Soil Nutrient Based Mobile App for Crop-wise Fertilizer Recommendation: A "SoilNutro" Application

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript

ABSTRACT

Agriculture is the most important occupation for most Indian families in India. A relatively larger Indian population lives in rural areas. The majority of rural people depend on agriculture for their livelihood. Therefore, it is the responsibility of the government and information technology to provide relevant information related to agricultural technologies for better crop production so that farmers can feed India's growing population. Soil fertility refers to the ability of soil to sustain agricultural plant growth. The farmer needs to know the soil fertility of soil of their farm holding that soil is either capable of better crop production or not. Therefore, it is very necessary to know soil health for increasing crop production and reduce the cost of production. The available nutrient content is an important parameter to determine soil health. Nitrogen (N), Phosphorus (P), and Potassium (k) are major nutrients that are needed in the crop field with large amounts in the form of fertilizers. In the technology front, we all are aware that the mobile phones have become one of the major sources of communication technologies in developed and developing countries in the last few decades. With the realization of this fact about the use of smartphones, the development of a mobile application called *'SoilNutro'* has been done. *SoilNutro*app has been developed to achieve the nutrient status of a specific location of users. It also recommends the combination of fertilizer doses required for crops based on current nutrient status for efficient use of various fertilizers. *'SoilNutro'* app has been developed using minimum SDK version of API 24: Android 7 on the android platform. The developed Android application *'SoilNutro'* will be of great use to provide farmers with a specific location of nutrients and recommend crop-wise fertilizer based on the available nutrient.

Keywords:Android; Soil Fertility; SoilNutro; Nutrient Status; Fertilize; Mobile Application

1. INTRODUCTION

Agriculture is one of the most significant and ancient human occupation. India is known especially for its agriculture. It has a significant part to play in the financial stability of the country. According to Food and Agriculture Organization, agriculture has proven to be the bedrock of the Indian economy as it contributes approximately 16.5% to the GDP of the country. The yield of any crop depends on the soil health and soil fertility where it is grown. The two big obstacles for sustainable agriculture are - sustaining soil health and increased crop production. As humans require nutrients, so do crops. A nutrient-rich soil must possess all primary nutrients. Typically, a productive soil should also have some organic matter that increases soil composition, preservation of soil moisture, and also the preservation of nutrients and a pH between 6 and 7.

Unfortunately, many soils don't have sufficient amounts of all the essential plant nutrients and conditions of the soil are unfavorable for taking other nutrients from the soil. Low nutrient content in the soil is defined as constraint to crop growth and production. But still, the farmers do not apply adequate amount of fertilizer doses resulting in mismatch with the nutrient requirements of the soil [1]. Soil scientists concentrating on soil fertility and soil testing, are interested in nutrient management to improve crop production. To add nutrients and organic matter to the soil, they focus on using chemical fertilizers, manures, waste products and composts.

Soil testing is an effective way of assessing its fertility status. It offers useful knowledge to establish a reliable fertility management system. Soil testing is important for the reasons such as maximizing crop output, assist in the diagnosis of plant cultivation problems, and improve the nutritional quality of growing media, save money and save resources by applying appropriate fertilizer. Soil testing is a science-based, time-tested method for determining soil fertility level, soil diseases and nutrient improvement recommendations.

Government of India has provided soil health card for spreading information about soil testing of their field to the farmers. The Soil Health website (http://www.soilhealth.dac.gov.in) [19] provides information about the available nutrient status. It has farmer-wise, sample-wise, village-wise, grid-wise nutrient status that is also updated regularly by this website. One of the most popular way these days could be use of a mobile app with user-friendly interface.

In the last few decades, information and technology related to agriculture have been transferred by groups of village-level workers, extension workers, agricultural scientists, KVK's subject matter experts, and agricultural universities. But information reached only a few users due to the cost of installing computer systems and apps such as e-choupals, kiosks, etc. Mobile apps are just the strategy of replacing computer-based services due to its lower cost and smooth installation with various cellular services. There are several smartphone applications developed globally, that have an excellent framework, for example, electronic tickets booking, electronic selling and procurement of agricultural goods, internet consulting services regarding livestock and many more. In agriculture too, many applications for performing different activities have been developed. For example, “Pusa Krishi” which is used to provide information about technology development in agriculture and helps in increasing farmer's income. Availability and use of mobile apps are becoming very common in the agricultural sector too. Thus, the mobile app is one of the platforms where farmers can obtain all the solutions and information in one single touch.

Nowadays, the focus of common people has moved from desktops and laptops to mobile devices. These days, mobile communication is very common and convenient way of information communication. Even farmers also have started feeling easy to use mobile devices for advisories and market information. Capability of running many essential applications on this handheld device, the advent of smartphones and tablets has expanded its usefulness. Installed on smart phones or tablets, the applications (apps) provide more accessible way to access the internet and retrieve any field related information. To keep this in mind, it would be very helpful to create a mobile app to provide soil nutrient status

where the farmers grow their crops. Therefore, a user-friendly mobile application to provide farmers, the information about requirements of crop-wise fertilizers for his place of farming or any other place can be a great resource.

Several apps have been developed in agriculture to calculate the quantity of fertilizers requirement directly or based on soil testing. According to Nayak *et al.* (2014), for soil test-based fertilizer recommendation when nutrient content belongs from a low category then 25% more than the recommended dose of fertilizer for a particular crop has to be applied. Similarly, when the nutrient content is belonging from a high category then 25% of the recommended dose of fertilizer for a particular crop can be reduced while applying fertilizer. Similarly, when the nutrient content belongs from medium or just above the critical limit, then only the recommended dose of fertilizer on a particular crop has to be applied. Singhal *et al.*[2] developed a mobile application for the Indian farmers for providing directions in their farm activities. This application is named "Krishi Ville" that is developed 8 on the basis of the android platform. This smartphone application provides detailed knowledge about different agricultural crops along with weather predictions and news related to agriculture. Intaravanne *et al.*[3] proposed a mobile based leaf color analyser application named as "BaiKhao" (means 'rice' in Thai). In case of rice plant, the color level of leaves corresponds to the nitrogen status of the crop. So, by using this application, the leaf color levels of rice can easily be identified. Delgado *et al.*[4] developed a mobile app. This app works as nitrogen management tool for assessing risk of nitrogen-loss from crop field environment. Patel *et al.*[5] developed an android application for horticultural crops for the farmers of Gujarat. This application acts as a farmers-helping service that provides information about fruits, vegetable and flowers in audio format in Guajarati language. Farm Calculator app has been developed by University of Agricultural Sciences, Bengaluru, Karnataka. Farm Calculator is a mobile based application that is developed to calculate exact quantity of N, P and K fertilizer required per unit area based on recommendation of soil testing. Sharma *et al.*[6] has been developed e-Agro app. This app is developed for sustainable development of farmer. "E-Agro" has been created on Android as base to serve farmers which supports android based platform that combines internet and mobile communication with GPS for effective and smooth farming. It not only offers details on existing weather conditions but also offers weather warnings to prevent potential harm to crops. And often recommend the most suitable crop, and also with the needed fertilizers, pesticides, and herbicides.

Koti [7] developed an app named as "Fertilizer Calculator" that is used for conversion of nutrient content of nitrogen, phosphorus, potassium in fertilizer doses. It provides eleven different combinations of fertilizers from nutrient doses. Delgado *et al.*[8] has been built an android application named as Ecofort that is used to reduce fertilizer cost in fertigation. This application is developed for the Android platform which selects the proper combination of fertilizers to achieve the optimal nutrient solution for the different crops, taking into consideration the existing market price of fertilizers. Soil Nutrient Manager app has been developed by ICAR Research Complex for Eastern Region, Patna-Bihar in 2018. In this app, farmers are required to put the nutrients availability status of their soil, crops to be grown and fertilizers to be used to get the readymade fertilizer recommendation. Davis [9] developed a unique application name "Soil Web" that utilizes Global Positioning System (GPS) and provide real-time access to USDA-NRCS soil survey data with data on soil types and detailed soil analysis with current location.Karolina *et al* [21]in 2020 assesses the viability of utilizing smartphones in soil analysis and developed an android based smartphone application, in conjunction with commercially available Quantofix® test strips, was employed to analyze 92 soil samples collected across Indonesia. Senapaty*et al* [20]in 2023have proposed an IoT-enabled soil nutrient classification and crop recommendation (IoTSNA-CR) model to recommend crops which helps to minimize the use of fertilisers in soil so as to maximise productivity.

Thoroughly review of existing work, many apps have been developed in agriculture to calculate the quantity of fertilizers requirement directly or based on soil testing. But these apps do not consider information about current nutrient status (N,

P and K) of specific location of farmer's fields. Also, these apps do not suggest crop-wise fertilizer recommendation. Thus, there was a need to develop an app that can provide information about nutrient status of specific location by using Soil Health Card (SHDs) data and also recommend the required fertilizer doses for the crops.

2. MATERIAL AND METHODS

In this study, an attempt was made to develop an android based smartphone application by using Android Studio IDE (Integrated Development Environment) to assess the nutrient status of a single individual or farmer's position and recommend crop-wise doses of fertilizers that are needed for their crops to be supplied. In this section, the methodology, architectural design and technologies used to create this application have been presented.

2.1 System Design

The smartphone application has been designed in such a manner that it is convenient to use and provides the consumer with a clear guide to find the nutrient status of his place by using soil health card data. This app also suggests the optimum doses of fertilizers that are needed to apply on farmer's field for getting more yield. The app asks for the permission from the user to detect his location using Global Positioning System (GPS) signal. The app finds out user's current location coordinates (Latitude and Longitude). Based on this information, it retrieves nutrient content of the nearest location available in the database. With this value of nutrient content, it computes crop-wise fertilizer recommendation. Steps of the process to determine nutrient status and to prescribe fertilizer doses of a specific area or location have been shown Fig 1

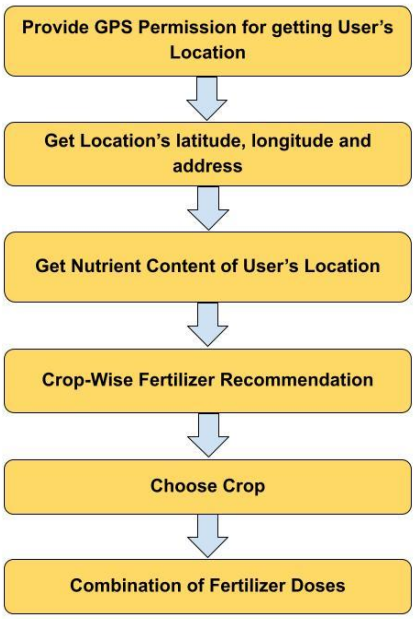

Fig.1: Steps followed by the app to determine nutrient status and required fertilizer doses.

The 'SoilNutro' application has been developed using data downloaded from the Soil Health Cards (SHCs) portal (https://www.soilhealth.dac.gov.in). A large amount of data is available on this portal which has been used to develop the 'SoilNutro' application. The data download process takes a lot of time to download and save data to the desired file. Hence, UiPath Studio software is used to download data from the website https://soilhealth.dac.gov.in. UiPath Studio is based on RPA (Robotic Process Automation) technology [10]. It is a technology that allows the configuration of computer software or "robots" to simulate and integrate human interaction actions within digital systems [11].

2.2 Architecture of *SoilNutro*

The architecture of the developed app mainly consists of two layers. Client-side interface layer [12] and database layer. The following section gives details about these layers:

Client-Side Interface Layer (CSIL): The mobile app itself is the interface layer on the client side which runs on Android-based platforms. The interface is implemented by XML, Styles of android Software Development Kit (SDK), and Java Programming language. The design or architecture of the mobile app is achieved by XML files [13]. The layout format of the mobile app is derived by android's Style files, and Java programming language that executes the logic and application's actual activities. The smartphone application is indeed the client-side interface layer that operates on a platform like an android. XML, Styles of android software development kit (SDK) and Java programming language implements the interface [14]. The designing or layout of the mobile app is done by XML files, the view format of the mobile app is specified by the Style files of android and the logics and the actual coding of activities of the application is written in a java programming language.The architecture of an Android system is a collection of different layers. Each layer has a specific role and set of functionalities. Each layer provides the functionality to the layer above it. As you can see in the Figure 2 that Android Architecture (also called Software Stack) has the following layers: Application layer, Application Framework, Native Libraries, Android Runtime and Linux kernel.

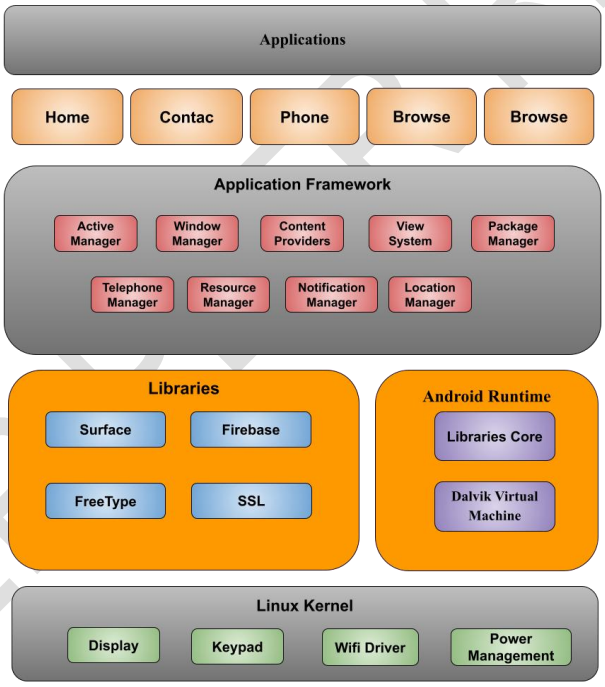

Fig.2: Application framework of android

Database layer: The database layer is implemented by using a firebase real-time database. Firebase started as a Backend-as-a-Service (BaaS) [15] and grew into a next-generation app-development platform on Google Cloud Platform. Firebase is a real-time database that allows developers to communicate directly with the client without implementation of a web service layer [16]. Firebase allows us to develop the whole application on the front-end without any server-side code. Firebase can itself be a server, API, and data store.

Figure 3 is showing architecture of *SoilNutro* application which is based on basic application framework of android. SoilNutro architecture has two major components: Database Layer (Firebase Real-Time Database), Client-Side Interface Layer (CSIL)

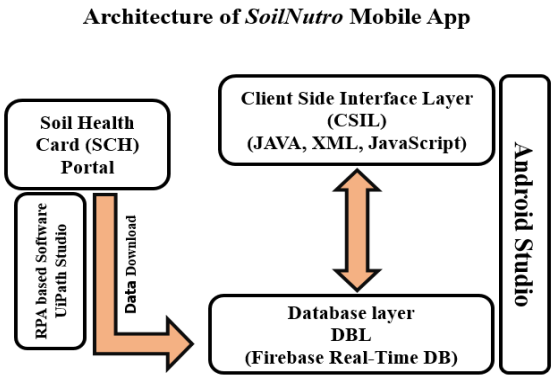

Fig.3: Application architecture of SoilNutro

2.4 Getting Current Location by using GPS Location Provider:

One or more components of the android app are written as java classes. Knowing the current location in an android mobile pave the way for developing many innovative Android apps to solve user's daily problem. For developing location aware application in android, it needs location providers [17]. There are two types of location providers namely - Network Location Provider and GPS Location Provider. It can be used to get current location of users. For getting accurate location of users, GPS Location Provider has been used to get the user's current location automatically. Fig 4 shows the android runtime environment of GPS based mobile application.

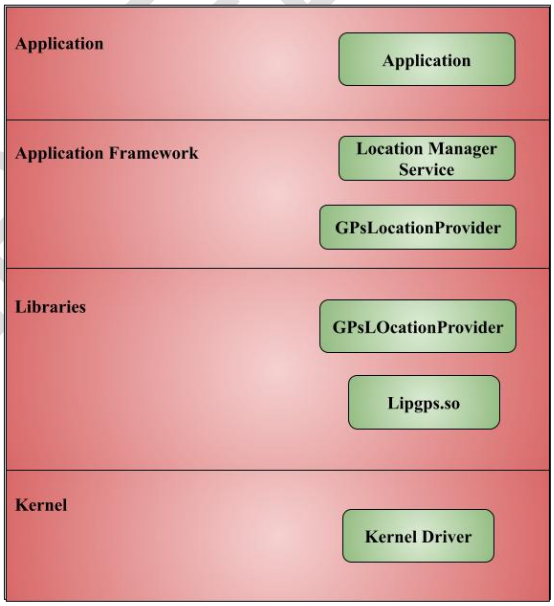

Fig. 4: Runtime environment of GPS based mobile application

2.5 Database Designing

2.5.1 Firebase:

Android Studio supports numerous methods or techniques for storing information and data. Firebase is a data-storage method. The Firebase Real-time Database is a cloud-based NoSQL database that syncs data in real-time throughout all users and offers offline functionality. It is used in JSON (JavaScript Object Notation) format to hold the data.As a mobile developer, we require back-end resources when developing large-scale apps, as well as a specific developer who can deal with kinds of stuff at the server-side. Apart from the Real-time database, storage, and networking, Firebase offers all those kinds of features that are expected on the server-side.

Adding Firebase to *SoilNutroapplication*: Firebase supports Android 2.2 or later Android versions. Below steps were followed for adding Firebase to Android Studio project: The data that is used by "***SoilNutro***" is stored in Firebase in JSON format. Figure 5 is showing format stored in the firebase.

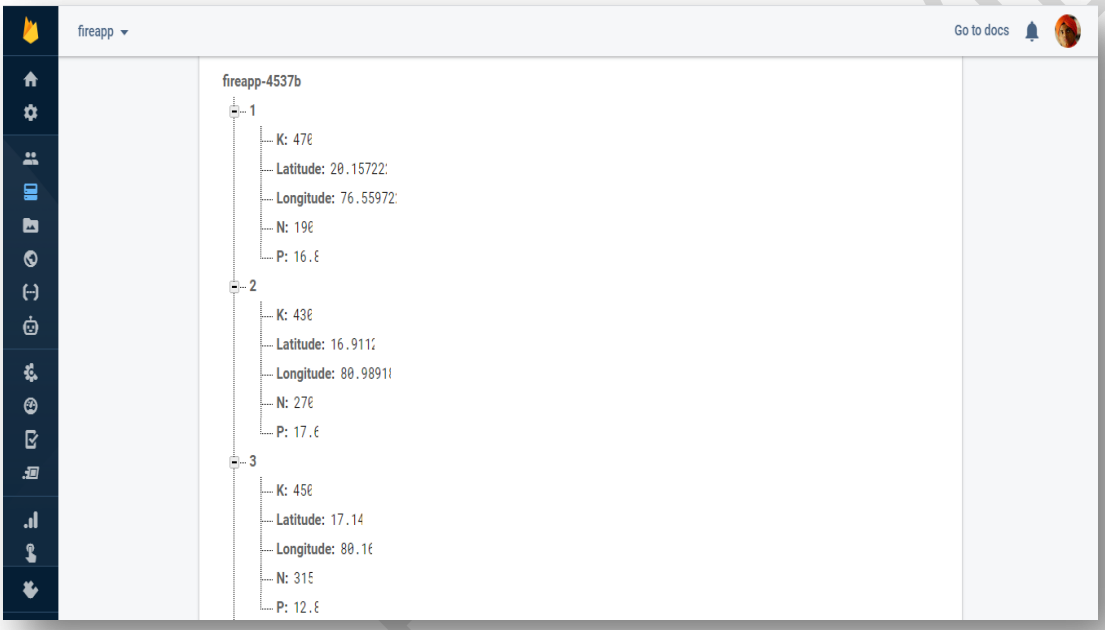

Fig: 5: Database format of Firebase

3. RESULTS AND DISCUSSION

An android based mobile application named 'SoilNutro' have been developed to determine the nutrient status of soil according to the location of the farmers. It also recommends dosage of fertilizer to be applied based on the nutrient status of soil at the retrieved location by the app using GPS signal.

3.1 Fertilizer recommendation by Soil Fertility Rating:

Based on available amount of N, P and K, soil is classified into 6 categories i.e., very low, low, medium, moderately high, high and very high. It is shown in Table 2 [18].

Table 1: Soil test classification based on soil fertility evaluation experiment

Parameters	Very low	Low	Medium	moderately high	High	Very high

Available Nitrogen (N) In Kg/ha	<140	141 – 280	281 - 420	421 – 560	561 – 700	>700
Available Phosphorus (P) In kg/ha	<7	7 – 14	14 – 21	21 – 28	28 – 35	>35
Available Potassium (K) In Kg/ha	< 100	100 – 150	150 – 200	201 – 250	251 – 300	>300

The general recommended dose is based on multi-locational trials conducted with different doses of N, P and K fertilizers. Its economic evaluation is done to reach at an optimum dose for a any chosen crop. These recommendations are suitable for medium soil fertility condition irrespective of wide variation that occurs in soil fertility status. In this approach, medium soil fertility is equated with general recommended doses (GRD).

Table 2: Computation of fertilizer dosage on the basis of soil test class

Soil Test class	Recommendation Dosage
Very Low	GRD + 50% of GRD
Low	GRD + 25% of GRD
Medium or Moderately High	GRD
High	GRD - 25% of GRD
Very High	GRD - 50% of GRD

(Source: Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, 2012)

3.2 Features of the Application

- Find user's current location using GPS.
- Information retrieval interface to get nutrient status and crop-wise fertilizer recommendation for the location found using GPS.
- Display nutrient status of the location available in the database nearest to the user's location.
- Recommend crop-wise different combination of fertilizer required based on nutrient content of N, P and K.
- Facilitate access to the application anywhere-anytime through portable mobile devices.

Application icon and splash screen of 'SoilNutro' is shown in Fig 6. The splash screen has the app's title and image related to the content of the soil of Nitrogen (N), Phosphorus (P) and Potassium (K).

The home screen of the mobile application 'SoilNutro' as shown in Figure 7, includes "proceed" button, logo, text about the app and address of the institute.

For detecting user's location details, user is asked for permission to access Global Positioning System (GPS) signal of the mobile device. When the user taps on the "Get Location" button provided on the home page, it detects the user's location automatically by executing google places API in the background.

Fig.6: shows the home page screen that shows latitude, longitude, city name and address of user retrieved.

When the user presses the "Nutrient Status" option, the next screen of the mobile application displays major nutrient content of the user's nearest location available in the database The data displayed about nutrient status of the GPS location is retrieved from the website (http://soilhealth.dac.gov.in). In case the app is unable to get latest data from this website, the app retrieves it from its inbuilt database. The inbuilt app database is used to store some of the retrieved data during previous access of the app ‘SoilNutro’. This database was developed on the Firebase Real-time database.

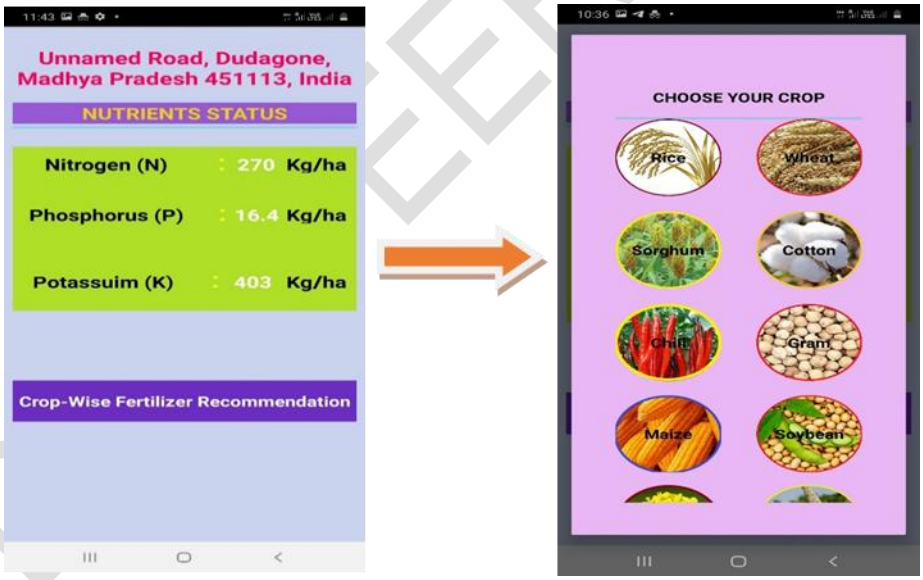

Fig.7: indicates Nitrogen (N), Phosphorus (P) and Potassium (K) content of the user's location.

When a user wishes to know his / her field's crop-wise fertilizer recommendation on the basis of the available nutrient content, it is required to tap the "Crop-wise Fertilizer Recommendation" button. After tapping on the "Crop-wise Fertilizer Recommendation" button, ‘SoilNutro’ displays the name of various crops along with its images on the next screen. After the selection of one of the crops, combinations of required doses of fertilizer based on the content of N, P and K have been provided.

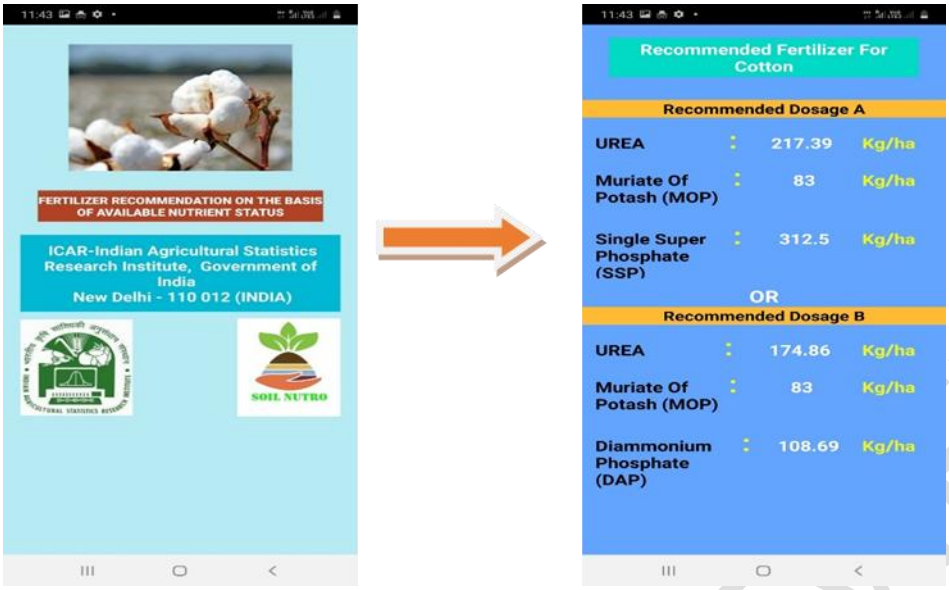

Fig. 8 show the recommended dose of crop-wise fertilizer after selection of one of the crops

4. CONCLUSION

Nutrient supply is an important factor to ensure profitable yields. In the recent years, a declining trend of total factor productivity and compound growth rates of major crops and low nutrient use efficiency have been observed primarily due to deterioration of soil health. One of the key factors for this dilemma is the large nutrient deficit between demand and availability of nutrients. In general, the fertilizer consumption in India is grossly imbalanced. Therefore, it is very important to get the information about soil health to maximize the production of the crop grown by farmers. Available nutrient content in soil is also used to determine soil health and soil fertility. Low nutrient content in soil indicates poor soil fertility. To know available nutrient content or nutrient status in the soil for the famers to apply correct amount of fertilizer doses to get the best yield of the grown crop is very important. At the same time, it is also a well-known fact that due to fast advancement in the technology, our farmers are also able to use smart mobile phones and get themselves updated about their farming practices. It has also made possible for a single mobile device to run more than one application at a time. In agricultural sector also, many useful applications have been developed for better growth in every aspect of it. For example, apps for weather forecasts, farm management, and crop development and so on have been made available by various app developers. With the support of smart apps, the transfer of information can be done accurately and reliably even to the rural areas. In this study also, a very useful app called ‘SoilNutro’ has been developed that provides information about available nutrient content either of the user’s location (retrieved by GPS signal of the user’s mobile device) or any location entered by the user. On the basis of nutrient content provided by this app, it also provides crop-wise optimum amount of fertilizer doses required to be applied on his/her field. This app is user-friendly and provides the output very fast provided the network connection speed is good. Although, ‘SoilNutro’ is a very useful mobile app for farmers but still there exists many possibilities for extending its functionality.

FUTURE SCOPE

Some of the future improvements that can be added to this have been listed below:

- As of now the web environments used to run app on local-host. It can be deployed on webserver.
- This app is developed in English language and can be extended to multi-lingual app.
- Nutrient content is displayed according to latitude and longitude. It can also display state-wise, village-wise, sample-wise and farmer-wise.

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