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ORIGINAL ARTICLE

Mathematical Modeling of Seed Germination Percentage of Some Chilli Cultivars in A Changing Salt Regime

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ABSTRACT
Low germination rates in salt-induced conditions can significantly impact the quality and yield of any crop. In the present communication, we have presented a mathematical model to forecast salinity's impact on seed germination dynamics in various chilli cultivars, namely Bullet, Pusa Jwala, Bird's Eye, Surjomukhi and Black. The prediction of germination percentage (GP) of the seeds of these cultivars has been selected by a partial differential equation with suitable boundary conditions on salinity concentration (NaCl) ranges from 0 mM to 200 mM. From the mathematical model, an analytical solution (GP) depends on time ('t'), and salinity concentration ('c') has been found. It has been observed that the GP exponentially decays with increasing salinity concentration when time is fixed. But the GP grows following a parabolic curve when salinity remains the same. We also plot the analytical (GP) solution in 2D and 3D, validating the raw data of the seed's germination of all the said cultivars. According to the model, a high salt content may reduce the possibility of seed germination and the quantity of germinating seeds. The model is helpful for better management of chilli cultivation under salinity. Remarkably, Bullet has the best response in GP on the entire salinity range. In contrast, the Bird's Eye has the least. The seed germination behaviour is qualitatively the same except for the Pusa Jwala, which has the best GP in higher salinity concentration.
Keywords: *Chilli, Germination Percentage, Salinity, Mathematical Modelling, Analytical Equation*

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INTRODUCTION

Seed germination is a vital and sensitive stage in the life cycle of terrestrial angiosperms that influences seedling establishment and further growth and development [1,2]. The process starts with the absorption of water by the seed coat, which triggers a metabolic switch from a quiescent state [3]. In any case, "germination comprises the sequence of activities that begin with the dormant dry seed's intake of water and end with the development of the embryonic axis", emphasizing that germination is a process rather than a single event [4]. To be clear, when mature, dormant seeds are exposed to favourable water availability conditions, temperature, and other physicochemical factors, all dormant seeds' biochemical, physiological, and developmental processes resume [5]. Salts usually exist in the soil as natural components of the earth's crust, providing advantages to plants up to a certain point. Still, they negatively influence plants above this level [6]. The impact of salinity on the germinating seed is highly variable for different species of a genus or among varieties of a particular species. Salinity has been identified as one of the essential factors slowing seed germination and lowering the ultimate germination percentage [7-11]. Salt stress can harm seed germination and post-germination events by producing an osmotic pressure that limits water absorption or by the toxicity of sodium and chloride ions [12]. It causes low water potential in the soil, which disrupts the plant's ability to acquire water and nutrients [13]. Therefore, it is essential to determine how much salinity a crop variety can tolerate during the stages of the seed process of germination and post-germination events. Screening different cultivars and landraces throughout seed germination is widely utilized to identify genotypes that can germinate and proliferate in salt-affected soils [14]. Many investigators have thoroughly examined the germination percentage (GP) for decades based on specific physical parameters such as temperature, water potential, floods and salinity. According to recent estimates, there is too much salt on around 1.125 billion hectares of agricultural land globally, while saline soil is around one of all cultivated areas [15]. Several mathematical frameworks are being used to contribute to diverse aspects of plant physiology and agriculture, such as the germination of seeds and the development of seedlings [16,17]. Mathematical modelling is one of the ways considered "safe" ways of analyzing crop yield quality estimates [18]. A subset of agricultural science called "agricultural mathematics" applies mathematical, physical, agronomic, biophysical, and molecular biology principles to widely understood research in the agricultural sector [19,20]. Despite numerous articles describing the growth and development of plants, there seems to be no agreement on the importance and application of mathematical models in agriculture and developmental biology [21]. Different plant species, even varieties of the same species, typically exhibit varying sensitivities towards salt stress at different stages of development [22]. Mechanistic or methodology-based models provide a complete description of germination events and allow for quantifying germination responses to environmental influences like salinity [23]. Even though germination has emerged as a qualitative change in the developmental response of seeds that takes place over time, different seeds within the same treatment will have very different responses. Mathematical models are calibrated by applying them to data gathered via testing in a parameter assessment or system recognition mode [24]. When germination is appropriately fitted to a mathematical function, the parameters of that function can be used to understand better germination behaviour and the effect of stressors on germination inhibition [25,26]. The testing of the improved economic and mathematical model demonstrated the possibility of providing a more accurate and objective justification for using one or more resource-saving agricultural production methods by deepening the analysis process and considering additional natural and production factors [27]. Crop modelling can also be beneficial in assisting scientists in defining research objectives. By utilizing a model to assess the significance and impact of different features, someone in the field can figure out which variables need to be looked into more in future studies [28]. This improves the general understanding of the system. Modelling also leads to less experimentation by trial and error and can reduce the time and cost of experiments. Most of mathematical modeling was conducted on cereals (29), where as there is scarcity of this type of works in vegetables. Among the vegetables Chilli (*Capsicum* spp.) is widely used as food and cooking ingredients in a variety of food. There are a huge number of cultivars under *Capsicum* spp., and there is also a lack of proper and systematic categorization of cultivars in respect of salt tolerance. So, we are interested in studying the seed germination of five cultivars of Chilli (Bullet, Pusa Jwala, Bird's Eye, Surjomukhi, and Black) concerning the concentration of NaCl within the wide range between 0 mM to 200 mM.

MATERIAL AND METHODS

The experiment was conducted in the Department of Botany, Dukhulal Nibaran Chandra College, Murshidabad, West Bengal, India and Plant Molecular Biology Laboratory, Department of Botany, Raiganj University, West Bengal, India. In the current work, sodium chloride was used because it is the most soluble and widespread salt [30]. In this study, the responses of five cultivars of chilli [Bird's eye (*Capsicum frutescens*), Bullet (*Capsicum annum*), Black (*Capsicum annum*), Surjomukhi (*Capsicum annum*), Pusa Jawala (*Capsicum annum*)] were evaluated for germination. Certified seeds of these cultivars of chilli were obtained from the Department of Agronomy, Visva-Bharati, Santiniketan, West Bengal, India. We have extensively investigated the effect of salinity concentration on Germination Percentage (GP) and on the curve, surface and mathematical expression within the independent domain of time and salinity concentration. Finally, we will discuss the biological basis of the experiment and its implications for growers.

Germination Protocol

Healthy, vigorous and uniform-size seeds were selected and subjected to surface sterilisation using a 30-second treatment with a 70% ethanol solution. The seeds passed through a 20-minute washing process in a 5% sodium hypochlorite solution and one drop of Tween-20. Finally, the seeds were washed thoroughly in autoclaved distilled water 5 times, then air dried on sterile tissue paper under a laminar hood. The treatments tested in the present study were selected to reproduce conditions of some natural agricultural zones, as characterized by infiltration of saline waters due to natural or anthropogenic factors. The type of salt used in the study was NaCl (Merck life science Catalogue number 106404). We have performed a Petri dish experiment as a complete randomized design in 6*5 factorial (six salt treatments: 0 mM (distilled water), 25 mM, 50 mM, 100 mM, 150 mM and 200 mM) and five chilli varieties. 5 ml of respective concentration of the salt was introduced to each Petri dish. The treatment was placed in a growth chamber maintaining 65–80 % relative humidity, 28 ± 2 °C temperature and a 16:8 light/dark cycle with three replications. Thirty sterilized seeds were spread and allowed to grow on Whatman No. 1 filter paper in a sterilized Petri dish of 10 cm diameter. Irrigated with different concentrations of NaCl solutions and monitored for 12 days to the end of germination.

Germination Attributes

Regular observation and counting of the number of sprouted and germinated seeds were carried out for up to 12 days. This experiment was conducted to observe the influence of different NaCl concentrations on GP. With the first appearance of the radicle (2 mm), seeds were considered germinated [31]. Counting germinated seeds was held until the day when no germination was observed [32]. The number of seeds germinated was recorded for 3 days after sowing (DAS), 5 DAS, 7 DAS, 10 DAS and 12 DAS and the results obtained each day were converted into a percentage. GP was calculated using the International Seed Testing Association (ISTA) method [33]. This parameter was calculated according to the formula

$$G\% = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds sown}} \times 100$$

Saline Model Construction and Data Analysis

As previously indicated, the GP of various chilli varieties is recorded based on the variation of salinity concentration up to twelve days (12 DAS). We have exclusively concentrated on the impact of salt on GP. Various salinity concentrations of NaCl are shown in two dimensions using the Matlab application to fulfil our inquiry goals. We would have derived two assumptions from the data and geometric simulations to create a basic mathematical model with appropriate boundary conditions. Through trial and error, we have discovered a solution that satisfies the original requirement but contains an additional component (here denoted by the constant 'K'). As it depends on the boundary condition, this 'K' was also approximated using the least squares approach. In this manner, the analytical answer is presented after the mathematical operations have been completed, as it would be used later.

Simulations have been plotted from analytical solutions and experimental raw data to assess the entire outcome. In addition to keeping salinity constant, the results section would have compared the GP of various chillies based on models and measurements.

RESULTS AND DISCUSSION

Impact of Salinity on Germination Percentage of Different Chilli Cultivars

Plant physiology research has contributed to quantitative evaluations of a range of variables relevant to the cellular processes that underlie germination. However, these measurements have typically been carried out during steady-state circumstances in addition to those that were produced by stress (Table 1).

Model Construction

By combining the increasing quantity of high-quality quantitative information achieved in life sciences via experimentation-based mathematical models and simulated situations, it is now conceivable to substantiate the current comprehension of physiological processes and enhance more plausible hypotheses for insufficiently understood processes [34].

For the construction of a mathematical model of germination percentage, we assume the following from the data obtained in Table 2.

- The rate of germination percentage decreases as the germination percentage increases.
- Initially, the rate of germination percentage is too high.

Let us consider the germination percentage $G = G(c, t)$, where 'c' represents the salinity concentration of NaCl and 't' stands for time, assuming that the other physical conditions (like temperature, humidity, etc.) remain unchanged during the germination. Then from the above two assumptions, we construct the following nonlinear partial differential equation as

$$\frac{\partial G}{\partial t} = \frac{k}{G} \qquad \textbf{(1)}$$

Satisfying the initial condition:

$$G(c,t) = 0, \qquad when\ t = \mathbf{1} \qquad \textbf{(2)}$$

And final conditions for bullet chilli, when t =12, are the following.

$$G(c,t) = \begin{cases} 93, \text{when c} = 0 \text{ mM of NaCl} \\ 76 \text{ when c} = 25 \text{ mM of NaCl} \\ 54 \text{ when c} = 50 \text{ mM of NaCl} \\ 34 \text{ when c} = 100 \text{ mM of NaCl} \\ 20 \text{ when c} = 150 \text{ mM of NaCl} \\ 7 \text{ when c} = 200 \text{ mM of NaCl} \end{cases} \qquad \textbf{(3)}$$

Where k is a function that depends on 'c'. The analytical solution of equation (1) using the initial condition (2) is of the following

$$G(c,t) = K\sqrt{(t-1)} \qquad \textbf{(4)}$$

Where $K = K(c) = \sqrt{2k}$depends on salinity concentration. Considering the final conditions (3) for all cultivars of chilli (Table 1), we have the following Table 2.

Analytical Estimation of Germination Percentage:

We have to rely on the least square approximation to find the analytical form of K(c) to find the analytical estimation of germination percentage. Assume the exponential form of it as the following.

$K(c) = ae^{bc}$, where 'a' and 'b' are constants
Taking logarithms on both sides of the above equation, we have
$\bar{K} = A + Bc$, Where,

$$\bar{K} = logK, \qquad A = loga, B = b\ loge \qquad \textbf{(5)}$$

Applying the least square method, we have the following equations.

$$\sum \bar{K} = 6A + B\sum c$$

$$\sum c\bar{K} = A\sum c + B\sum c^2$$

Solving the above two simultaneous linear equations of A and B, we can find the values of A and B. Finally, using the relation (5), we get numerical values of two constants: $a = 21.5656,\ b = -0.0122$ (Bullet cultivar). Likewise, for the other species, the numerical values of the same two constants will be found (Table 3 and Figure 1).

The model demonstrated that salt concentration and salt exposure period have a substantial effect on germination percentage. Different cultivars responded differently to different salt regimes, as seen in Figure-1. Among the cultivars investigated, Bullet was shown to be salt resistant at higher salt concentrations. At 25 mM NaCl concentration, the germination percentage of Bullet, Surjomukhi, and Bird's Eye is comparable. The germination percentage of Black is less affected by NaCl concentrations below 25 mM. In the case of Pusa Jwala, the decline in germination percentage of less than 25mM NaCl is considerably more pronounced. The fall of germination percentage under 25 mM NaCl is much higher in the case of Pusa Jwala. At 50mM NaCl, the germination percentage is recorded as highest for Surjomukhi, followed by Bullet Chilli, Black, Bird's Eye, and Pusa Jwala.
Further salinity increase causes a rapid decrease in germination percentage for Surjomukhi and Bird's Eye. The germination percentage of Pusa Jwala and Bullet at 150 mM NaCl was found to be more or less similar values. However, at 200 mM, the NaCl germination percentage of Bullet has a much higher value than other cultivars. We have obtained by plotting data for comparative analysis to forecast how salt

would affect the germination dynamics of the seeds of five different chilli cultivars: Bullet, Pusa Jwala, Bird eye, Surjomukhi, and Black. There is a need to invent new chilli cultivars with better and more consistent yields under various environmental and management situations, and a mathematical model can be a valuable resource for breeders in this endeavour. Thus a mathematical model is built upon assumptions drawn from the data. This finding will aid in assessing salt tolerance in Chilli cultivars and the production of salt-resistant variations.

Figure 1 shows that the germination of all chiles diminishes as salinity rises. Notably, the relationship between germination and salinity is not linear since the data do not fall on a straight line; instead, it is more accurate to argue that germination declines exponentially as salt increases. Hence, we may conclude that salt substantially impacts the germination of such seeds. Also, irrespective of their number, the intervention during the germination of all chillies is the same. The graph (Figure 2) is intended to demonstrate the degree of accuracy of the statistically calculated 'K' (=2k). We have drawn another 3D plot (Figure 3). It represents the findings of the mathematical model evaluating the effects of salinity, exposure period, and cultivar type on seed germination. This is more intriguing since the percentage of germination we calculated analytically (Table 2) is represented along a vertical axis (let's call it the z-axis). The independent variables of time and salinity are plotted alongside one another in a two-dimensional xy plane. As this simulation agrees with experimental results, it is considered highly accurate.

Mathematical models are created primarily to resolve one or more problems in a real system [35]. The study demonstrates that seed germination may be anticipated using a modeling approach [36, 37]. Mathematical models offer a quantitative method for forecasting growth, developmental process, and yield. They are valuable for predicting the correlations between environmental circumstances and development of the crops, enabling the assessment of growth restrictions brought on by climatic factors such as soil salinity. There has been much research on the effect of salt on the germination and yield of chilli cultivars, but no mathematical modelling of chilli as a crop has yet been developed. Usually, the germination process follows an S-shaped curve or sigmoid curve with a recess phase in which no seedlings emerge, followed by an exponential period of emergence, and ending with a plateau when emergence is complete [36,38,39]. Any influence of biotic or abiotic factors results in deviating from the sigmoid curve to another pattern. The combined impacts of chilli cultivars and salt levels considerably influenced the final germination percentage, mean germination time, mean germination rate, rate of germination, speed of germination, and germination energy. However, farmers prefer the seed germination percentage per area when selecting cultivars as the most valuable outcome [40]. Modern agricultural engineering is concerned with developing safe techniques for improving the quality of crop production by combining mathematics, biophysics, agronomy, molecular biology, and physics [41]. Plentiful statistics are available in the various agricultural institutions around the globe, where agricultural investigations are going on to provide a basis for various analytical studies [18,41,42]. Predicting the impact of several complex stressors on plant development and production may need a macroscale mathematical model [43]. Mathematical modelling addresses the challenges associated with implementing modern prediction techniques in agriculture, which can result in significant financial benefits [21]. Constructing a precise mathematical model that correlates the germination percentage with salt concentration may avoid the failure of crop fields due to a mismatch between the plant species and soil salinity. Generally, the final germination percentage is adequate for the seed industry; however, biological research requires more precise figures encompassing almost all of the dynamic aspects of the germination process [44,45]. Agronomists, plant physiologists, seed technologists, and ecologists agree that the final germination percentage (FGP) is highly significant for crop establishment, even though it is insufficient for comparative analysis of data sets [46]. Numerous alternative indices have been developed, yet most of them do not provide information beyond the FGP, and none of them can be advised as a means of summarizing germination owing to the ambiguity involved in gathering different aspects of germination, such as commencement, pace, and dimension [47].

Chilli seed growers may face several challenges due to poor germination and seed susceptibility resulting in lower seed output and quality [48]. Constructing an empirical model with a physiological explanation of seed germination under salinity is advantageous. However, it should be emphasised that mathematical models applied to real-world systems (biological, agricultural, social, economic, etc.) are valid only if their underlying assumptions and hypotheses are accurate [49]. On the other hand, many fitted curves lack biological significance. The primary goal of developing empirical models is to discover a convenient way to describe events rather than explain them. This research also suggested that the mathematical model may help forecast seed germination and provide precise data for the germination parameter of various chilli cultivars in some geographical regions (Figure 2). Under favourable conditions, seed populations tend to germinate in a predictable pattern over time, resulting in a sigmoid curve when the proportion (or absolute number) of germinated seeds is plotted against time [46]. The presence of salinity or any similar stressor can alter the pattern of the curve. This study found that different cultivars of chilli respond differently against salinity at various intervals of time (Figure 3). Germination percentage decreases linearly in the Bird's Eye cultivar, and beyond the 150 mM salinity, it cannot germinate significantly. Other cultivars can tolerate up to 200 mM salinity. For all cultivars in this study except Pusa Jwala, germination percentage decreases linearly under salinity stress. In the case of Pusa Jwala, it is sigmoid in shape. Appropriate selection of land and chilli cultivars might be achieved using models that anticipate things like days to seed germination or threshold salinity.

The threshold values of these cultivars can also be determined through this model. Mathematical models also have tremendous promise for rapidly characterizing and quantifying the effects of seedbed salinity on seed germination and seedling emergence. Mathematical modelling has successfully predicted seed germination in many crops, including, such as *Oryza sativa* [17], *Solanum tuberosum* [50], *Citrullus vulgaris* [51], *Sesamum indicum* [52], *Eruca sativa* [53], *Suaeda maritima* [54] and *Cichorium intybus* [55]. Tartarini *et al*. (2019) illustrates the model's validity and provide evidence for its use in research assessing or forecasting the response of various rice cultivars to the temporal variations in Na^+ concentrations found in soil and water [29]. Rapid assessment of seed germination percentage and germination rate is a helpful tool for seed testing centres and commercial seed producers. Finding a suitable geographic location where a species can germinate and establish successfully necessitated an examination of germination patterns under the impact of various abiotic variables [56]. In addition, mathematical models hold considerable promise for elucidating the biochemical reactions and networks that underpin all physiological processes, from seed germination upwards.

Chilli Cultivar	Days	Different concentrations of Salt (NaCl)					
		0 mM	25 mM	50 mM	100 mM	150 mM	200 mM
Bullet	1 DAS	0 %	0 %	0 %	0 %	0 %	0 %
	3 DAS	33 %	26 %	17 %	10 %	3 %	1 %
	5 DAS	50 %	40 %	30 %	17 %	11 %	3 %
	7 DAS	67 %	49 %	39 %	23 %	16 %	6 %
	10 DAS	84 %	70 %	51 %	26 %	17 %	7 %
	12 DAS	93 %	76 %	54 %	34 %	20 %	7 %
Pusa Jwala	1 DAS	0 %	0 %	0 %	0 %	0 %	0 %
	3 DAS	33 %	26 %	20 %	11 %	4 %	0 %
	5 DAS	51 %	31 %	23 %	11 %	4 %	0 %
	7 DAS	71 %	40 %	26 %	14 %	4 %	0 %
	10 DAS	83 %	50 %	33 %	29 %	11 %	3 %
	12 DAS	89 %	54 %	40 %	26 %	19 %	3 %
Bird's Eye	1 DAS	0 %	0 %	0 %	0 %	0 %	0 %
	3 DAS	9 %	9 %	9 %	4 %	4 %	0 %
	5 DAS	27 %	23 %	14 %	7 %	4 %	0 %
	7 DAS	46 %	40 %	26 %	7 %	4 %	0 %
	10 DAS	67 %	56 %	33 %	10 %	6 %	0 %
	12 DAS	81 %	74 %	46 %	10 %	6 %	0 %
Surjomukhi	1 DAS	0 %	0 %	0 %	0 %	0 %	0 %
	3 DAS	16 %	14 %	11 %	4 %	3 %	0 %
	5 DAS	37 %	34 %	17 %	6 %	3 %	0 %
	7 DAS	69 %	41 %	29 %	11 %	6 %	0 %
	10 DAS	81 %	63 %	41 %	17 %	11 %	0 %
	12 DAS	86 %	74 %	54 %	21 %	11 %	0 %
Black	1 DAS	0 %	0 %	0 %	0 %	0 %	0 %
	3 DAS	13 %	11 %	10 %	7 %	3 %	0 %
	5 DAS	30 %	29 %	29 %	26 %	3 %	0 %
	7 DAS	54 %	54 %	40 %	29 %	9 %	4 %
	10 DAS	84 %	77 %	43 %	29 %	11 %	4 %
	12 DAS	87 %	83 %	49 %	29 %	11 %	4 %

Table 1: Germination Percentage of different cultivars of chilli at different salt regimes

K(c) / C (mM)	Bullet	PusaJwala	Bird's Eye	Surjomukhi	Black
0	28.04	26.83	24.42	25.93	26.23
25	23.00	16.28	22.31	22.31	25.03
50	16.28	12,06	13.87	16.28	14.77
100	10.25	7.84	3.01	6.33	8.74
150	6.03	5.73	1.81	3.32	3.32
200	2.11	0.90	0.00	0.00	1.21

Table 2: Numerical values of K for different chilli cultivars

Cultivar	a	b	K (c)	G (c, t)
Bullet	21.5656	-0.0122	$K(c) = 21.5656\, e^{-0.0122c}$	$21.5656\, e^{-0.0122c}\sqrt{(t-1)}$
Pusa Jwala	19.4910	-0.0148	$K(c) = 19.4910\, e^{-0.0148c}$	$19.4910\, e^{-0.0148c}\sqrt{(t-1)}$
Bird's Eye	38.6586	-0.0338	$K(c) = 38.6586\, e^{-0.0338c}$	$38.6586\, e^{-0.0338c}\sqrt{(t-1)}$
Surjomukhi	45.2018	-0.0324	$K(c) = 45.2018\, e^{-0.0324c}$	$45.2018\, e^{-0.0324c}\sqrt{(t-1)}$
Black	22.6602	-0.0153	$K(c) = 22.6602\, e^{-0.0153c}$	$22.6602\, e^{-0.0153c}\sqrt{(t-1)}$

Table 3: Numerical values of two constants a and b for several cultivars of chilli

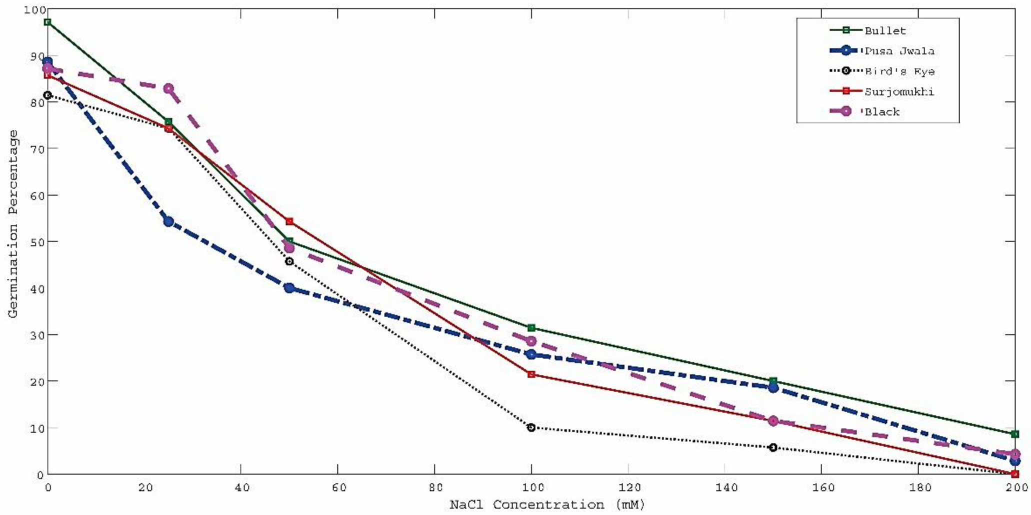

Figure 1: Germination percentage versus NaCl concentration (mM) of respective five chilli cultivars for 12 days after sowing (DAS)

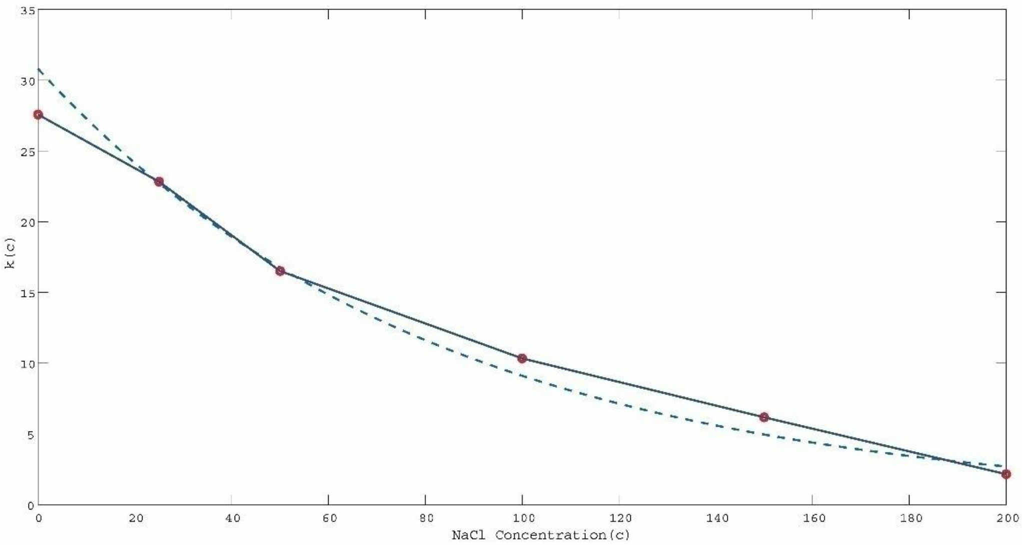

Figure 2: Exponential decay of the function k(c) with increasing NaCl concentration (Normal line represents real value and Dotted line represents estimated value)

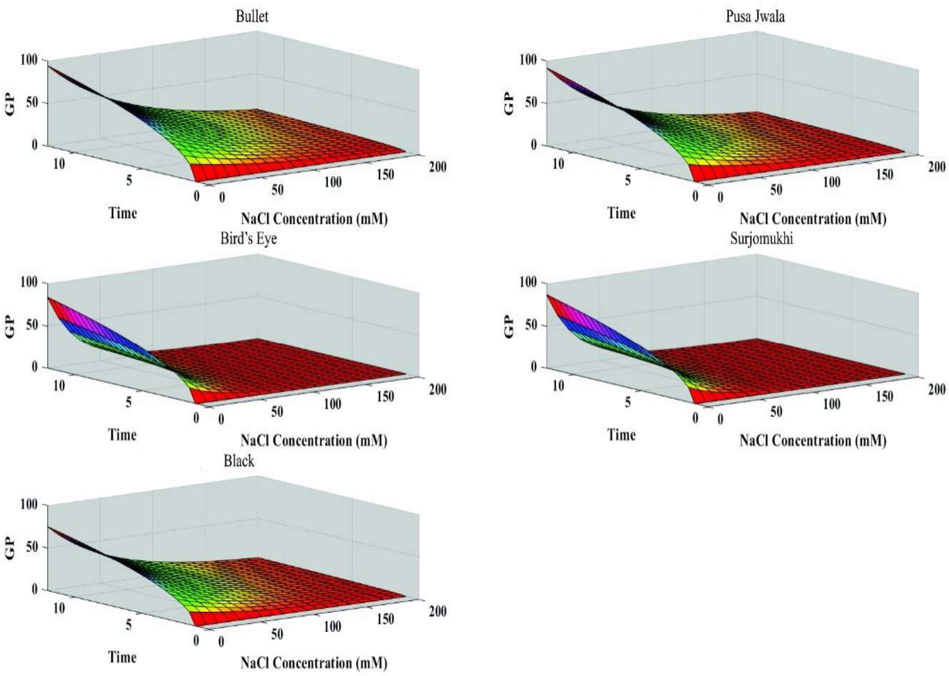

Figure 1: Graphical representation (3D) to explain germination percentage under the different salt regimes (NaCl) at different time intervals (DAS)

CONCLUSION

This proposed model has provided insight into the salinity-mediated alteration of seed germination percentage of different chilli cultivars and can help predict characteristics of the overall germination indices. The equations generated in the current study may be helpful in this area, given a recent upsurge in interest among researchers in simulating salt-affected seed germination. In general, a botanist is interested in knowing if a cultivar of a species is more advanced than other cultivars under stressful situations like salinity. Utilizing salt-tolerant cultivars may be a viable alternative strategy for minimising production issues on salty arable soils. The final germination percentage of any cultivar can frequently screen salt tolerance. Even though biological study needs more accurate numbers that cover the vast majority of the changing germination process, the FGP is usually a good enough indication. Understanding and modelling the behaviour of germinating seeds is relevant from both a fundamental and applied science point of view. Since salinity appears to be one of the crucial environmental variables influencing the germination of several cultivars included in *Capsicum* spp., establishing a precise mathematical framework that correlates germination with salt concentration may avoid cultivation failure due to unsuitable land or inconsistency between a plant variety and climate zone. We hope the present communication can provide a starting point for future research in determining salt responses in germinating seeds by using mathematical modelling. We also believe gradual research based on mathematical modelling could provide new insights into understanding plant stress responses.

Funding and/or Conflicts of interests/Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

Data Availability Statement

Our manuscript has no associated data.

Authors' contributions

All the authors listed have made a substantial, direct and intellectual contribution to the work and approved it for publication. All the authors had the idea for the article; AKS and SC performed the research work and data analysis; AKS and SC drafted; SC and SS drew figures. SS critically revised the work.

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