



Original papers

Application of Artificial Neural Network modeling for optimization and prediction of essential oil yield in turmeric (*Curcuma longa* L.)Abdul Akbar^{a,1}, Ananya Kuanar^{a,1}, Jeetendranath Patnaik^b, Antaryami Mishra^c, Sanghamitra Nayak^{a,*}^a Center of Biotechnology, Siksha O Anusandhan University, Kalinga Nagar, Ghatikia, Bhubaneswar 751003, Odisha, India^b Department of Botany, SKCG College, Paralakhemundi, Gajapati 761200, Odisha, India^c Department of Soil Science, OUAT, Bhubaneswar 751003, Odisha, India

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ABSTRACT

The essential oil obtained from rhizome of turmeric (*Curcuma longa* L.) is highly valued worldwide for its medicinal and cosmetic uses. Lack of requisite high oil containing genotypes and existing variation in the quality and quantity of essential oil with plant habitat and agro-climatic regions pose problem in commercialization of essential oil. Thus the present work was carried out for optimization and prediction of essential oil yield of turmeric at different agro climatic regions. An artificial neural network (ANN) based prediction model was developed by using the data of essential oil of 131 turmeric germplasms collected from 8 agro-climatic regions of Odisha and analysis of their soil and environmental factors. Each sample with 11 parameters was used for training and testing the ANN model. The results showed that multilayer-feed-forward neural networks with 12 nodes (MLFN-12) was the most suitable and reasonable model to use with R^2 value of 0.88. This study indicates that ANN based prediction model is a suitable way of predicting oil yield at a new site and to optimize the yield of turmeric oil at a particular site by changing the changeable parameters of the prediction model and thus is of enough commercial significance.

1. Introduction

Turmeric (*Curcuma longa* L.) of family Zingiberaceae is highly valued worldwide for its medicinal and economic significance (Roses, 1999). Its use in medication, culinary and cosmetics is well known since centuries. India is the world's largest in the production and export of turmeric (Rama Rao and Rao, 1994). The drug yielding potential of turmeric is largely due to the presence of phytoconstituents such as curcumin, oleoresin and essential oil. Essential oil is a useful secondary metabolite of turmeric. The oil from turmeric contains many important constituents having varied properties like anti-microbial, anti-inflammatory, anti-dermatosis, and insect repellent and also used in various digestive ailments (Purseiglove et al., 1981; Apisariyakul et al., 1995). These essential oils are valuable for pharmaceutical as well as cosmetic industries. The cost of rhizome essential oil of turmeric is nearly 50\$ per 100 ml in international market. The rhizome essential oil has antiseptic, antacid, carminative and antifungal properties (Asolkar et al., 1992). The volatile oil of turmeric exhibits potent anti-inflammatory effects and suppresses acute oedema.

The major barrier for production of turmeric oil from the state is the unavailability of requisite high oil containing genotypes. Identification of genetically superior turmeric with high oil content would not be possible by simple chemo typing as oil production is largely influenced by environmental factors. Further, the quality and quantity of several secondary metabolites including essential oil vary with plant habitat and agro climatic regions (Garg et al., 1999; Rahimmalek et al., 2009; Singh et al., 2013; Anandaraj et al., 2014). Hence, it would be necessary to analyse soil nutrients and climatic factors of different agro climatic regions of Odisha with respect to high oil yield.

In agricultural practices, crop production is influenced by a great variety of interrelated factors and it is very difficult to describe their relationships by conventional methods (Paswan Raju and Begum, 2013). Thus artificial neural network (ANN) is highly recommended to present the complicated relations and strong nonlinearity between different parameters and crop production. It is considered to be one of the best techniques for extracting information from imprecise and nonlinear data (Caselli et al., 2009). Hence neural network methods have become a very important tool for a wide variety of applications

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across many disciplines including prediction of crop production where traditional techniques were used. Many authors have attempted a comprehensive survey of articles involving neural networks in different field of applications; but a very little work have been done on review of articles using neural networks for prediction of agricultural crop production (Drummond et al., 1995; Sudduth et al., 1996; Tourenq et al., 1999; Liu et al., 2001; Safa et al., 2002; Boonprasom and Bumroongitt, 2002). Report on drug yield of medicinal plant is still less (Alam and Pradeep, 2009).

This present paper reports on the development of artificial neural network (ANN) model for prediction and optimization of drug (essential oil) yield in turmeric for the first time.

2. Materials and methods

2.1. Plant materials and sample stations

Turmeric samples were collected from 131 sites covering 8 agro climatic regions at different altitudes (2.8–872 m) from different districts of Odisha from May to July 2013. From each site, representative plant samples were collected in replicates of three. The interval between replicates was 2–5 m. The fresh rhizomes were collected from plants and washed with running tap water to remove the soil particles, followed by washing with double distilled water. The washed rhizomes were then air dried and used for essential oil estimations. Soil samples from each sampling site were collected in replicates and brought to the laboratory for analysis of soil nutrients. From each sampling site, the data on environmental factors such as temperature, humidity and rainfall was taken as monthly averages from May 2012 to February 2013 and properly documented.

2.2. Extraction of essential oil and quantification

Essential oil was extracted by hydro-distillation of fresh turmeric rhizomes in a Clevenger's apparatus according to the method of Guenther (1972).

2.3. Quantitative analysis of soil

The soil samples were collected in replicates of three from each site. About 200 g of soil was collected and then sieved through a 2 mm mesh. The fine soil was used for nutrient analysis. pH of the soil samples was determined in 1:2 soil: water suspension after equilibration for half an hour with intermittent stirring using the Systronics pH meter (Model MKVI). Organic carbon content of the soil was determined by wet digestion procedure of Walkley and Black as outlined in soil chemical analysis (Jackson, 1973). Total nitrogen was determined by using alkaline KMnO_4 method (Subbiah and Asija, 1956). 100 ml of 0.32% KMnO_4 solution was added to 20 g of soil sample in an 800 ml Kjeldahl flask and then 2.5% NaOH solution was added with some distilled water. Distillation was continued and was collected at receiver tube in the 250 ml conical flask containing 20 ml boric acid (2%) with mixed indicator. The distillate was titrated against 0.02 N H_2SO_4 taken in burette to a pink colour end point and available nitrogen was calculated.

Total phosphorus in the surface soil samples was determined using Brays No-1 method. Two grams of soil was extracted with 40 ml of Bray's-1 solution (0.03 NH_4F and 0.025 N HCl) and was shaken for 5 min by the help of mechanical shaker and filtered through Whatman filter paper. 0.5 ml aliquot was transferred into a 25 ml flask. 5 ml of ammonium molybdate solution was added and the volume is made up to 25 ml by adding distilled water. Diluted SnCl_2 (0.5 ml was diluted to 66 ml) was added and the volume was made up to the mark. Phosphorous concentration was analysed by the help of spectrophotometer (Model: Systronics 166) at 660 nm. The concentration was calculated from the standard graph prepared by taking different

phosphorous concentrations.

Soil potassium content was determined by taking 5 g of soil samples in 100 ml conical flask and 25 ml of 1 N NH_4OAc solution was added to it. Then it was shaken with the help of mechanical shaker for five minutes and the potassium concentration in the filtrate was analysed by the help of a flame photometer (Model: Sistronics128).

2.4. Statistical analysis

The correlation and regression analysis between the oil content and soil nutrients, environmental factors and altitude were examined using STATISTICA statistical package.

2.5. Artificial Neural Networks model development

For predictions and classifications, neural networks are useful tools. The main structure of the artificial neural network (ANN) is made up of the input layer and the output layer (Yang et al., 2014). For a complicated system a neural network model can determine the input-output relationship based on the strength of their interconnections present in a set of sample data (Howard et al., 2000). Such a model can provide data approximation and signal filtering functions (Clifford, 1992). So, neural network models provide accurate results for complicated system analysis than conventional mathematical models (Alam and Pradeep, 2009). In this case, a back-propagation (BP) neural-network model was created using Stuttgart Neural Network Simulator package (SNNS version 4.2; Institute for Parallel and Distributed High Performance Systems (IPVR) at the University of Stuttgart, Germany) and trained using the environmental parameters and soil parameters as the inputs and oil content as the output.

The structure of the neural network model consisted of 11 input neurons in the input layer and one output neuron in the output layer to match the 11: 1 input – output pattern of the training data set. One hidden layer with 12 neurons was the optimal topology for the neural network determined by a trial and error method (Fig. 1). The neural-network model was trained in an iterative training process using the obtained training set as follows:

$i = \{0.630.290.790.760.630.820.460.41 \ 0.49 \ 0.68 \ 0.57 \ 0.23\}$

The first five values are the climatic factors. The sixth one refers to altitude. The next five values are the soil parameters and the last one is the rhizome oil content collected from the corresponding site. To avoid possible bias, the order of input-output data pair was randomised before the training process. During the process of training the BP training compares the estimated output value with the target value connecting all the neurons to minimize the difference between the estimated and the target values until the error is smaller than a predefined level. The constructed model was trained with the input data for an epoch of 12,000 with 0.1 learning rate. After completing the training process, the interconnection strengths between neighbouring neuron are fixed and the neural network model will be capable of mapping input variables to an estimated output promptly and accurately.

The input variables in this model were normalised based on their possible ranges to avoid data saturation using the following equation.

$$a_{\text{norm}} = (a - a_{\text{min}}) / (a_{\text{max}} - a_{\text{min}})$$

where a , a_{min} , a_{max} and a_{norm} are the real valued input variable, the minimum and maximum values of the input variable and its normalized value respectively. The output from this model is an indexed value that corresponds to the input variable. To get the real-valued output, the indexed output value needs to be denormalized according to the following equation:

$$b = b_{\text{norm}} * (b_{\text{max}} - b_{\text{min}}) + b_{\text{min}}$$

where b , b_{min} , b_{max} and b_{norm} are the real-valued output variable, the minimum and maximum possible values of the real-valued output and

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