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Rice diseases detection using Convolutional Neural Networks: A Survey

Rishabh Sharma
Chitkara University Institute of Engineering and Technology
Chitkara University
Punjab, India
rishabh.sharma@chitkara.edu.in

Vinay Kukreja*
Chitkara University Institute of Engineering and Technology
Chitkara University
Punjab, India
vinay.kukreja@chitkara.edu.in

Virender kadyan
Department of Informatics
School of Computer Science
University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India
vkadyan@ddn.upes.ac.in

***Abstract*— Crop diseases have become a common part of the agricultural field and with the growth of the agricultural field, these crop diseases are also increasing day by day. Rice crop is one of the main crop and its plantation has spread in almost every region of India and many parts of the globe also. Rice diseases are very common and in recent decades various machine learning techniques have been introduced to detect those diseases. In this paper, we have conducted a survey study on eight major rice diseases namely bacterial leaf blight, false smut, rice hispa, blast, stemborer, sheath blight, brown spot, brown planthopper, and work conducted on them using CNNs technique. The paper is divided into two major parts, first is the survey methodology followed for conducting the work and second is state of the art used for rice disease detection (RDD) using CNNs technique.**

***Keywords*— Rice disease detection, Convolutional neural networks, survey, rice diseases, CNN**

I. INTRODUCTION

Agriculture is the lifeline for every country in the world and also it ensures food security for the population over the globe. In the agricultural field, rice is one of the most principal crops and it has about 70% of the consumers worldwide [1]. Rice is also regarded as one of the most essential cereal in every meal. So with the high amount of production and consumption, it is also very much prone to the various types of plant diseases which will have negative consequences [2] on the quality and quantity of rice production. These RDD are very difficult and time-consuming by manual human vision therefore with the advancement of computer technology and vision many techniques and tools [3], [4] have been proposed in recent decades for detecting diseases in the field of rice harvesting.

Within these computer techniques, deep learning methods also show some of the promising results in analyzing and detecting rice diseases. Mostly used support vector machine (SVM), pattern recognition, neural networks, image processing techniques, and computer vision, are not only helpful in case of rice agriculture but also diagnose the disease in case of other crops like wheat [5], apple [6], maize [7], tomato [8], lemon [9], cotton [10], etc.

From the last decade, convolutional neural networks (CNNs) have been proved to be a very successful deep learning technique in the field of image classification [11], speech recognition [12], natural language processing [6], human action recognition [13], etc. The study of CNNs, its working, and research have been gained attention in the early years of the 1990s [14]. With its unique feature extraction, mapping ability, layered structure, and design, this technique has able to deliver accurate and efficient results in case of diagnosis, analyzing, and detecting diseases.

Recently several studies have been done which conducted their experiment on RDD using CNN technique. The researchers [15] have experimented recognizing 10 rice diseases to differentiate brown spot, false smut, blast, sheath blight, bakanae disease, sheath rot, bacterial sheath rot, seeding blight, bacterial wilt, and bacterial sheath blight and achieves the accuracy of 95.4%. The authors [16] have used AlexNet CNN for classification of 3 classes of rice- normal rice plant, diseased rice plant, and insect infected rice plant with an image dataset of 277. A study [2] has conducted on rice plant disease detection with bacterial leaf blight, brown spot, and leaf smut disease with diverse photographic image datasets. This study [17] has used Deep CNN and conducted a centered classification of pests rice diseases which achieves an accuracy of 95%. A paddy crop predictive model has been prepared for classification and prediction of paddy crop using CNN [18] which achieves the accuracy of 93.58%.

This paper makes three contributions in the field of RDD first is the classification of 8 main rice diseases and its effect on a rice plantation, and the application of CNN on these diseases with state of the art accuracy for detecting each disease. The rest of the paper is organized in the following manner, section 2 covers the motivation behind the work, section 3 states the survey method used for conducting this survey, reported work on rice diseases have been covered under section 4, sections 5 covers the contribution of the studies to the framed research questions, issues and challenges have been covered under section 6 and the paper concludes in section 7 with future work.

II. MOTIVATION

The motivation behind this paper is that every year a huge amount of rice plants get wasted due to different type of plant diseases and because of this many researchers have done a lot of work on RDD using CNNs, therefore, there is a need for classification of work conducted so far and to analyze that which disease outperforms in case of detection using CNNs so that an efficient amount of work and experiment can be further conducted on those rice diseases on which an efficient amount of work has not been done using CNN technique and secondly, those which are dangerous for rice plantation and very difficult to detect. This work seeks to provide the systematic framework of the experiments conducted so far on different RDD using the CNN technique with their detailed state of the art, technique used and accuracy achieved.

III. SURVEY METHOD

The main purpose of the survey method is to give the idea of a layout plan and a roadmap used to conduct this survey. As we have followed a protocol based method and form

certain guidelines for conducted this work as it helps us to find the quality research articles and studies for this work. It will also be helpful for researchers and readers to conduct further study in this field so that they will know that how the study has to be done, what are the specific requirements of the study, and where the study is useful. This work also helpful for the type of rice diseases, data collection, CNN technique, an experiment conducted, and analysis of the resulting accuracies.

A. Survey planning:

Intending to design this survey work we have set some guidelines for this study and concerning that we have divided our survey roadmap into 4 steps. The very first step is research questions, second is data extraction, then is the inclusion/exclusion criteria and the last step is quality assessment policy which we have used to select the studies from various sources and databases.

B. Research questions:

The purpose of research questions is that readers will have knowledge that what kind of questions and problems the proposed work is intended to solve and answer. The questions are selected to address the problems related to rice diseases and CNNs technique used. The research questions are framed with the help of other co-researchers and experts in the field of plant disease detection and machine learning techniques. The framed research questions are shown in table 1 with its motivation or purpose of the questions framed.

Table 1 Framed research questions

Research questions	Motivation
What are the various types of rice diseases studied for RDD?	To know about the diseases and did the experiment is conducted on multiple rice diseases.
What are the different CNN types or CNN frameworks that has been used for RDD?	To find the various types CNNs technique and frameworks used for rice disease detection.
What features have been used for RDD?	To explore the features which have been extracted for RDD.
What are the various feature extraction methods used for RDD.	To explore the various feature extraction methods used for extracting features of rice plant while RDD.
Which technique results in high accuracy using CNN?	To conclude that which CNN technique and framework results in high accuracy of RDD.
What are the various types of datasets used for RDD?	It will help to know the type, size, and quality of datasets used so far for experimenting.
What are the dominant journals for RDD using CNN technique?	To find out the dominant journals for RDD using CNN techniques.

C. Data extraction:

Data extraction is the second step of the survey planning, it is the most difficult and time-consuming step, various studies have to find out for the work which is relevant to the topic of the work. We have extracted our data from two sources, the first is primary and the other is secondary sources. In the case of primary sources, we have used various research databases and repositories for finding out the articles relevant to our topic using a search string, and for secondary, we have used the references of the primary sources for finding out some more studies related to our work. One of the key points, while data extraction is on the basis of framed research questions as we have included on those studies for our work which contributes to our framed research questions and table 2 shows the selected studies and their contribution to the framed research questions.

D. Inclusion and Exclusion criteria:

The inclusion and exclusion criteria are a standard on which basis we have selected our studies for this work. The main purpose of this step is to make sure that only relevant study will be included for the work and all other studies, articles, and research papers will be excluded which are not relevant to the topic and aim of the survey. So, for this piece of work, as we are working on RDD and CNNs, the studies related to RDD and CNNs both have been included and the studies other than RDD and CNNs both have been excluded from the work. Other than the topic of the work, the specific name of the disease, dataset, year, and journal/conference has also been taken care of while including and excluding the studies.

Table 2 Answers to the framed research questions

Study identifier	Year	RQ 1	RQ 2	RQ 3	RQ 4	RQ 5	RQ 6	Reference
S1	2019	✓	✓	✓	✓	×	✓	[1]
S2	2020	✓	×	✓	✓	×	✓	[2]
S3	2017	✓	✓	✓	✓	×	✓	[15]
S4	2018	✓	✓	✓	✓	×	✓	[16]
S5	2020	✓	✓	✓	✓	×	✓	[17]
S6	2020	✓	✓	✓	✓	×	✓	[18]
S7	2017	✓	×	✓	✓	×	✓	[19]
S8	2020	✓	✓	✓	✓	×	✓	[20]
S9	2019	✓	✓	✓	✓	✓	✓	[21]
S10	2019	✓	✓	✓	✓	✓	✓	[22]
S11	2020	✓	✓	✓	✓	×	✓	[23]
S12	2019	✓	✓	✓	✓	×	✓	[24]
S13	2019	✓	✓	✓	✓	×	✓	[25]
S14	2019	✓	✓	✓	✓	×	✓	[26]
S15	2020	✓	✓	✓	✓	×	✓	[27]
S16	2020	✓	✓	✓	✓	×	✓	[28]
S17	2019	✓	×	✓	✓	×	✓	[29]
S18	2018	×	✓	×	✓	×	✓	[30]
S19	2019	✓	✓	✓	✓	×	✓	[31]
S20	2019	✓	×	✓	✓	×	✓	[32]
S21	2020	✓	✓	✓	✓	×	✓	[33]
S22	2019	✓	×	✓	✓	×	✓	[34]
S23	2020	✓	✓	✓	✓	×	✓	[35]
S24	2010	✓	✓	✓	✓	×	✓	[36]

E. Quality assessment:

The last step of the survey planning is quality assessment, as after the inclusion/exclusion criteria relevant studies and research articles have been selected, these selected studies

should be high-quality research, and secondly should cover at least some of the research questions framed for the proposed work. Some of the studies have been excluded in this step also so that more refined and quality survey work can be done.

IV. ANSWERS TO THE FRAMED RESEARCH QUESTIONS

A. What are the various types of rice diseases studied for RDD:

a. Bacterial leaf blight:

The researcher [17] have experimented on 8 rice diseases on which one of them is bacterial leaf blight using a rice image dataset of 1426 images taken from Bangladesh rice research institute (BRRI). The researchers have taken 138 total images of bacterial leaf blight for the experiment and conducted the above setup experiment using a simple CNNs technique and achieve the highest precision without any prior training on the ImageNet dataset.The researcher [2] has provided the method for automatic classification of rice plant diseases by analyzing photographs of the rice plants using image processing algorithm and conducted a comparison of the proposed algorithm with other existing algorithms like Decision table algorithm, Random forest, Random tree algorithm, Naïve Bayes algorithm and Bayes network with unlimited parents. This experiment is conducted with 3 types of rice diseases: Bacterial leaf blight, brown spot, and leaf smut. The authors [19] have developed a system for the detection and classification of rice diseases by taking images of diseased rice plants. The author has mainly worked on three diseases that is bacterial leaf blight, brown spot, and leaf smut. They have done multi-classification with the help of a support vector machine (SVM) and achieves the accuracy of 93.3% on the training dataset and 73.3% on the testing dataset. The researcher [20] have studied the deep learning approach for image processing and classification, they have used the CNNs framework like DenseNet and inception module for achieving the accuracy of 94.7% on a public dataset. The researchers have focused on 12 rice diseases. The researchers [21] have conducted a review on various machine learning techniques, size of the dataset, preprocessing techniques, segmentation techniques, and classifier used for carrying out the various experiments. The authors [15] have proposed a rice disease identification technique based on CNNs using a dataset of 500 natural images of infected and healthy rice plants which are covering 10 rice diseases, resulting in recognition accuracy of 92.48%. The researchers [37] has proposed an image recognition method for detection of bacteria leaf blight, brown spot and leaf smut disease using Otsu method for image segmentation and SVM for classification of images, this method has achieves an accuracy of 94.6% in rice leaf disease detection. The author [38] has proposed a method for detecting rice disease based on faster region based CNN (R-CNN) on rice bacterial leaf blight, rice blast and sheath blight with a dataset of 3010 images which results in a RDD accuracy of approx. 97%, 96% and 98% in case of rice diseases mentioned above respectively.

b. Rice blast:

The authors [22] have combine SVM classifiers with the Deep CNNs technique and transfer learning has been used for the improvement of the rice disease identification model. This experiment is conducted with a dataset of 1080 images of nine different rice diseases which results in the identification accuracy of 97.5%. The authors [23] has developed a deep CNNs model for the identification of rice blast diseases using the ImageNet dataset which achieves the accuracy of 96.50%. The authors [24] has used twin SVM image processing technique on the dataset of around 150 images classified into two rice diseases (blast and bacterial blight) and healthy rice images, which results in disease detection accuracy of 97.1837%. The researchers [25] have developed a machine learning model for detection of rice diseases using CNN pre-trained model like Inception-v3, MobileNet-v1, and ResNet50 on the dataset of Bangladesh Rice Research Institute (BRRI) which results in the mean accuracy of 97.6% in all the three trained model of CNNs. The authors [26] has developed a rice disease identification method using CNNs and conducted a comparative analysis of proposed technique with other conventional feature extraction techniques like SVM, KNN, genetic algorithm, and artificial neural networks (ANNs). The experiment is conducted with the dataset of 600 images classified into 10 different types of diseases which gives the identification accuracy of 93.7%.The researchers [27] has proposed a system for rice blast disease prediction using CNNs and SVM for feature extraction and classification respectively. Dataset of 60,000 images has been taken for conducting an experiment which proves that CNNs combined with SVM results higher accuracy than single CNNs applied. The author [39] has proposed a framework based on image recognition on five types of rice disease including rice blast, bacterial blight, brown spot, narrow brown spot and bacterial leaf blight with total of 12223 image dataset of affected rice crop plantation, this experiment is conducted using ResNet and DenseNet CNN frameworks which achieves the accuracy of 91.68% and 95.74% respectively. The authors [40] has developed a project based on RiceTalk using non-image Internet of things (IOT) device for detection of rice blast disease. The authors have treated an artificial intelligent (AI) model as an IOT device for prediction of rice blast which results an accuracy of 89.4%. The authors [38] has also conduced RDD experiment on rice blast and other two diseases mentioned on Bacterial leaf blight section.

c. Brown plant hooper:

Brown plant hopper is a type of pest disease which feeds the rice plants and is one of the most dangerous pests for rice production. Since till now, no work has been done on detecting this rice disease using CNNs but as we have studied other work related to this also and came across one of the works which are conducted keeping in mind this major rice disease and its detection with the help of computer vision. The researchers [41] have studied the attack of brown plant hooper on rice plantation by analyzing captured plant reflectance with various wavelengths and proved that near-infrared bands are suitable for detecting brown plant hooper attack on a rice plantation. The author [42] has proposed an machine learning approach based on remote sensing technique and achieved accuracy of 96.31%.

d. Brown spot:

The authors [43] proposed a method for detection of rice brown spot and blast disease using radial base function neural networks (RBFNN) which is an efficient computational method that results in the accuracy of 95% on 100 images of both diseases. The author [28] have proposed a VGG-16 based CNNs architecture for classification of three rice diseases namely leaf blast, leaf blight, and brown spot with dataset size of 1600 images approximately. The proposed model gives an accuracy of 92.46%. The researchers [29] have proposed a RDD system using machine learning algorithms namely KNN, logistic regression, Decision tree, and Naive Bayes on three types of rice diseases: leaf smut, bacterial leaf blight and brown spot with 480 dataset images resulting in an accuracy

of 97%.The author [30] has presented the work which highlights the important and essential factors which affect the design and structure of the deep neural network (DNN) on plant pathology. This experiment is conducted by taking 50,000 images of 9 plant diseases using CNNs and achieves an accuracy of 81%.The researcher [31] has proposed a rice disease prediction system using CNNs and R language on images from UCI machine learning repository having three types of disease images namely brown spot, bacterial leaf blight and leaf smut. The experiment conducted results in an accuracy of 86.6%. The authors [32] have proposed a recognition and classification technique for rice leaf detection using DNN with jaya algorithm. Dataset of 650 images have been taken for conducting the experiment covering bacterial leaf blight, brown spot, blast images and sheath rot including 95 image of normal healthy rice also. The proposed method achieves the accuracy of 98% for blast, 95.7% for bacterial blight, 92% for sheath rot and 94% for brown spot rice disease. The study [37] [39] mentioned in bacterial leaf blight and rice blast section respectively has also worked on brown spot disease.

e. False smut:

In case of false smut also we encounter the same difficulty which we have faced in case of brown plant hooper. As not much amount of work have been conducted in case of false smut and some of the work we already mentioned above which has been conducted in case of this disease also [15] [17] [20] [37] [22] [24] [31]. [33] have proposed a novel approach for detection of rice false smut disease using regional-based CNNs (R-CNNs) on 50 rice false smut images which have increased using rotation and data augmentation.

f. Rice hispa:

Rice hispa is a type of larval insect which removes all the leaves from a plant. There is almost no amount of work has been conducted till now on rice hispa disease using CNNs except [17] but extensively no amount of work has been encounter on rice hispa disease using CNNs. The researcher [44] has presented a technique for clustering and classification using K-mean, SVM and CNN method on dataset of 50 images of rice hispa which results in an accuracy of 95%.

g. Sheath blight:

The authors [34] has proposed a machine learning algorithm for RDD to detect the disease at early stage of cultivation. For classification KNN and ANN, methods have been used and have achieved accuracy of 85%, 99% for KNN, ANN respectively. The researchers [35] have developed a video RDD system for rice plant diseases and pest control using R-CNN framework on dataset comprises of images and videos of rice sheath blight, stemborer and brown spot with a total of 5400 images approximately and consider their system to be applied on other crops also for disease detection in them. Some of the work done on sheath blight have been already discussed in above sections [15] [17] [19] [20] [21][38] [22] [24] [25].

h. Stemborer:

Stemborer is a type of larva insect that bores the stem of the rice plant. The authors [17] and [35] have only experimented on this disease so far, except that we do not encounter any type of work on stemborer rice disease using a machine learning approach. The authors [45] have used a deep learning model for paddy disease detection and classification, the researchers have used 4511 images for 13 classes of pest and 4 classes of rice disease in which steam borer is one of them with a dataset of around 600 images without augmentation which results in an output of 80% accuracy while detection rice disease.

B. What are the different CNN types or CNN frameworks / architecture has been used for RDD?

Figure 1 shows the distribution of CNN frameworks. VGG16 has been noted as the most frequent CNN framework used as its usage is about in 50% of the studies and LeNet, NesNet, and DenseNet are some of the frameworks which are very rarely used by researchers in their studies and experiments.Around 83% of the studies used these frameworks or architecture in combination.

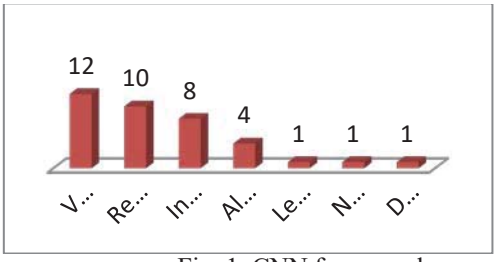

Fig. 1. CNN frameworks

C. What features have been used for RDD?

In this study we have come across a lot of features which have been used for applying CNN technique for RDD, but the main 3 features which have been used in every research of RDD are texture, shape and color. As 87.5% of our studies use these features either individually or in combinations. Around 79.8% of the studies use these 3 features together. Other than these features, we have encountered other features also which have been helpful for some researchers in their experiments. Figure 2 shows the distribution of these features and their implementation in studies.

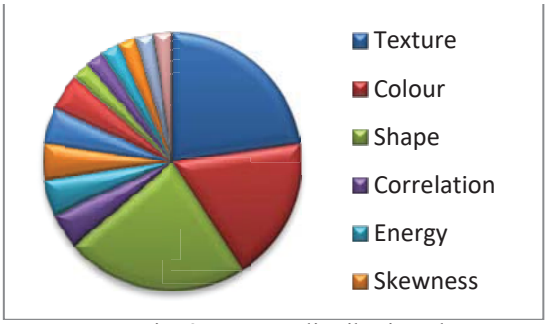

Fig. 2. Feature distribution chart

D. What are the various feature extraction methods used for RDD?

Feature extraction is one of the necessary methods before image classification for resulting in higher accuracy. In our study of RDD using CNN we have gone through many feature extraction methods. Almost every study uses a different approach and method for feature extraction. Table 3 shows the list of study and the feature extraction methods employed by them in their experiment for RDD.

Table 3 Features and Feature extraction methods

Study identifier	Year	Feature Extraction method	Features used	Reference
S1	2019	Principle component analysis	Texture, shape, and color	[1]
S2	2020	Correlation-based feature subset selection method	Texture, shape, and color	[2]

S3	2017	Principle component analysis (PCA)	Texture and shape	[15]
S8	2020	Deep CNN (DCNN)	Shape and color	[20]
S10	2019	Inception V3	Texture	[22]
S11	2020	Histogram oriented gradient (HOG), Gaussian mixture model (GMM), Gabor feature	Texture, shape, and color	[23]
S12	2019	Gray level co-occurrence matrix (GLCM)	Smoothness, energy, entropy, skewness, correlation, homogeneity, contrast	[24]
S14	2019	SVM, KNN, genetic algorithm, ANNs	Texture, shape, and color	[26]
S15	2020	CNN	Texture, shape and color	[27]
S16	2020	VGGNet	Texture, shape and color	[28]
S20	2019	GLCM	Texture and color	[32]
S21	2020	Resnet50	Texture, color and shape	[33]
S22	2019	GLCM	Texture	[34]
S23	2020	DCNN	Pattern, color and texture	[35]

E. Which technique results in high accuracy using CNN?

According to the proposed work, we have considered only those studies which are using CNN for RDD and we have recorded that each study has shown good results in terms of accuracy and detection of rice disease using CNN approach. Figure 3 depicts the accuracy graph of each study using either a single CNN approach or some hybrid approach with CNN.

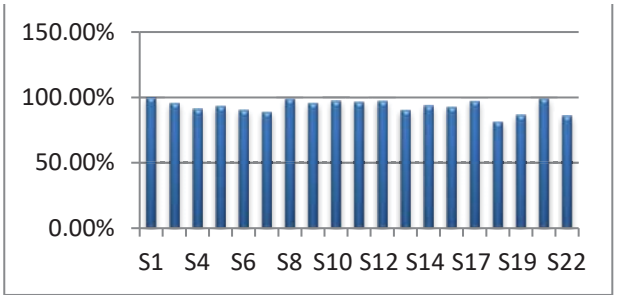

Fig. 3. Accuracy graph

F. What are the various types of datasets used for RDD?

Studies with various types of datasets along with their size have been listed in table 4 which have been used in RDD using CNN. it has been concluded that most of the work done in the field of RDD has been conducted on small size dataset which will not result inaccurate results, so there is a wide scope of conduction experiment in the field of RDD using CNN with large size dataset.

G. What are the dominant journals for RDD using the CNN technique?

The dominant journals for RDD using CNN have been analysed based on the quality of research published on those journals, the h-index and publisher of those journals and the number of studies published on RDD on that journal. In the proposed work, 79.16% of the studies are from journal and rest is from conference. According to the proposed work it has been found that Biosystems engineering is the dominant journal and Elsevier is a dominant publisher in the field of RDD. Figure 4 depicts the proportion of several studies according to different years.

Table 4 Size of different datasets

STUDY	SIZE OF DATASET (No. of images)
S1	500
S3	5000
S4	600
S5	1426
S7	120
S8	515
S9	500
S10	1080
S11	4511
S12	146
S13	600
S14	600
S15	60000
S16	1649
S17	120
S20	120
S21	150
S22	450
S23	5320

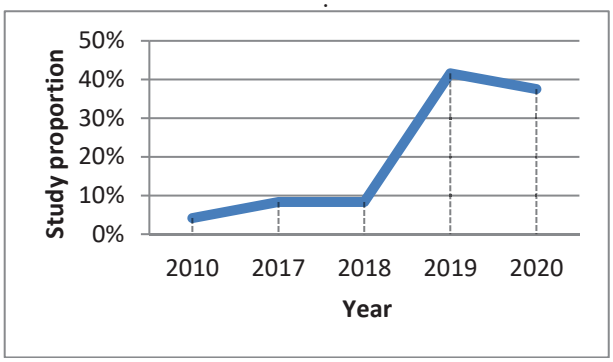

Fig. 4. Year wise study proportion

V. ISSUES AND CHALLENGES:

The challenges which we have observed that very less amount of work has been done on some of the important rice diseases including brown plant hooper, stemborer, false smut, and hispa disease. Most of the studies conducted on RDD have taken a very small size of rice images dataset, which is a major challenge as for working of CNNs we require a large amount of dataset mainly around 10,000 images approximately in testing and training phases. Diseases severity has not been the focus point of research till now in most of the studies, as severity will improve the RDD system's output accuracy.

VI. RESULTS AND DISCUSSIONS:

By conducting this survey we have come across a some of the findings and observation of the work which will help the reader to understand the output of the work more clearly, the major finding of the survey is CNNs technique outperforms other major machine learning techniques in case of RDD but still, some room of improvement is there as some of the efficient machine learning techniques perform better than CNNs, the maximum amount of work has been conducted on rice leaf blight, blast and brown spot disease while stemborer, hispa, and false smut diseases are yet to be experimented and explored using CNNs technique. The highest accuracy

encounter is of 99% using ANN technique by [34] in case of non-CNNs techniques, while on the other side CNNs techniques used by [18] gives the highest accuracy of 93.58% on detecting bacterial leaf blight and brown spot disease.

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