (x axis) and t (y axis), V4 variant

The growth rate of the plants, during the study period, was described by mathematical models under conditions of statistical safety. Different parameters were analysed for horticultural species of economic interest and plant response models were generated in relation to growing conditions, nutritional factors, stress factors with importance for practice and breeding programs [5], [23], [20], [2].

Parameters determined in geranium plants showed different correlations, under statistical safety conditions. The results recorded with *Pelargonium x zonale* "Orbit Rot" F1, regarding seed germination and plant growth under the study conditions, contribute to the database, with importance for scientific research and horticultural practice.

Conclusions

The generative propagation of geranium, *Pelargonium x zonale* "Orbit Rot" F1, recorded differentiated values in relation to the four substrates for germination and plant growth. Plant growth parameters registered different values, with higher values were presented RN on the V2 variant (RN = 13.60±0.47), RL under the conditions of the V4 variant (RL = 19.13±2.62), LN under the conditions of the V4 variant (LN = 20.00±3.09), respectively PH under the conditions of the V4 variant (PH = 31.50±4.87). In the V4 variant, the geranium seedlings showed a better growth rate, a fact that recommends this variant for geranium propagation, under the study conditions.

Very strong positive correlation between PH and RL ($r = 0.920$) and between PH and LN ($r = 0.976$), strong positive correlation was recorded between LN and RL ($r = 0.883$).

According to PCA, PC1 explained 73.355% of variance, and PC2 explained 25.732% of variance. Polynomial equations of the 2nd degree described the variation of the biometric parameters in relation to time during the study period, under conditions of statistical safety ($p<0.001$). Models in the form of mathematical equations and graphic models described the variation of the PH parameter in relation to LN and time (t, days) under statistical safety conditions ($p<0.001$, RMSE = 0.1377 to RMSE = 0.4357).

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