FUZZY MATRIX MODELING FOR AGE-BASED COTTON LEAF DISEASE ANALYSIS IN GUJARAT

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ABSTRACT
Cotton is an important crop worldwide and India is the second largest producer of cotton. Cotton is a major source of income for millions of farmers, allowing for financial stability and investment in their farms. Gujarat is a top cotton-producing states of India. Farmers of Gujarat are facing problems in production of cotton due to many diseases in cotton plants. Cotton plants are affected by various types of diseases, including viral, bacterial, soil-borne, and leaf diseases. There are several types of leaf diseases exist in cotton plants and it affects the growth of healthy cotton plant and ultimately results in reduced yield. Using Fuzzy Matrix Theory, we determined the critical age range during which cotton plants in Gujarat are most susceptible to leaf disease. Farmers can use this to determine the critical age range for peak leaf disease occurrence in cotton plants.

KEYWORDS: Fuzzy matrix, ATD matrix, IRDM matrix, CETD matrix, RTD matrix.

1. INTRODUCTION

India is an agricultural country because a significant portion of population relies on farming and related activities for their livelihood, and agriculture is deeply ingrained in the nation's culture and heritage [1]. According to the Economic Survey, at current prices, the agricultural industry in India accounts for 18.2% of the nation's GDP [2]. Cotton crop is famous as Cash Corp due to short term cultivation time and multiple times income source. Cotton plays crucial role in shaping textile economy of India. The top cotton-producing states of India are Gujarat, Maharashtra, Telangana, and Rajasthan [3]. Due to the prevalence of multiple diseases, cotton farmers in Gujarat often face reduced yields. Determining the peak age of disease occurrence can provide valuable insights for timely and effective disease management [4].

Lotfi Zadeh a professor at the University of California at Berkeley, first presented fuzzy logic in the mid-1960's. Zadeh developed fuzzy logic as a way of processing data, instead of requiring a data element to be either a member or non-member of a set, he introduced the idea of partial set membership [5]. The fuzzy set theory is based on making the membership function lie over a range of real numbers from 0.0 to 1.0. The fuzzy set is characterized by (0.0, 0, 1.0). A variety of domains use fuzzy matrices, which use membership values ranging from 0 to 1 to represent information with uncertainty. These domains include medical diagnosis, which links symptoms and diseases [6-9]; decision-making, which evaluates options such as mobile phones [10]; and robotics and control systems [11], which optimize complex operations. In various fields, such as power engineering and industrial automation [12-13], they are employed to handle and model ambiguous or fuzzy data, and in artificial intelligence [14] for pattern identification. Very few researchers have used Fuzzy matrix for identifying the problems and probable solutions in the field of agriculture [15-17].

2.MATERIALS AND METHODS

2.1fuzzy Matrix Model

A fuzzy matrix [18-20] is a matrix with element having values in the fuzzy interval. The unit interval [0, 1] and the interval [-1, 1] are called fuzzy intervals. The raw data gives the matrix representation. Entries corresponding to the intersection of rows and columns are values corresponding to a live network. The raw data is directly converted into Initial Raw Data (IRD) Matrix without modification. Now, Initial Raw Data Matrix is converted into the Average Time Dependent (ATD) Matrix (aij) by dividing each entry by the width of class interval. This will produce a matrix that represents uniformly structured data. Then average (mean) and the standard deviation (SD) of every column in the ATD matrix, are determined by the formula $\bar{x} = \frac{\sum x}{n}$, SD= $\sqrt{\frac{\sum(x_i-\bar{x})^2}{n}}$respectively.

The ATD matrix is thus, converted into the Referred Time Dependent (RTD) Matrix. This matrix is also at times termed as the fuzzy matrix as the entries are 1, 0 & -1. One can combine these matrices by varying the parameter αϵ0,1, so that the Combined Effective Time Dependent Data (CETD) matrix is obtained.

The row sum is found out for the CETD matrix and conclusion are derived based on the row sums. All these are represented by graphs and graphs [21] play a vital role in exhibiting the data by the simplest means that can be ever understood by everyone.

2.2Data Preparation

The questionnaires were carefully developed by the author to directly support the research objectives, offering comprehensive and accurate data collection in a format that is user-friendly for both interviewers and respondents. A field survey was carried out across various cotton-growing regions of Gujarat to collect a representative dataset on cotton leaf diseases. Sampling sites were selected with support from local agricultural bodies, research organizations, and farmers. Data was collected from total 200 farmers across various parts of Gujarat. Fuzzy Matrix Theory was applied to construct the Initial Raw Data (IRD) Matrix using data collected from farmers.

The list of leaf diseases [22] observed in cotton plants by the farmers in various regions of Gujarat are as follows:

D1: Leaf Curl Disease
D2: Alternaria Leaf Spot
D3: Bacterial Blight
D4: Areolate Mildew
D5: Fusarium Wilt
D6: Ascochyta Blight
D7: Leaf Reddening

Below are the initial raw data collected from the farmers.

Table 1 Initial Raw Data Matrix

Month	D1	D2	D3	D4	D5	D6	D7
0-1	7	17	39	3	54	13	67
1-2	5	20	37	7	59	12	63
2-3	20	34	54	70	8	24	2
3-4	32	52	69	7	12	27	5
4-5	21	50	72	7	28	15	7
5-6	27	29	78	6	5	5	56

The Initial Raw Data Matrix has been converted into Average Time Dependent Matrix (ATD Matrix) by dividing each entry with width of the respective class-interval.

$$\begin{bmatrix} 7 & 17 & 39 & 3 & 54 & 13 & 67 \\ 5 & 20 & 37 & 7 & 59 & 12 & 63 \\ 20 & 34 & 54 & 70 & 8 & 24 & 2 \\ 32 & 52 & 69 & 7 & 12 & 27 & 5 \\ 21 & 50 & 72 & 7 & 28 & 15 & 7 \\ 27 & 29 & 78 & 6 & 5 & 5 & 56 \end{bmatrix}_{6\times 7}$$

The average (mean) and standard deviation (SD) of every column were worked out as follows

Table 2 Average and SD of ATD Matrix

Average	18.66	33.66	58.16	16.66	27.66	16.00	33.33
SD	10.74	13.47	15.99	23.89	21.68	7.43	28.88

3.Results And Discussion

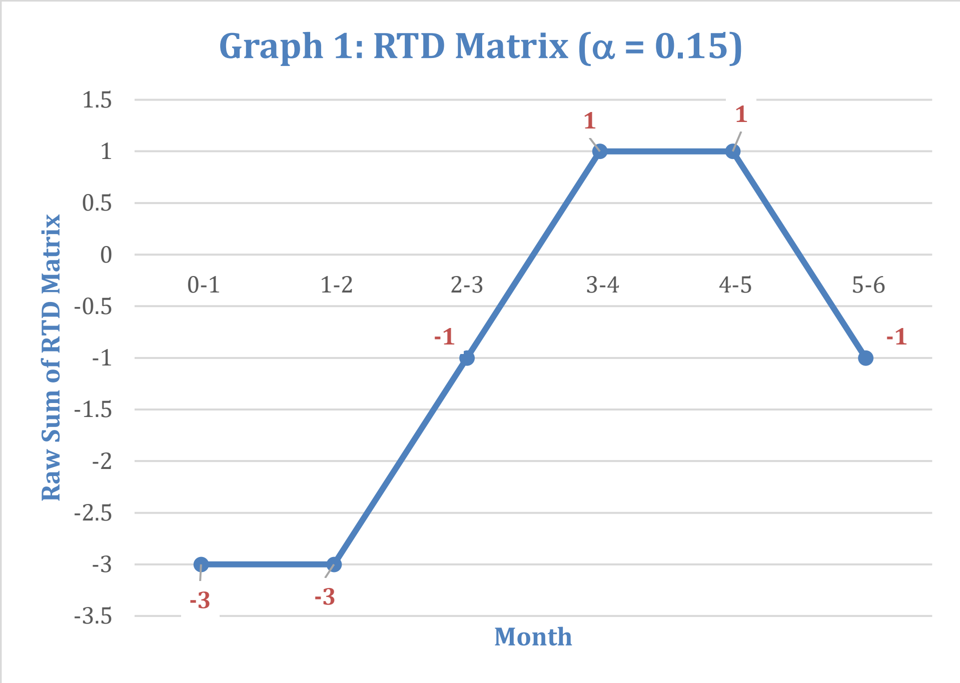
Make Refined Time dependent (RTD) matrix for different values of α by using average time dependent matrix.

RTD Matrix Calculation For α=0.15

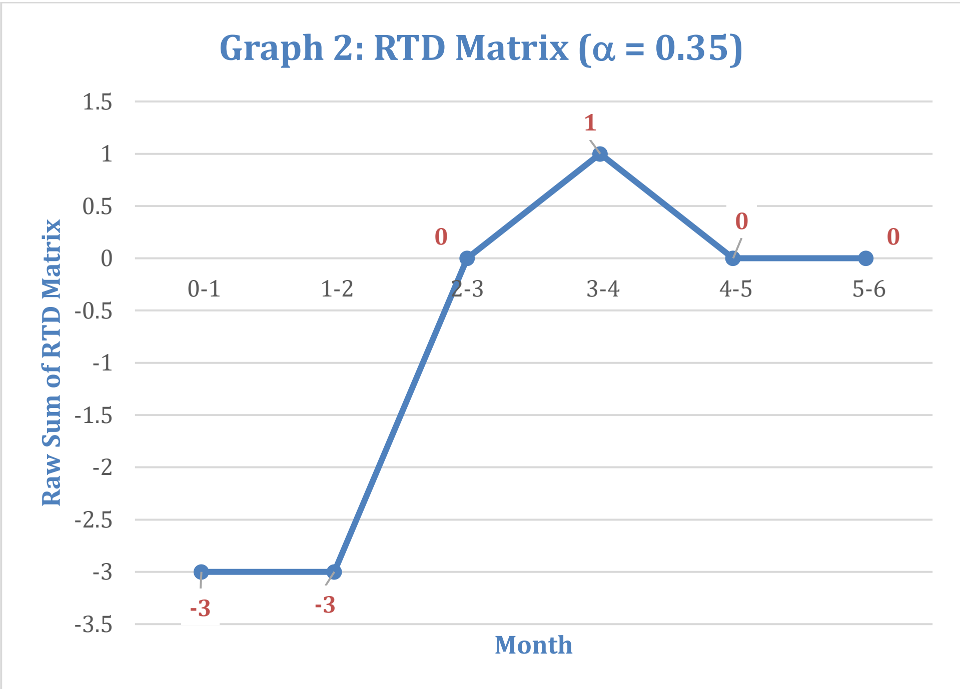
For first column bij as compare {μj−(α·σj), μj+(α·σj)} = {18.66−(0.15·10.74) ,1.92+(0.15·10.74)} = {17.05, 20.27}
For second column bij as compare {μj−(α·σj), μj+(α·σj)} = {33.66−(0.15·13.47),33.66+(0.15·13.47)} = {31.64, 35.68}
For third column bij as compare {μj−(α·σj), μj+(α·σj)} = {58.16−(0.15·15.99), 58.16+(0.15·15.99)} = {55.76, 60.55}
For fourth column bij as compare {μj−(α·σj), μj+(α·σj)} = {16.66−(0.15·23.89), 16.66+(0.15·23.89)} = {13.08,20.24}
For fifth column bij as compare {μj−(α·σj), μj+(α·σj)} = {27.66−(0.15·21.68), 27.66+(0.15·21.68)} = {24.41,30.91}
For sixth column bij as compare {μj−(α·σj), μj+(α·σj)} = {16−(0.15·7.43), 16+(0.15·7.43)} = {14.88,17.11}
For seventh column bij as compare {μj−(α·σj), μj+(α·σj)} = {33.33−(0.15·28.88), 33.33+(0.15·28.88)} = {29,37.66}

RTD Matrix for α = 0.15 Row sum

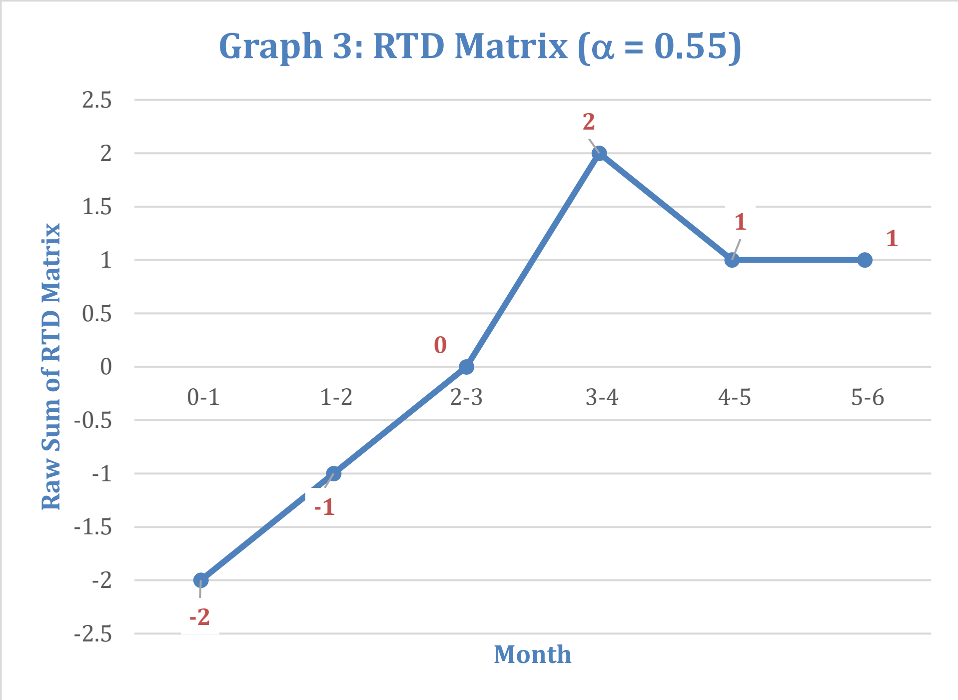
$$\begin{bmatrix} -1 & -1 & -1 & -1 & 1 & -1 & 1 \\ -1 & -1 & -1 & -1 & 1 & -1 & 1 \\ 0 & 0 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & -1 & -1 & 1 & -1 \\ 1 & 1 & 1 & -1 & 0 & 0 & -1 \\ 1 & -1 & 1 & -1 & -1 & -1 & 1 \end{bmatrix} \quad \begin{bmatrix} -3 \\ -3 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$$



$$\text{RTD Matrix For } \alpha=0.35 \quad \begin{bmatrix} -1 & -1 & -1 & -1 & 1 & -1 & 1 \\ -1 & -1 & -1 & -1 & 1 & -1 & 1 \\ 0 & 0 & 0 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & -1 & -1 & 1 & -1 \\ 0 & 1 & 1 & -1 & 0 & 0 & -1 \\ 1 & 0 & 1 & -1 & -1 & -1 & 1 \end{bmatrix} \quad \text{Row Sum} \quad \begin{bmatrix} -3 \\ -3 \\ 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

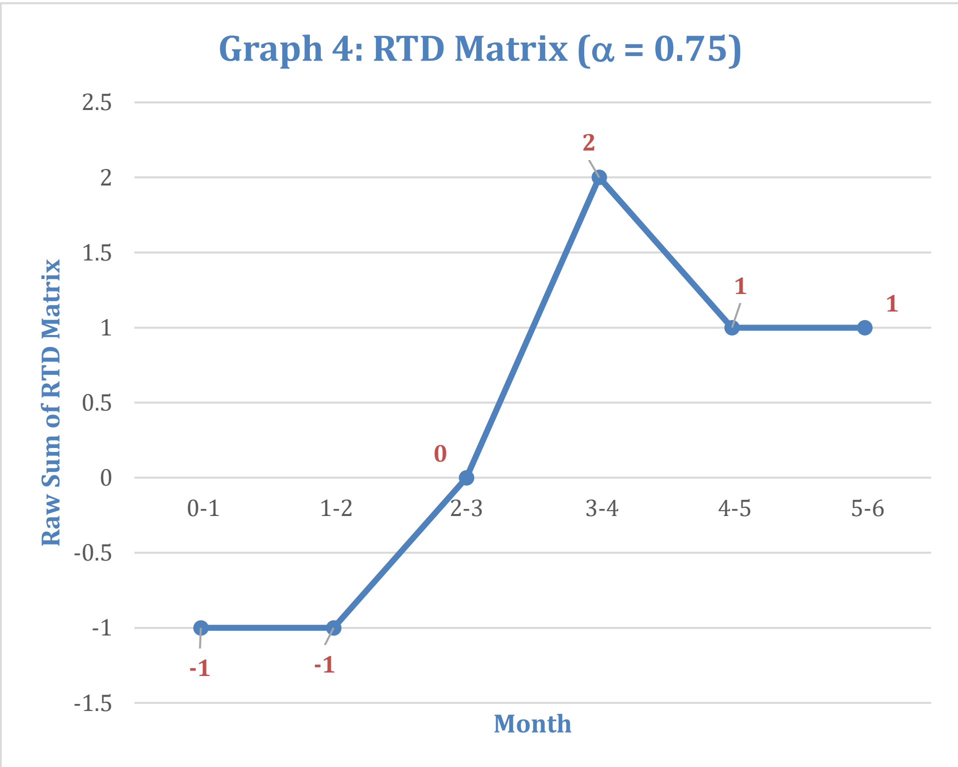


$$\text{RTD Matrix For } \alpha=0.55 \quad \begin{bmatrix} -1 & -1 & -1 & -1 & 1 & 0 & 1 \\ -1 & -1 & -1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 0 & -1 & 1 & -1 \\ 0 & 1 & 1 & 0 & 0 & 0 & -1 \\ 1 & 0 & 1 & 0 & -1 & -1 & 1 \end{bmatrix} \quad \text{Row Sum} \quad \begin{bmatrix} -2 \\ -1 \\ 0 \\ 2 \\ 1 \\ 1 \end{bmatrix}$$

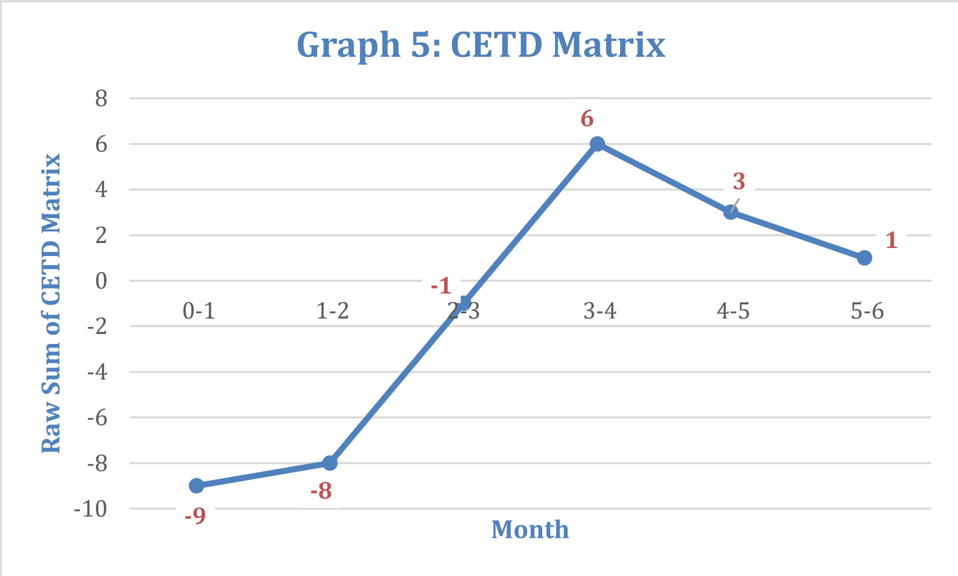


RTD Matrix For α=0.75   Row Sum

$$\begin{bmatrix} -1 & -1 & -1 & 0 & 1 & 0 & 1 \\ -1 & -1 & -1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & -1 & 1 & -1 \\ 1 & 1 & 0 & 0 & 0 & 1 & -1 \\ 0 & 1 & 1 & 0 & 0 & 0 & -1 \\ 1 & 0 & 1 & 0 & -1 & -1 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 \\ -1 \\ 0 \\ 2 \\ 1 \\ 1 \end{bmatrix}$$



$$
\begin{array}{cc}
\text{CETD Matrix} & \text{Row Sum} \\
\begin{bmatrix}
-4 & -4 & -4 & -3 & 4 & -2 & 4 \\
-4 & -4 & -4 & -2 & 4 & -2 & 4 \\
0 & 0 & -1 & 4 & -4 & 4 & -4 \\
4 & 4 & 3 & -2 & -3 & 4 & -4 \\
1 & 4 & 4 & -2 & 0 & 0 & -4 \\
4 & -1 & 4 & -2 & -4 & -4 & 4
\end{bmatrix}
&
\begin{bmatrix}
-9 \\ -8 \\ -1 \\ 6 \\ 3 \\ 1
\end{bmatrix}
\end{array}
$$



4.CONCLUSION

Collected data on cotton leaf disease from farmers was carefully processed, tabulated, analyzed, and interpreted to derive meaningful insights. Based on Graph-5 of the CETD matrix, it was observed that leaf disease in cotton plants typically occurs between 3 to 5 months, reaching its peak severity in the fourth month. Bacterial Blight is most common disease in cotton leaf disease. The CETD matrix and collected data suggest that farmers should begin pesticide application at the start of the third month and repeat it every 15 days to control leaf disease in cotton plants.

5.Acknowledgement

I would like to express my sincere gratitude to Dr. Prashant B. Sandipan and Dr. Mahesh Patel of Navsari Agricultural University, Surat, for their valuable support in enhancing my understanding of leaf diseases and guiding me in efficient data collection.

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