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Current Research in Crop and Soil Science

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Current research in crop and soil science (CRCSS journal) aims to promote excellence in agricultural, crop, and soil science research, with a vision to advance scientific knowledge that strengthens practice, education, and research in the agricultural domain. The journal is committed to disseminating high-quality research papers, reviews, and contemporary articles addressing key challenges and innovations in crop production, soil management, sustainable agriculture, plant health, and related disciplines.

The target audience for CRCSS includes agricultural scientists, soil scientists, agronomists, horticulturists, researchers, academicians, extension personnel, and allied professionals at all levels who are dedicated to advancing scientific practice and professional development through evidence-based knowledge.

CRCSS follows a rigorous peer-review process and is published bi-annually. The journal welcomes articles that contribute to improving agricultural productivity, environmental sustainability, soil health, farm management, and community-based agricultural development. High-quality papers related to agricultural education, training, policy, and administration are also considered for publication.

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From the Editor’s Desk

Dear Readers,

It is my pride and privilege to announce the inaugural issue of *Current Research in Crop and Soil Sciences (CRCSS)*, published in 2025, featuring carefully selected research papers from contributors across the world. This issue includes articles covering a wide range of topics in crop and soil sciences, agronomy, soil fertility, sustainable agriculture, and allied disciplines.

CRCSS aims to provide a platform for academics, researchers, and professionals in the field of agriculture and soil science to share their findings, innovative practices, and explore future trends and applications. The journal also serves as a venue for disseminating both theoretical and applied research, with the ultimate goal of bridging the gap between research and practical agricultural applications.

Through this forum, we hope to accelerate scientific progress and technological advancement for current and future generations. The publication offers a comprehensive view of contemporary issues and innovations in crop and soil sciences. All submitted manuscripts, including original research and review articles, undergo a rigorous double-blind peer-review process, ensuring the highest standard of quality and integrity.

I would like to extend my gratitude to the eminent experts and reviewers who have generously contributed their time and expertise in reviewing articles for this inaugural issue.

I am confident that *CRCSS* will quickly gain recognition among educators, researchers, and professionals in the agricultural sciences. This inaugural issue of Volume 1 includes ten selected articles addressing diverse topics in crop and soil science research, showcasing the quality and breadth of work that CRCSS aims to promote.

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Current Research in Crop and Soil Science (CRCSS) is the official biannual, peer-reviewed publication of the **School of Agriculture, DRIEMS University, Tangi, Cuttack, Odisha**. The journal invites scholarly contributions in the form of **original research articles, review articles, systematic reviews, case studies, and reports related to agricultural education, extension and farm management**.

CRCSS aims to promote excellence in crop and soil science research and advance scientific knowledge for agricultural practice, education, innovation, and sustainable resource management. The journal publishes high-quality research, reviews, and contemporary issues relevant to crop production, soil health, climate-smart agriculture, and environmental sustainability. The intended readers of this journal include students, academicians, researchers, scientists, extension professionals, and agricultural practitioners who are dedicated to advancing agricultural science and applying evidence-based practices.

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2. Abstract

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Abstracts of research articles must be structured under the following headings: **Introduction, Objectives, Methods, Results, Conclusion**

At the end of the abstract, provide **3 to 10 keywords**.

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A brief introduction outlining the purpose of the study, background information, and relevance to existing research. Only essential information should be included.

4. Materials and Methods

This section must contain:

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- Present results clearly and concisely
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Summarize the key findings and state their significance in relation to crop and soil science.

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Mention individuals or institutions who supported the study, including funding sources, equipment, field assistance, or laboratory support.

9. Conflicts of Interest

Authors must declare any potential conflicts of interest, financial or otherwise.

Lime and Potassium (K) Interaction Effect on Soil acidity and K availability in an upland acidic soil of Eastern India

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Abstract

In order to investigate the effect of liming on potassium (K) dynamics at various levels of K fertilizer application in an acid soil growing groundnut one laboratory incubation study was conducted for 5 weeks with 4 levels of lime (0, 0.1 LR, 0.2 LR, 0.3 LR) and 3 levels of potassium (0, 10 ppm, 20 ppm K) on a soil collected from an upland located in the Central Farm of Odisha University of Agriculture and Technology (OUAT)at Bhubaneswar . At weekly interval, soil samples were analysed for pH, exchange acidity, various forms of K (water soluble, Exchangeable and non-exchangeable), water soluble Ca^{++} and Mg^{++} and activity ratio. Liming significantly increased soil pH but effect of application of potassium on soil pH was nonsignificant up to 5 weeks. Exchangeable acidity and exchangeable Al^{3+} got significantly reduced with liming at 0.1 LR and at higher levels there was complete neutralisation of exchangeable Al^{3+}. Liming at 0.1 LR significantly raised the water soluble K content which decreased with liming at higher levels of 0.2 LR and 0.3 LR. Application of K increased both exchangeable and non-exchangeable K significantly but liming effect was non significant. The intensity of K measured in terms of activity ratio also increased with periods of incubation. The intensity increased with increase in K level, with increased liming the intensity decreased. From the results it may however be suggested that in acidic red and lateritic soils more benefit from applied K fertilizer can be obtained by liming @0.1 LR and increased lime level requires increase in K fertilizer dose for greater availability of K to plants.

Key Words: K Dynamics, ws-K, Exchangeable K, Non-exchangeable-K, Activity ratio, Buffering capacity

Introduction

Acid soils particularly acidic upland is the main area of production of pulses, oilseeds and coarse cereals. Liming increases the soil pH, improves availability of plant nutrients and crop growth, increases nutrient uptake, stimulates biological activity, decreases 3+ extractable Al and reduces toxicity of some elements

Acid soils that occupy more than 70% of the total cultivated area of Odisha have many soil related production constraints. Liming is the single most important technology developed and tested multilocationally to enhance crop yield in acidic uplands. Liming along with fertilization has significantly increased the productivity of acid soils (Annual Progress Report, NAE, 2009-10).

Potassium as a nutrient element plays many a vital role in plant growth. It is essential in nearly all processes involved to sustain plant life. The average nutrient consumption of Odisha was 59.78 kg/ha of cropped area which consisted of 33.65 kg N, 17.11 kg P_2O_5 and 9.02 kg K_2O (Anonymous, 2004). The consumption rate is far less than the national average. Although requirement of K_2O is almost same or more than that of N in most crops, the consumption rate of K_2O is only 27% of that of N. Mishra and Mitra (2001) reported that crop removal of K_2O from the soils of Odisha was 282.34 thousand tonnes and addition as fertilizer only 39.47 thousand tonnes, which left a huge negative balance of 242.87 thousand tonnes. This accounted for a negative balance of 29.16 kg K_2O/ha. In Odisha, as compared to N and P much less work has been done on K. This is because of the general impression that soils are well supplied with this element and that in most of the cases there is little need for potash fertilizer. Much of the works on response of crops to K in the state have been restricted to rice only.

Groundnut is an important oilseed crop of the state. There is huge potential to increase the area and productivity of groundnut by covering upland acid soils of the state through crop substitution and providing adequate nutrition. Acid soils that occupy more than 70% of the total cultivated area have many soil related production constraints. Liming when used along with adequate nutrition is the single most important technology developed and tested multilocationally to raise the productivity of acid soils in the state. Application of liming either directly or indirectly influences various soil processes responsible for nutrient availability in soil.

Effects of liming on K availability are not well documented. The efficiency of fertilizer K use in a particular soil under a particular crop requires understanding of K-lime interactions. Considering the importance of potassium in groundnut nutrition and liming in increasing crop productivity in the acid soils of the country and the state of Odisha in particular, the present investigation was carried out.

Materials and methods

In order to fulfil the objectives of the present investigation, the incubation study was conducted in the laboratory of the Department of Soil Science and Agricultural Chemistry, Orissa University of Agriculture and Technology, Bhubaneswar. The laboratory incubation study was laid out in complete randomized design (CRD) with 12 treatments (table 1) replicated thrice. The study was conducted for a period of 5 weeks. The treatments consisted of 4 levels of lime (L_0=No lime, L_1=0.1LR, L_2=0.2LR, L_3=0.3LR) and 3levels of potassium (K_0=No potassium, K_1=10 ppm potassium, K_2=20 ppm potassium).The source of liming material was $CaCO_3$ and potassium source was MOP fertilizer. The treatment details are given below:

Table 1. Description of treatments of the incubation study

Treatments	Treatment details
L_0K_0	CONTROL
L_0K_1	10 PPM K
L_0K_2	20PPM K
L_1K_0	0.1 LR
L_1K_1	0.1 LR+10 PPM K
L_1K_2	0.1LR+20 PPM K
L_2K_0	0.2 LR
L_2K_1	0.2 LR+10 PPM K
L_2K_2	0.2 LR+20 PPM K
L_3K_0	0.3 LR
L_3K_1	0.3 LR+10 PPM K
L_3K_2	0.3 LR+20 PPM K

The soil for incubation study was collected from an upland located in the Horticulture orchard of OUAT .The soil was a moderately well drained red soil. It was air dried under shade, crushed and shieved (10 mesh) and stored .Then approximately 1Kg of soil was taken in each of the 36 nos. of wide mouth bottles. After maintaining field capacity moisture bottles were incubated at room temperature for 5 weeks. One set of samples were used for estimation of soil moisture by gravimetric method and the moisture content was used for the calculation of different nutrients.

The fresh soil samples were subjected to various physical and chemical analysis following standard methods such as Soil pH(Jackson, 1967), Soil EC(Jackson, 1967), Exchangeable Acidity and Exchangeable Al^{3+} **(**Yuan 1959), Water Soluble potassium and Neutral-Normal Ammonium Acetate (NH_4OAc) Extractable Potassium(Hanwayard Heidel, 1952), 1N HNO_3 Extractable K(Wood and De Turk, 1940), Exchangeable Ca^{2+} and Mg^{2+} (Perkins Elmer Atomic Absorption Spectrophotometer), Activity Ratio (AR_0^K) and Potential buffering capacity (PBC^K). Statistical Analysis was done by the method given by Gomez and Gomez (1976).

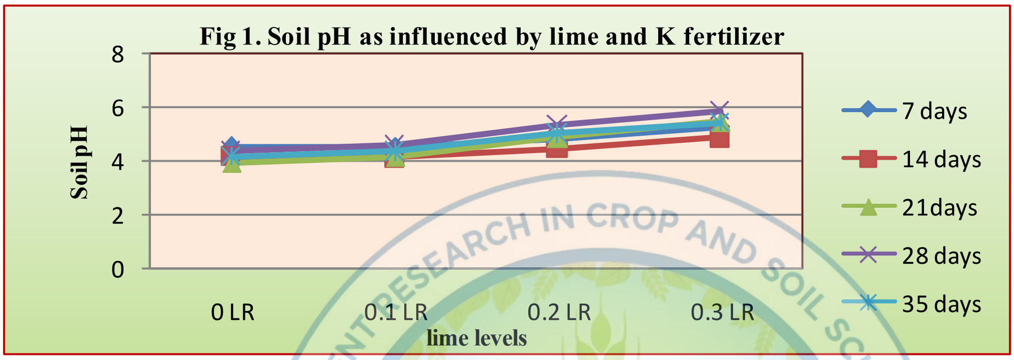
Result and Discussion

Results on effect of liming and potassium levels on some important soil physical and chemical properties are presented and discussed below:

Soil pH

Data pertaining to soil pH as influenced by different levels of liming and K application to the test soil under incubation revealed that soil pH varied between 4.05 and 5.90 which was slightly below and above the initial soil pH of 4.83. The pH was inconsistent over the period of 35 days.

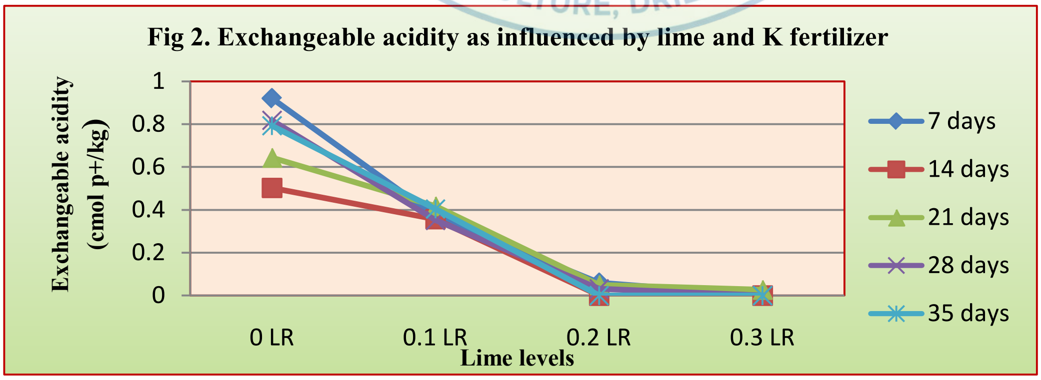
Application of lime at or above 0.2LR significantly increased the soil pH. At 0.1LR the pH however was lower than no lime situation particularly in 1st 2weeks after which it increased. Inspite of liming the pH remained within moderately acidic range. Application of K had no significant effect on soil pH. The interaction effect was also non significant.



Exchangeable acidity

Liming significantly influenced the exchangeable acidity that significantly decreased to a lower value at 0.1LR and to almost nil at or above 0.2LR which is illustrated in fig 2.

In relation to pH, the exchangeable acidity decreased with increase in pH and reduced to almost zero when pH became more than 4.84. This has also been reported by the workers at OUAT (Annual Report, NAE-2009). Application of K and the interaction effect of lime and K were non significant.



Exchangeable Al^{3+}

Similar to exchangeable acidity, the lime application significantly decreased the exchangeable Al^{3+} at 0.1LR level and to almost nil at 0.2LR and above which corresponds to pH values of about

4.84 and above. The decrease in Al^{3+} exchangeable acidity. Application of K and the interaction effect of K and lime were non significant.

Water soluble K

Application of lime increased the ws-K and the measured increase was significant at 14th and 28th day irrespective of the levels of K applied. Out of the 3 levels of lime applied, 0.1 LR recorded almost highest ws-K at each stage of incubation. With higher levels of lime application ws-K either remained almost constant or slightly decreased. Decrease with increased levels of lime application has also been reported by (Cutin and Smillie, 1983). The decrease is due to more fixation of K at higher pH (Grewal and Kanwar, 1967).

Application of K fertilizer significantly increased the ws-K at each stage of incubation. With increased level of application, the ws-K increased. No significant interaction effect of lime and K on ws-K was observed. However, at higher levels of liming, ws-K was more at higher levels of K application. This suggests that increased lime level requires increase in K fertiliser dose for greater availability of K to plants. Similar findings have also been reported by Raychaudhuri and Raychaudhuri (2009).

Exchangeable K

Unlike ws-K, exchangeable K showed a sharp decrease during 7-14 days, followed by a slight fall at 21 day and a progressive increase thereafter. Exchangeable K varied from a lowest of 14-60 ppm in L_2K_2 treatment that received lime @ 0.2LR and 20ppm K. The exchangeable K values measured for incubated acid soil were much lower than the ws-K values which might be due to low CEC associated with the soil that has low kaolinite as the dominant mineral with little of illite mixed with it (Tisdale *et. al*., 1985) and no leaching of K^+ as soil is at FC moisture and soil is under a closed system.

Lime application caused a sharp increase in exchangeable K particularly during 1st and 2nd week of incubation upto 0.1LR. At higher levels of lime (0.2LR) application the exchangeable K suddenly dropped which might be due to absence of pH dependent charges and more fixation of desorbed K. More K fixation at higher lime levels (≥0.2LR) in acid soils (pH <5.5) has been reported by Grewal and Kanwar, (1967). Raychaudhuri and Raychaudhuri (2009) reported a fall in exchangeable K at 0.25 to 0.75 LR. The exchangeable K when averaged over K levels increased from 36.30ppm at L_0 or no lime application to 74.88ppm at 0.1LR level followed by a sharp fall to 46.64ppm at 0.2LR. The increase within 1st week and drop there after might be due to initial adsorption followed by gradual desorption for establishment of a new equilibrium among all the forms.

Application of K also caused an increase in exchangeable K at all the stages of measurement except the 2nd week. The increase with application of 10ppm and 20ppm K was higher in the first week than later periods indicating more adsorption in the early period followed by fast release and fixation. The interaction effect of lime with K on exchangeable K was significant on 2nd, 4th and 5th week.

Non exchangeable K

Data related to non exchangeable/ fixed K showed an increase in the 1st week followed by a decrease in the 2nd week. Again there was an increase in 5th week. The decrease in fixed K observed at the end of 1st week and there after might be due to the direct release into solution K pool of the soil which is evidenced by an increase in soil solution K due to low CEC, low pH dependent charge and restriction to leaching. This result was supported by the increase in soil solution K.

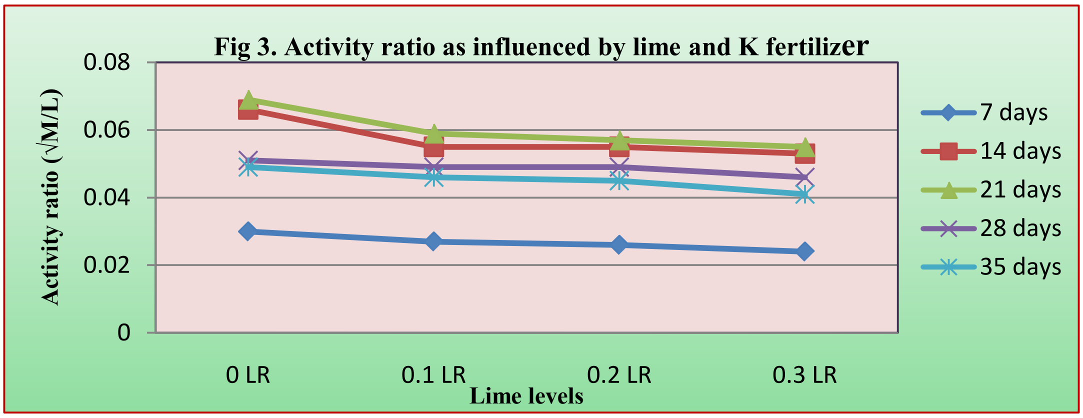
Under no lime condition, the fixed K measured highest particularly in 1st and 2nd week. With liming @0.1LR it dropped sharply followed by an increase with increased levels of liming *i.e.,* at 0.1LR. The soil maintains a low level fixed K that gradually increased with increase in lime level. Increase in K fixation at higher levels of liming has been reported by Grewal and Kanwar, (1967). Thus liming had significant effect on the fixed K level of such an acid soil.

It is also interesting to note that with increased level of K application there is decrease in fixed K measured up to 5 weeks. With period the level gradually falls. This is in contrast to the result of exchangeable K that increased with K level. The interaction effect was non significant.

Activity ratio

Results on activity ratio or intensity of potassium measured for soil under incubation at different liming and K levels shows variation between 0.024 and 0.066√M/L. With period of incubation the intensity showed an upward trend up to the 3 weeks after which it decreased. The intensity was higher in 2nd week (0.057√M/L) and at 3rd week (0.060 √M/L) as compared to other weeks.

Between liming and K levels the latter had significant effect on the intensity after 1st week onwards. Liming resulted in decrease in activity ratio. With increased in liming levels the activity ratio showed a decreasing trend at all stages of incubation, but the decrease was non significant. Sparks and Liebhardt (1981) while investigating the effect of lime on K equilibrium in soils, found that the amount of labile K estimated from Q/I parameters decreased with liming. Raychaudhuri and Sanyal (1999) also reported similar result.



This indicates that at one stage the unlimed soil supplies more K to plant followed by liming at 0.1LR level than the soil with higher levels (0.2LR and 0.3LR) of liming. Thus it may be concluded that liming decrease availability of K to crop plants and with increased liming the availability decreases further. Sudhir (1983) reported antagonistic effect of calcium on K uptake where high levels of calcium were accompanied by low levels of K. In a recent study conducted on the acid soil of Odisha. Raychaudhuri and Raychaudhuri (2009) reported a decrease in water soluble K, exchangeable K and non-exchangeable K with increased doses of liming from 0.25 LR to 0.75 LR.

The intensity increased with K level showing least intensity at no K application and maximum at 20ppm K indicating higher availability in soil which received K. This result is in conformity with the findings of Grewal and Kanwar, (1967).

Potential buffering capacity

For describing the K supplying power of soils the quantity, intensity and buffering capacity of a soil proposed by Beckett (1964) are very useful. The potential buffering capacity (PBC^K) indicates how the K-level in soil solution (intensity) varies with the amount of labile form of K (quantity). The wider the PBC^K more buffered is the soil which has higher capacity to replenish the depleted soil solution K (intensity).

Results on PBC^K calculated by Q/I show a range between 0.67 to 18.40 cmol (p+)/kg/√M/L. On the 7th day of incubation the buffering capacity was highest and it ranged between 6.23 and 18.40 cmol (p+)/kg√/M/L that sharply fell down to 0.67 to 5.51 cmol (p+)/kg/√M/L on 14 day and 1.31 to 3.16 cmol (p+)/kg/√M/L 0n 21 day and to 1.80 to 8.75 cmol (p+)/kg/M/L on 28 day and to 1.66-5.06 cmol 0n 35 day. In general, buffering capacity of soil increased with liming at 0.1LR level. But with higher levels of liming at 0.2LR and 0.3LR it decreased.

Thus highest buffering capacity is maintained with liming at 0.1L. Sengupta (1982) and Nanda (1977) reported low buffering capacity of soils to be associated with low pH and liming of acid soils increased the buffering capacity but lowered K activity in soil solution. In contrast application of K had no significant effect on PBC^K. The interaction effect was also non significant.

CONCLUSION

From the findings of the present study it may be concluded that liming significantly increased soil pH but the effect of application of potassium on soil pH was non significant up to 5 weeks. Liming significantly influenced the exchangeable acidity and exchangeableAl^{3+} that significantly decreased to a lower value at 0.1LR and to almost nil at or above 0.2LR. In relation to pH the exchangeable acidity decreased with increase in pH and reduced to almost zero when pH became more than 4.84, the interaction effect of K and lime were non significant. Highest content of water soluble K is measured at 0.1LR and 0.2 LR in incubation study the contents are high because of low CEC and lack of K fixing minerals in the red soil tested. Optimum amount of calcium results in an increase in the availability of exchangeable and water soluble potassium. Excessive addition of calcium to soil often decreases the availability to plants. The exchangeable K values measured for incubated acid soil were much lower than the ws-K values which might be due to low CEC associated with the soil. Activity ratio which is a measure of K intensity was found be inversely related to levels of liming. There was –ve correlation between AR^K and ws-K. In contrast PBC^K which is a measure of the replenishing or buffer power of soil to supply K to crop is positively correlated with ws-K and exchangeable. At lower liming level of 0.2 LR PBC^K measured higher value. Thus it may be suggested that in acedic red and lateritic soils more benefit from applied K fertilizer can be obtained by liming @ 0.2 LR and increased lime level requires increase in K fertilizer dose for greater availability of potassium to plants.

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Methodologies for Soil Quality Assessment

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ABSTRACT

Soil quality or soil health appraisal is needed to identify problem production areas, make realistic estimates of food production, monitor changes in sustainability and environmental quality as related to agricultural management. Soil quality can be assessed in two ways:1)qualitatively and 2) quantitatively. Early concepts of soil quality dealt mainly with various soil properties that contribute to soil productivity with little definition for soil quality itself. In early 90's Soil quality test kits and farmer based score cards focusing on soil quality were developed. Later in the late 90's various soil quality indexing approaches were pursued.In India work on assessment of soil quality started only recently with the implementation of National Agricultural Technology Project (NATP) during 2000. . For assessment of soil quality the capacity of the soil to function needs to be measured using appropriate indicators. Although several minimum dataset(MDS) of soil attributes have been proposed for use as soil quality indicators at the field scale, none have been evaluated at a regional scale. How ever, there is lot of scope to standardize the methodology for quantitative soil quality assessment on regional basis and identify problem areas and suggest important remedies for restoration of soil health.

INTRODUCTION

Soil health and soil quality are new concepts having meaning much broader than soil productivity. Maintaining or enhancing soil quality is a key to sustaining the soil resources of the world. High quality soils will produce more food and fibre and provide a better quality of life for the world's growing population. More over, high quality soil will play a major role in stabilizing natural ecosystems and enhancing air and water quality. Soil quality or soil health appraisal is needed to identify problem production areas, make realistic estimates of food production, monitor changes in sustainability and environmental quality as related to agricultural management.

ASSESSMENT OF SOIL QUALITY

In early 90's Soil quality test kits (Liebig *et. al.,* 1996) and farmer based score cards(Romig *et.al.,* 1996) focusing on soil quality were developed. Later in the late 90's various soil quality indexing approaches (Karlen and Stott,1994, Andrews, 1998, Andrews *et.al.,* 1999; Hussain *et. al* .,1999 Karlen *et.al.,* 1999b , Wander and Bollero 1999, Dalal and Moloney,2000, Andrews and Caroll,2000; Andrews *et. al.,* 2002) were pursued.Soil quality can be assessed in two ways:1)qualitatively and 2) quantitatively.

Qualitative Assessment

Various qualitative approaches(soil health score card and soil test kit) have been suggested by a number of scientists to measure soil quality. Qualitative measures of soil quality tends to be more subjective in their measurement, but can be assessed more easily, and sometimes be more informative to the land manager. In this approach for assessing scientists and agricultural professionals work with land managers to identify and describe soil quality indicators in their own terms. The indicators they choose can be easily observed and rated qualitatively.

Soil Health Score Card

Based on the farmer's perception of soil quality; a scorecard was developed for assessing soil quality (Harris and Bezdick,1994; Roming et al.1997). The scorecard is a farmer- based subjective rating system that placed indicators into three rating scales of healthy(score of 3.0-4.0), impaired(score of 1.5-2.0) and unhealthy(score of 0-1).

The Wisconsin soil health scorecard is a field tool to monitor and improve soil health based on field experience and a working knowledge of a farmer. It has 43 soil health indicator properties(Table 1) that integrate observations made throughout the growing season. The indicators are almost exclusively based on sensory observations (e.g. look, feel and smell). Correctly, the scorecard doesn't recognize the relative importance of indicators, and is only developed cropping systems in Wisconsin. Modifications of the scorecard to encompass other regions and cropping systems would require structured input from additional farmers (Romig et al.,1997). For indicators either in the impaired and unhealthy categories, careful consideration is necessary to identify that caused the property to be in a less than optimum condition. Unhealthy properties need immediate attention and corrective action.

Limitations and Prospectives of Qualitative Soil Quality Assessment

One shortcoming is that the scorecard represents the unchallenged perception of relatively small group of farmers. A second limitation may be its narrow frame of reference- especially in the light of the expanded definition of soil quality. This approach is also subject to internal bias.

While qualitative approaches are subject to internal bias, they have been found to compare well to quantitative measurements (Liebig and Doran, 1999). Qualitative approaches also have the advantage of making the farmer an active participant in the assessment.

Quantitative Assessment

Early concepts of soil quality dealt mainly with various soil properties that contribute to soil productivity with little definition for soil quality itself. However, mere analysis of soil properties alone, no matter how comprehensive or sophisticated, cannot provide a measure of soil quality unless properties evaluated are calibrated related against role function of soil.

To evaluate soil quality the capacity of the soil to function needs to be measured using appropriate indicators. The most desirable attribute of an appropriate indicator include the following:

1) It measures one or more soil functions
2) It is sensitive enough to measure changes due to disturbance, restoration and land use management
3) It provides benchmark, critical and threshold values
4) It can be readily interpreted and
5) It is cost effective

Many soil attributes including physical, chemical, biochemical and microbiological parameters have been suggested as indicators of soil quality changes, each assessing probably one or more specific functions of soil quality, but none of them alone is comprehensive enough to cover all the components of soil quality. Therefore, it is essential to establish one or more indexing systems with each index covering a number of inter related, directly measurable parameters to better reflect the complex processes affecting soil quality and to compensate for wide variations occurring in individual properties.

The different steps are:

1. Defining goal functions of the soil
2. Identifying the soil properties that influence the functions & selection of a minimum data set that can be used as potential indicators
3. Assigning scores to the observed values of the indicators in the data set
4. Calculation of soil quality index from the score values either integrating with variable weights or simply by summation

1. Defining Goal functions of the Soil

Given the wide scope of functions encompassed in the definition, it would be difficult, if not possible to directly assess the quality of a soil. It is necessary to first identify the functions of interest and then select some set of indicators to observe and measure, thereby inferring the ability of the soil to perform that function. The first step in evaluating soil quality within any ecosystem management practice is therefore identification of management goals (or soil functions) specific to the objective of the experiment.

2. Selection of Indicators

It would be unrealistic to use all ecosystem or soil attributes as indicators, so a minimum data set (MDS) consisting of a core set of attributes encompassing chemical, physical and biological soil properties are selected for soil quality assessment (Larson and pierce, 1991). To assess soil quality, Larson and Pierce (1994) suggested measuring various soil attributes or indicators that controlled or were influenced by various soil functions. There are different ways how indicators are selected. Broadly there are three ways by which scientists have selected the indicators. Those are:

1. Indicators as suggested by scientists
2. Indicator selection by simple scoring and elimination approach
3. Indicator selection through a statistical framework

Indicator sets as suggested by scientists

Several authors have proposed sets of soil quality indicators(Larsen and pierce, 1991;Doran and Perkin,1994; Sarrantonio et. al,1996 and Karlen et al.,1998). A common feature of the indicator sets is that they all include some combination of physical, chemical and biological soil properties suggesting that for a soil to function effectively all three components must be addressed.

Doran and Parkin(1994) developed a list of basic soil properties or indicators for screening soil quality. They are : (1) Physical indicators: soil texture, depth of soils, top soil or rooting, infiltration, soil bulk density and water holding capacity. (2) Chemical indicators: soil organic matter or organic carbon and nitrogen, soil pH, electrical conductivity and extractable N, P and K (3) Biological indicators: microbial carbon and nitrogen, potential mineralizable N and soil respiration.

Harris and Bezdick(1994) indicated that soil quality indicators might be divided into two major groups; analytical and descriptive descriptions. Hseu et al., (1999) selected some indicators for the evaluation of Taiwan soils. The indicators were; (1) Physical: depth of the A –horizon, soil textural classes, bulk density, available water content and aggregate stability; (2) Chemical: soil pH, EC, organic carbon, extractable N, P, and K and extractable trace elements (3) Biological: potential mineralizable N, microbial C, N and P, soil respiration, the number of earthworms and crop yield. Because organic matter can have a tremendous effect on the capacity of a soil to function, it has been recommended to be a basic component in every minimum data set for assessing soil quality(Gregorich et al.,(1994).

Indicator selection by simple scoring and elimination approach

Cameron et al. (1998), suggested the use of simple scoring approach to help users decide whether to accept or reject a potential soil quality indicators for degraded or polluted soil. They used the equation, A = f (S+U+M+I+R) where ,

A= Acceptance score for indicator

S = Sensitivity of indicators to degradation

U = Ease of understanding of indicators value

M = Ease or cost effectiveness of measurement of soil indicators

I = Predictable influence of properties on soil, plant and animal Health and productivity

R=Relationship to ecosystem process

Each parameter in the equation is given a score (1-5) based on the user's knowledge and experience of it. The sum of individual scores gives the levels of acceptance(A) score which can be ranked in comparison to other potential indicators, thus aiding the selection of indicators for a site.

Statistical Techniques for Indicator Selection

Few statistical techniques have been suggested for a minimum dataset selection. Hatcher and Stefanskii (1996) suggested for a two step analysis . Multivariate analysis of variance (MANOVA) was the first step used to determine whether there were significant inherent (regional) or management (tillage) effects on at least one of the physical, chemical and biological variables assessed. After this criteria was met, analysis of variance (ANOVA) of individual parameters was run all the parameters. Those variables for which the F-statistic was significant at $p < 0.06$ and that had CVs <40 were retained for further analysis. All retained physical, chemical and biological variables were then used in principal component analysis(PCA) for further screening. The number of components were determined by eigen values.. PCs that explained more than 5% of the total variance were considered to be significant.

For comparing the alternate and conventional treatment means for 6 different farms, Andrews et. al (2002) used non parametric Wilcoxin rank sum (C_2) test on JMP $_{v\text{-}3}$ software for Window(SAS Institute, Cary, NC). This non parametric test finds differences less often than its parametric counterpart the t-test (Ott,1988). However, for farm they used one way analysis of variance(ANOVA) and student's t for comparison of means at $\propto = 0.05$.To select a representative MDS they first performed standardized PCA of all untransformed data that showed statistically differences between management system using ANOVA or Student's t. They examined the PCs with Eigen values > or =

1.(Brejda et al 2000b). and retained only the highest weighted variables from each PC of MDS.. Highest weighted variables remained within 10% of the highest factor loading (using absolute values). Under each PC they eliminated the redundant variables. Among well correlated variables within a PC the variable with the highest sum of correlation coefficient (absolute values) are chosen for the MDS (Andrews and Carroll, 2001; Karlen et al., 1999). If the highest weighted variables were not correlated (assumed to be a correlation coefficient of >0.60), then each was considered important and was retained in the MDS.

Dalal and Moloney(2000) suggested a scoring approach to select indicators by assigning scores (0 to 10) depending on the extent of fulfillment of these 10 criteria by any indicator.These criteria are: Indicator should

1) Respond to change in management practice and provide trends over time
2) Be easily measured
3) Have expected or threshold values
4) Have low error associated with measurement
5) Be stable in short term to enable measurement
6) Not be required to be frequently measured
7) Be cost effective
8) Have the ability to be aggregated from paddock or site to farm /catchment region
9) Be mappable in space and time
10) Have community acceptance and involvement

Finally for each indicator variable all the 10 score values are summed to get a total score and on the basis of the total score, indicators are either selected or deleted. Benchmarking the positive and undisturbed environments for soil quality and biodiversity using the sustainability indicators and then determining the extent of deviation from the bench values in a given landscape or environment may provide a suite of values. These values then could be integrated over space, attribute and time.

3. Assigning scores to observed values of Indicators

After the MDS selection process, each MDS variable observed value was transformed into a value between 0 and 1 using scoring functions. These scoring functions are widely used in economics as utility functions(Norgaard,1994), in multi objective decision and management sciences as preference functions (Miller ,1970; and Raiffa,1976) and in systems engineering approach(Wymore, 1993).

Wang and Gong(1998) used an information system approach to develop and indexing system for assessing acid soil quality. This approach was applied to evaluate quality changes of acid soils after 11 years of reclamation at the Qian-Yan-Zhou experimental Station, located in sub tropical China.The Qian-Yan-Zhou soil quality information system(QYZSQIS) was developed using ARC/INF Qian-Yan-Zhou O and FOXBASE software. A relative soil quality index(RSQI) defined as fractions of soil quality indicators in the tested soils against a reference soil and its difference(ΔRSQI) before and after 11years reclamation was established for comparing land use effects on soil quality indicators.The equation for calculating RSQI value is : RSQI(%) + SQI/ SQIm) X 100, where SQI is soil quality index and SQIm is the maximum value of SQI.The SQI is calculated from the equation: $SQI = \sum W_i \times S_i$ where, Wi is the weight assigned to each individual indicator and Si is the score assigned to each indicator class.An optimal soil in a specific region has a normalised RSQI of 100 but real soils have lower values which indicate directly their distance from the optimal level. The RSQI and the ΔRSQI provide a standard for evaluating spatial or temporal changes in soil quality.

Another approach for developing an acid soil quality indexing system is to define a reference soil against which the quality change of soils can be compared or quantified. A native soil supporting climax vegetation that has undergone minimal anthropogenic disturbance is used as a high quality reference soil(Leiros etal.,2000). Trasar-Cepeda etal.,(1998) examined three such native acid soils of Garcia(NW Spain) and found that the native soils of Garcia exhibit a biochemical equilibrium such that total N can be defined as a function of five biochemical and microbiological parameters:Total N($X10^{-3}$) = 0.38 MBC + 1.40N mineralization capacity + 13.6 phospho mono esterase + 8.9 ß glucosidase + 1.6 urease.the ratio of thecalculated total N(Nc) to the total N measured by the Kjeldahl method (Nk) was proposed as an index of soil quality(Leiros et al., 1999). For these climax soils ,the Nc/Nk ratio is 1.00 and for disturbed soils soil degradation is reflected by the ratio of less than one. For the samples polluted by tannin effluent intense contamination is indicated by decreased Nc/Nk ratios ranging from 0.15 to 0.28(Trasar-Cepada et al., 2000a).these results together with some previous reports by the same research group (Leiros et al.,1999) indicate that this kind of indexing system is simple, but has the advantage of providing common criteria for comparing the degree of soil degradation at different sites. And caused by different factors(pollution, land use and management) because all the examined soils can be ranked by a single index.

Andrews and Caroll (2000) used non linear scoring functions with Y axis ranging from 0 to 1 and the X axis representing a range of site dependent scores for that variable. The actual shape of the decision function either a sigmoid curve with an upper asymptote, a sigmoid curve with a lower asymptote or some variation on a bell shaped curve was indicator dependent. Accordingly they assumed an upper asymptote to total N and extractable Ca, lower asymptote to bulk density and mid point optimum for pH, nitrate N , extractable Zn and WHC (Karlen et al., 1994).This assignment of scoring functions both curve shape and X axis range assumed value judgements on the part of the user(Andrews and Caroll,2000).

Using Wymore's Standard scoring functions(SSF) scores were assigned to the observed values of MDS using specific algorithms developed by Wymore(1993).Using algorithm of SSF –3

$Score = 1/(1+(B-L)/(V-L) \wedge (2*S*(B+V-2*L))$ where $V =$ or $< B$

And $score = 1/(1+B-(2B-U)/V-(2B-U) \wedge (2*S*(B+V-2*(2B-U)(2B-V))$ where $V > B$

L= Lower threshold value

U=Upper threshold value

S=Slope of the curve

B= Base value and

V= Observed value

4. Integration of scores into Index Values

After transforming the MDS variable into scores for each observation, Andrews and Caroll(2000) added them to get a cumulative soil quality index(SQI).

$$SQI = \sum_{i=1}^{n} S_i$$

Higher SQI meant grater soil quality. They compared the SQIs for different management practices by calculating means, standard deviations, student's t at $\propto = 0.05$ and ANOVA for each treatments SQI score.The SQI values obtained by them indicated that for both the alfisol and ultisol sites the compost management had the best soil quality.Instead of using an additive index where the scored were simply added , Andrews et al (2002) used an integrative Index. Each PC explained a certain amount (%) of the variation in the total data set.This percentage divided by the total percentage of variation explained by all PCs with eigen values > 1, provided the weighted factor variables chosen under a given PC . They then summed the weighted MDS variable scores for each observation in the following formula:

$$SQI = \sum_{i=1}^{n} W_i \times S_i$$

where W is the PC weighting factor and S is the indicator score. They compared the calculated SQI treatment means using ANOVA and students t at $\propto = 0.10$ and assumed that higher index scores meant better soil quality or greater soil performance of soil functions.Using this formula, they demonstrated that soil quality indices for the manure and compost systems were significantly lower than the organic system but significantly higher than the conventional treatments. These results supported the SQI outcomes of Karlen et al., (1999).

As discussed above, soil quality has various components(fertility quality, environmental quality and health quality) corresponding to different functions of the soil. All indicators can be grouped as subsets of data under each component of soil quality and SQI for each component can be developed.If necessary all the component indices from each subsets of data can be integrated and processed using an GIS –data base system to establish one or more comprehensive indexing systems for quantifying and monitoring quality changes of soils as a whole(He et al.,2001).

In a study Hussain et al., (1999) calculated an overall soil quality index from functional components and they could provide a comprehensive assessment of soil quality. These functional components were used to identify soil management problems which were considered important for sustaining or improving the soil resources.

WORKS DONE IN INDIA

In India work on assessment of soil quality started only recently with the implementation of National Agricultural Technology Project (NATP) during 2000.Works started in 8 different centres located in the states of West Bengal(BCKV and CRIJAF), Orissa(OUAT), Assam(AAU), Andhra pradesh(CRIDA & ANGRAU) and Uttar pradesh(BHU) with BCKV in West Bengal as the lead center and others as co-operating centers where the results of long term experiments on dominant cropping systems of the region were used for the study. Standard methods already used by Andrews et al., 2002 were used for selection of MDS and quantification of soil quality. The MDS were selected entirely through a statistical frame work from a large set of variables drawn from physical , chemical and biological domain and both linear and non linear scoring functions were used for assigning scores. The soil quality index values were calculated through integrative approaches. All the centres reported that INM practices involving FYM maintained better soil and crop quality than other management practices. Most of the results have been published in Annual reports and bulletins. In Orissa Rout et. al., (2004) compared 3 different methods of integrative indexing(Andrews et al., 2002), component integrative indexing (Hussain et al., 1999) and integrative indexing (Andrews et al., 2002) through Wymore's algorithm scoring approach (Wymore,1993). The results clearly demonstrated differences in soil quality of among differently manured treatments which were in the order of 100%NPK+FYM> 100%NPK>100%NP>100%N.

Singh(2006) in India recently suggested nine indicators such as soil depth, texture, slope, organic matter, available N, available P , available K , CEC, and pH to evaluate soil quality under integrated nutrient management at farm situation. He calculated the soil quality index of each indicator separately by multiplying weight of indicators with marks allotted to the observed value. In his study he suggested weights to the indicators on the basis of existing soil conditions, cropping pattern, agro climatic condition and prevalence of flood so that all weights is normalized to 100%. He also divided all the indicator values into 4 categories and assigned marks of 4,3,2 and 1 to these classes depending on their suitability for crop growth. Through this study he showed improvement in soil quality under both farmers' practice and INM practice. Soil quality under INM trial was improved by 12-19 units as compared to 7-9 units of farmer's practice of farming.His results were however more speculative and based on assumptions.

In a study Masto et al.,(2007) normalised soil quality indicator values on a 0 to 1 scale using the following linear and non linear scoring functions.

Linear Scoring Function,LSF(Y) = (x-s)/(t-s)…………………(1)

and Y = 1 – (x-s)/(t-s) …………………(2)

where Y is the linear score, x the soil property value, s and t are the lower and upper threshold values.Equation 1 is used for more is better scoring function and equation 2 is used for less is better and a combination of both for optimum scoring function.

Non Linear Scoring Function, NLSF (Y) = $1/(1+e^{-b(x-A)})$………….(3)

Where x is the soil property value, A the base line value where score equals 0.5 and b is the slope. After deciding the shape of the anticipated response(more is better, less is better or optimum) they assigned the limits or threshold values for each indicator and quantified the soil quality index using three processes;1). Unscreened transformation, 2).based on regression equation and 3). based on Principal Component analysis(PCA).

SQI with unscreened transformation

SQI = Σ Si / n where S denotes linear score of observed indicator and n is the number of indicators.

SQI based on Regression Equation

SQI = ΣSi. ß

Where S denotes linear or non linear score and ß is the standardized regression co-efficient of the retained parameters.

The PCA based index remained the same

$$SQI = \sum^{n} W_i \times S_i$$

i=1

Based on the results they suggested that regression based index as the most sensitive index and PCA based index related well with the wheat grain yield.Thus either regression equation or PCA with non linear scoring function can be used successfully to evaluate soil quality.

Limitations and Prospectives of Soil Quality Assessment

The progress of soil quality research has been hindered because in most cases scientists have established ranges and benchmark values for only a few of the parameters listed in the MDS. Many biochemical and microbiological parameters which are considered early indicators of soil quality lack benchmark values. This makes it difficult to correctly convert the measured values to scores.

Future studies need to focus on development of relationship between indicator values and scores for all potential parameters. Application of GIS database can be immensely useful for this purpose. Although several MDS of soil attributes have been proposed for use as soil quality indicators at the field scale, none have been evaluated at a regional scale. Accurate, relatively inexpensive , less time consuming and simple methods need to be developed. How ever, there is lot of scope to standardize the methodology for quantitative soil quality assessment on regional basis and identify problem areas and suggest important remedies for restoration of soil health. Soil quality research data need to be translated into management tools for end users such as farmers, growers, agricultural production agencies, environmental production agencies and decision making organisatioins.

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PRECISION FARMING: THE FUTURE OF AGRICULTURE AND NATURAL RESOURCE MANAGEMENT UNDER CHANGING CLIMATIC CONDITIONS

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ABSTRACT

Agricultural production frameworks are profoundly powerless against variability in environment, soil and geography of various areas. For future agricultural production, every one of these variables should be dissected on spatio-temporal premise. The modern technologies like GIS, GPS and remote sensing, could bring about a great use for their evaluation and management. Precision farming is data and innovation based agricultural administration framework to distinguish, dissect and oversee site-soil, spatial and temporal inconstancy inside fields for ideal benefit, supportability and insurance of the climate. Remote sensing innovation assumes a significant part in precision agriculture, its applications are most definitely going to bring enhancement in agricultural practices. With assistance of global positioning system (GPS), it is feasible to record field information as geographically latitude and longitude information. It has ability to decide and record the right position constantly, so consequently, it can make a bigger information base for the users. For further analysis geographic information system (GIS) is required, that can help in storage and handling of these information. This writing features about remote sensing innovation, GIS, GPS and give you a thought regarding, how it tends to be important in precision agriculture.

Key Words: Precision farming, GIS, GPS, Remote Sensing

INTRODUCTION

Since early period, people are utilizing land for significant purposes. Food and water are essential assets which we need for our lives and are our extreme concern when we are making a sustainable world. Improvement in annual yield is a significant concern in agriculture. All the components such as farming, or dairy, or fishery, everything should maintain an equilibrium. Such areas should be selected, where crops can be grown at its maximum potential. Those soils need particular treatment and balanced nutrients for growing best crop. Hence the interest of site-specific agriculture emerged (Hartkamp et al., 2000).

Today, new digital technologies have been made in agriculture sector to utilize soil fertility, soil survey, crop production, crop protection and fertilizer application. Computer applications like geographical information system (GIS), global positioning system (GPS) and remote sensing add to the speed and productivity of overall agronomic practices. Hence, precision agriculture which depends on data and information is a combined strategy of modern agribusiness. It is a complete framework that exploits available agricultural assets, diminishes environment pollution and boosts sustainable agriculture.

Agricultural productivity these days may arrive at highest point due to worldwide accessibility of synthetic fertilizers, pesticides and herbicides. However, maximum use of these products and lack of consciousness can diminish our agricultural productivity and endanger the ecological equilibrium.

Agriculture is turning out to be more modern by the use of remote sensing, GPS, GIS and data analytics. A huge number of farmers are adapting new technologies to make their cultivation more exact. Farm equipment can map fields, drive themselves and check its own movement inside inches so it can minimize the loss of fertilizer, seed and fuel.

Precision agriculture can be characterized as the principle of spatial and temporal irregularity that is related with all agricultural practices to improve crop and environment quality (Pierce et al. 1999). Precision agriculture is about controlling variation in the field precisely to develop more food production by utilizing less inputs and decrease cost of cultivation.

All part of climate such as soil, vegetation, weather, water changes from one place to another. Each factor of these variables decides crop growth and its success rate. Farmers have always known about this, yet they came up short on the device to quantify, plan and deal with these variations. Subsequently, precision farming can have an effect to food production facing the challenge of increasing population and can help farmers to get (Venkataratnam et al.,2001):

- Crop details such as growth stage, crop health, nutrient requirements of the crop

- Soil physiochemical parameters such as electrical conductivity, soil temperature, soil moisture content, evapotranspiration
- Microclimatic data such as humidity, wind direction and speed, canopy temperature
- Surface and sub surface drainage conditions

Geographical information system (GIS)

A geographical information system (GIS) is a combined structure that gathers, manages and analyses the data. Established in the study of geography, GIS coordinates many types of information. It analyses a particular area and coordinates layers of data into visualization by utilizing map and 3D scenes. With this extraordinary capacity GIS converts deeper insights into data like relationships, patterns and circumstances which helps people to take smarter decisions.

GIS is a piece of a setup of technology that helps to make a research more appropriate. The framework requires fundamental essential data that is relevant to specific project. This importation of data into a GIS would require time and consideration, because this data will give the essential information on the domain and individual parameters and it is hard to modify latter (Basso et al., 2005). According to Basso et al., all the data in a GIS can be interconnected with each other and processed simultaneously, acquiring a syntactical articulation of the progression induced in the system by the varieties of parameters.

GIS offers valuable support to handle out voluminous information that are created through general and spatial format and for the incorporation of these data indexes (Vadivelu et al., 2007). GIS producers utilizes a computerized map that permits the user to see, update, question, analyse and control the spatial and tabular information either alone or together, in a quick time. Unlike paper map, GIS can plan and analyse huge agricultural data necessary for crop production (Senthurpandian et al., 2007).

Use of GIS in Agriculture

In agricultural production around the world, GIS has played a very beneficial role, providing farmers with the most suitable solutions to increase crop yields, reduce costs by applying fertilizers in a balanced way, and managing their land more effectively (A.Fourie 2009).

All sectors that are related to agricultural industries use Geographic Information System (GIS) technology to share data, increase production, predict results, and enhance business opportunities. With addition of GIS technology to their operations, farm operators can co-list resources and responsibilities more effectively, can design data portals that gets large amounts of farm data published, form interactive maps, and support farming communities. One layer on the agricultural area map can represent the boundary of a particular land part, while the second layer represents the type of soil and the third layer represents the crop yield or specific soil management (ESRI, 2007)

In this age of computer and information technology, it is very important to elevate farm management to a new level. In developed countries, for information technology reasons, the solution to every problem can be achieved with a single click on the Internet. For a long time, GIS has been providing spatial solutions and suggestions for different agricultural problems through remote sensing, statistical analysis of spatial data, and delineation of sustainable agriculture fields. With the help of Web-GIS, all aspects of any agricultural problem can be solved at any time through maps, graphs and user interaction functions in the area. In this way, farmers can complete their work more efficiently without wasting time and money. In underdeveloped countries, information technology is an emerging platform through which relevant information can be transmitted to farmers, educational institutions, researchers and any other interested party.

Use of GIS in regional levels

The combination of these technologies and remote sensing data has been used to assess land capacity (Corbett et al., 1996), crop conditions and yields (Carbone et al., 2005), grassland conditions, floods and droughts, soil erosion, soil compaction and the impact of climate change at the regional level (Kern et al.).

In particular field and subfield scale applications are tied to precise or site-specific agriculture, helping to target seeds, fertilizers, pesticides, and pesticides in a way that optimizes agricultural yields, minimizes chemical inputs, and hazards. environmental Water application in the field (Carr et al., 2011). GIS can be used to produce production-based production systems in precision farming, which can be designed to promote long-term, special-on-site along with total production efficiency, elaborate productivity and profitability. The majority of sites-specific agricultural systems employ some merger of GPS receivers, that continuous to yield sensors, remote sensors, and changable rate processing implementations.

Use of GIS in Agrometeorology

Due to the increasing pressure on land and water resources for agriculture, the management and forecasting of land use (crops, climate, fires, etc.) are becoming more important day by day. Therefore, GIS is an important tool that decision-makers can use. For example, precipitation and solar radiation are meteorological conditions that can be mapped and monitored to directly aid agronomic processes and provide suggestions for the occurrence of droughts (McVicar et al., 2008). It is reported that developed countries use geographic information systems for drought monitoring. Planning the time and type of agricultural practice requires certain information, such as soil type, land cover, climatic data, and geological information when describing the specific situation in a given place. Each layer of information gives the operator the possibility to consider its impact on the final result (Basso et al., 2005).

Use of GIS in Soil Survey

GIS uses advanced sensors and smart target positioning and geoprocessing algorithms to generate accurate, high-resolution information about the ground and terrain. By better understanding the physical and chemical properties of the soil, including the way inputs move through the soil, GIS enables trusted consultants of farmers to implement more effective solutions to the unique challenges faced by each area of their fields. Soil maps can be used to make key agricultural management decisions regarding irrigation, drainage and fertility.

Use of GIS as Agronomic Land-Use Planning Tool

The GIS is used for land use planning. Coleman AL and Galbraith JM noted that soil survey data and geographic information systems (GIS) are important tools in land use planning. They report that after adding soil data to other data and image layers, explanatory records from map units are used to create explanatory maps, flood frequency maps, and runoff maps.

GPS

The Global positioning system (GPS); is a combination of around 30 satellites circling the Earth at a height of 20,000 km, which sends and gets continuous information. This continuous information assortment gives precise position data, which prompts productive examination and control of a lot of geospatial information. Accuracy agribusiness is about assembling ideal geospatial data on soil and plant necessity and endorsing site-explicit activities to secure the harvests and to increase agricultural production. GPS is a significant device of precision farming which is utilized in various agricultural cycles (Reshma et al., 2020).

Role of GPS in Agriculture

In this present case, GPS has become an fundamental part of precision agriculture. In order to inspect and process remote sensing images, it is absolutely required to gather factual information on the ground in the experimental field at several locations all-round the crop production season, generally at various times. Conventionally, this collected data is manually been recorded on field worksheets, aerial photographs, or paper maps, and which requires a lot of time and effort to be translated into a digital format for remote sensing or GIS. In order to perform image survey, the ground data collected are necessary to be digitized as it requires to create a mask to train the software which recognizes different situations and classify remote sensing images. We have grown an interactive portable system that records field data directly into a digital database that incorporates yield, soil, road, water and contour maps superimposed on aerial photographs or remote sensing images. The GPS receiver is associated with a laptop that shows the suitable preloaded information layer, and the software package blends the input GPS signal with the presented data to authorize the user to view their position relative to the map component. Multiple layers of facts and figures can be easily improved and modified on site, and recently developed data such as a point or surface layers and credit table can be added. (Ravi et al., 2002).

Use of GPS for Yield Monitoring and Mapping:

The majorly recognized utilization of the GPS in agribusiness is to plan yield and varying rate of fertilizer or pesticide tool for the yield planning collector travel speed and flow rate of matter are estimated (Dong et al., 2019).

The control computer facilitates the infield activity. It has the guide of movement as an element of a given geographic area. It gets the hardware's present area from the finder, which has a GPS in it, and chooses what to do in view of the guide in its memory or information stockpiling. It at that point gives the order to the actuator, which makes the information application (Ravi and Jagadeesha, 2002).

Remote Sensing

Remote Sensing gives a wellspring of information just as the limit with respect to information handling and investigation, appraisal, observing and forecasting. Satellite Remote sensing addresses an innovation for succinct obtaining of spatial information and the extraction of scene utilizing satellites (Pierpaolia et al., 2013). A conversation of the Remote Sensing innovation would not be completed without the notice of GIS. Remote Sensing in India is sensibly well grown however not so are GIS applications. GIS is a developing innovation that has now arrived at certain development in the application regions. The native specialized information with the assistance of Remote Sensing also, GIS gives significant understanding into practical agribusiness. A precise spatial information base empowers the portrayal of agro-frameworks (Gebbers et al.,2010).

Use of Remote Sensing in Agriculture

Today, RS is possibly a practical management apparatus for site-explicit harvest the board. Presently, there is a wide scope of satellite information that differs in (i) method (dynamic/detached, radiometer/scatter meter), (ii) spatial goal from centimetres to kilometres (iii) spectral reach, also, (iv) geometry (Hedley et al., 2014). The full business accessibility of high goal satellite information has opened up various new opportunity for the utilization of Earth Observation (EO) information. Today, we can perform numerous applications with EO information that in just the new past were selective to human examination and in situ reviews, which was taking longer time and hard-sledding, regardless of the geographic impediments of such information and strategies (Jha et al., 2019). Satellite symbolism can be procured over any space internationally, in a time period and at a given cost. As of now, higher goal satellite symbolism defeats past imperatives and licenses the utilization of such information as a speedy and simple apparatus for regional administration, including farming investigation, measurements and sponsorship control (Elijah et al., 2018).

Use of RS in Irrigation Water Management

Application time and flow of irrigation system assume a significant part in relieving crop water stress and accomplishing ideal harvest and yield (Uphoff et al., 2018). Different types of water management practices are utilized by farmers relying upon numerous components including water accessibility, existing water availability framework at the field (e.g., capacity and movement framework, kind of water system framework), nearby/territorial water laws, financial status, size of the homestead, skill and knowledge of farmer, and others (Pardossi et al., 2009).

Numerous farmers apply uniform water at standard spans dependent on their prior information or experience of cultivation, soils, and environment at the area (Boland et al., 2006). Large scale commercial farmers deploy soil moisture monitoring systems (wired or wireless moisture sensors) to irrigate (automatically or manually operation mode) based on the measured soil moisture data and crop/plant water requirements (Holt et al., 2019).

Practically these conventional cultivation practices don't take the variability inside a field and utilize a uniform water flow for the whole field. Remote sensing information can help observe the inconstancy inside the field and apply variable rate water system with usually utilized water system frameworks like a focus rotate. Variable rate application can help relieve water pressure emerging from outrageous wet and dry conditions to accomplish consistently exceptional returns in all parts in the field while decreasing water and nutrient loss (Evans et al., 2013).

Use of RS in Water Stress Management

Remote sensing items, either in optical, thermal, and microwave groups, have been utilized to create and test various indices and methods for exactness water the board. For instance, normalized difference vegetation index (NDVI) and soil adjusted vegetation index (SAVI), created from optical pictures, can be utilized to analyse water pressure and soil dampness conditions for numerous yields. These indices, joined with anticipated climate information, could be utilized for water system booking. Thermal remote sensing–based crop water stress index (CWSI) is a famous sign used to evaluate irrigation supply and planning (Khanal et al., 2017).

Use of RS in Determining Evapotranspiration

Evapotranspiration (ET), the largest water flux from the Earth's surface to the atmosphere, is a critical component of the hydrologic cycle and water balance. Conventional methods of ET measurement (e.g., weighing lysimeter and eddy covariance) are generally expensive and do not provide spatiallyvariable ET estimates resulting from differences in land use, soils, topography and other hydrologic processes (Liou et al., 2014).

Remote sensing information is broadly used to determine ET, which is expected to decide crop water prerequisites to plan water system (Mendes et al., 2019). ET assessment draws near, in view of the far-off detecting information, can be assembled into three classifications: (I) surface energy balance, (ii) crop coefficient, and (iii) the Penman–Monteith technique (Barker et al., 2018). Numerous examinations in the past have given a survey of far off detecting based ET assessment methods.

Use of RS in Determining Soil Moisture Data

Remote sensing information gained in different groups, including optical, thermal and microwave, have been utilized to gauge soil moisture universally (Zhou et al., 2016). Optical and thermal remote sensing information has been broadly utilized for soil dampness and ET assessments in a methodology known to as "triangle" or "trapezoid" or land surface temperature-vegetation index (LST-VI) technique. The triangle or LST-VI strategy depends on the actual connection between the surface temperature and vegetative cover attributes (Zhang et al., 2016).

Use of RS in Nutrient Management

Convenient and proper use of fertilizers is the key to enhance crop development and yields while limiting ecological harm through nutrient loss to groundwater and surface water. Normally, RDF is consistently applied during planting and later harvest development stages. But, the manure necessity of yields changes spatially and temporally because of contrasts in soils, its management, geography, climate, and hydrology (Hendricks et al., 2019). Planning of such fluctuation in crop nutrient status/necessity for PA applications could be challenging with conventionally utilized apparatuses.

A few vegetation indices (e.g., NDVI, SAVI), got from remote sensing information, have been demonstrated to be essentially corresponded with plant chlorophyll content, photosynthetic action, and plant productivity (Marino et al., 2015). Planning of these indices would thus be able to help comprehend the spatial changeability in crop nutrient status, which is significant for PA. Recently, a few work vehicles mounted remote sensors have become accessible that can gauge plant and soil nutrient status for constant use of spatially-factor fertilizer rates. Green Seeker, Yara N-sensor, and Crop Circle are a few instances of commercially accessible hand-held and farm vehicle mounted remote sensors that utilization crop reflectance information to decide also, apply spatially variable fertilizer rates progressively (Ali et al., 2017).

Use of RS in Disease Management

Disease can cause a huge loss in yield and can lower B:C ratio. Timely detection of plant disease and its spatial degree can help contain the spread of disease and diminish yield loss. Manual method of disease detection is tedious, work concentrated, inclined to human mistakes (Ehsan et al., 2013). Also, with field exploring, it very well might be hard to distinguish the infection during the beginning phases when the side effects are not completely apparent. Moreover, a few infections don't show any apparent manifestations, or the impact may not be perceptible until it is past the point where it is possible to act. It is too hard to plan the spatial degree and seriousness of the illness spread with the customary technique for field exploring (Sladojevic et al., 2016).

Remote sensing could be utilized to screen the disease infection effectively, particularly in the beginning phases of infection improvement, when it might be hard to recognize the indications of infection with field exploring. Various strategies utilizing RGB, multi-ghastly, hyperspectral, thermal, and fluorescence imaging have been utilized to recognize illnesses in different crops (Mahlein et al., 2016).

CONCLUSION

Precision farming permits the exact following and tuning of agricultural production. Precision agriculture makes farmers arranging both simpler and more composite. There is considerably more guide information to use in deciding long haul editing plans, disintegration controls, salinity controls and evaluation of cultivation systems. If the number of information grows, more work is expected to decipher the information and this builds the danger of distortion. Farmers executing precision agriculture will probably work nearer with a few experts in the agricultural, GPS and computer sciences. Thus, the establishment advancements in precision agriculture are GIS, GPS and remote sensing.

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Evaluation of different locally available mulching materials *vis a vis* plastic on the basis of their impact on soil properties , crop yield and water use efficiency of Rajmash (*Phaseolus vulgaris*) under different irrigation levels

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Abstract

A field experiment on a newly introduced demanding pulse crop, Rajmash(*Phaseolus vulgaris*) was conducted during two consecutive winter seasons of 2007-08 and 2008-09 in the Central Farm of Regional Research and Technology Transfer Station(RRTTS) of Orissa University of Agriculture and Technology(OUAT) at Chiplima in Sambalpur district of Odisha in India on a moderately well drained sandy loam soil in order to study the impact of three different mulching materials viz; two organic mulches, paddy straw, and sugarcane trash applied @3t ha^{-1} and the third a 50 micron black plastic at three different water management options of providing irrigation at 30, 40 and 50% depletion of available soil moisture(DASM)) on some important crop production related soil properties, availability of three primary nutrients N, P and K , grain yield. and water use efficiency(WUE). The study revealed that in both the years when averaged over the irrigation levels, paddy straw mulch caused highest increase in yield with a mean increase of 66.7% over the un mulched control treatment followed by plastic (51.9%) and sugarcane trash (11.6%). When averaged over the mulching treatments the three irrigation

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treatments were at par in influencing the yields in both the years. Among the mulching materials paddy straw which is the most common crop residue left in the field after harvest of kharif rice (June-November) created a most favourable soil environment measured in terms of bulk density, porosity, pH, organic carbon (SOC), available N, P and K and microbial respiration and enzyme urease, phosphatase and dehydrogenase followed by plastic mulch. Sugarcane trash was most inefficient in its effect on increasing grain yield and maintaining soil fertility. All the three irrigation treatments were at par in influencing the soil properties. When considered on the basis of favourable effect on soil properties and maintenance of soil fertility and crop yield, paddy straw which is available plentily in situ in the region is suggested to be used as a suitable mulching material for winter Rajmash crop for boosting the yield in water deficient areas of Sambalpur district which has a large acreage under rice.

Key words: Rajmash, mulch, irrigation, grain yield, water use efficiency, soil properties

1. Introduction

Rajmash or French bean (*Phaseolus vulgaris*) which is a rich source of protein is a newly introduced winter season (Rabi) pulse crop in Sambalpur district (20° 21' N latitude and 80° 55' E longitude) of Western Odisha, a state in eastern India. This crop has a growing demand in the region as a popular dish (Tadka) is prepared from it. To meet the increased local demand more area needs to be covered under this crop. However, there are some limitations for expansion of area under this crop. It is mostly grown in the medium lands at a wider row to row spacing of 45 cm which is favourable for weed flora to come up in a large scale and therefore the crop has to compete with weeds for its growth. Further due to high day temperature (27^0 to 34°C) and low relative humidity (50 to 56%) during crop growth period there is high evaporative and transpiration loss of water especially through weeds. Rice-rice is the major cropping system of the region and canal supply of irrigation water is largely scheduled to meet the water requirement of rice-rice system and it does not match the phasic water requirement of Rajmash crop. Therefore the crop has to be grown under deficit water supply. Thus deficit moisture and weed infestation hold the key for successful production of rajmash.

Mulching is an established technique for increasing crop yield (Duranti and Cuocolo, 1989; Gimanez *et al.,* 2002) in different crops due to its capacity to conserve soil moisture (Vavring and Roka, 2002) and increase early soil temperature (Shaw, 1959) which may influence soil properties especially of surface layer. Mulching conserves water by checking evaporation and transpiration by weeds and also modifies soil temperature and influences soil environment especially biological (Li Feng- Min *et al.* 2004).Very little weed growth occurs under the mulches. The mulches prevent penetration of light or exclude certain wavelengths of light. The effects however, vary with the type of mulch, soil and climatic conditions under which the crop is grown. Rice and sugarcane are two most important common crops extensively grown in the region where the farmers traditionally either remove the paddy straw from field for cattle feed or burn the residues of both the crops *in situ* before planting of the next crop to facilitate the tillage operation. Burning causes loss of nutrients to the tune of 80% of N(Raison,1979) 25% of P and 21% of K(Ponnamperuma,1984) and 4-60% of S(Lefroy *et al.* 1994) and soil organic matter and negatively contributes to carbon sequestration. Use of these residues as mulching materials in Rajmash will get rid of these twin problems and help the crop to grow under deficit irrigation with reduced weed problem. For optimum crop growth with profitable cultivation the practice of mulching and irrigation needs to be standardized. Therefore the study was conducted to evaluate paddy straw and sugarcane trash *vis -a- vis* plastic film as mulching materials with respect to their effect on some selected soil properties important from nutrient cycling point of view and crop yield of Rajmash under different irrigation schedules.

2. Materials and Methods

A field experiment on Rajmash (*Phaseolus vulgaris*) was conducted during winter seasons of 2007-08 and 2008-09 on a moderately well drained medium land of the Central Research Farm at the Chiplima Centre of Regional Research and Technology Transfer Station (RRTTS) of Orissa University of Agriculture and Technology (OUAT), Sambalpur district about 360 kms away from the state capital of Bhubaneswar. Mean annual rainfall at the experimental site is 1459mm with average maximum temperature of 40.20C (May) and minimum of 12.5^{0}C (December).

The soil of the experimental site is a sandy loam composed of 74.38% sand, 12.56%silt and 13.06 % clay with acidic reaction (pH 5.78).The soil contained 0.78% organic carbon,1440 kg/ha of total nitrogen(Kjeldahl method)), 34kg $ha^{-1}$of available Phosphorous(Bray's-1) and 122 kg/ha of available potassium(Ammonium acetate extraction). The experiment consisted of three irrigation schedules such as irrigation at 30%, 50% and 60% depletion of available soil moisture (ASM) taken as main plot treatments and three mulching treatments such as sugarcane trash, paddy straw and plastic and an un mulched control taken in subplots. The experiment with twelve treatments was laid out in a split plot design with 3 replications.

2.1 Land preparation and planting

Following harvest of a medium duration (120days) kharif rice, the land was ploughed three times , leveled and Rajmash (cv:*Chitra in 2007-08 and cv; Contender in 2008-09*) seeds were sown in narrow and shallow furrows in the month of November with row to row spacing of 45 cm and plant to plant spacing of 10 cm in plots of dimension 6m × 5m in both the years with rice as kharif crop (July-October). Uniform dose of FYM @ 2t ha^{-1} and fertilizer NPK(100-60-40) was applied through urea, DAP and MOP in both the years Half dose of N and full doses of P and K were applied at sowing and rest 50% N was top dressed at 20 days after sowing.

2.2 Mulching and Irrigation

The mulching treatments were imposed at 20DAS when first intercultural operation was undertaken. Black plastic films of 50μ thickness and 45 cm width were placed between the rows and paddy straw and sugarcane trash mulching was done on the same day @3t ha^{-1} by uniformly spreading over the surface as a carpet manually. The straw contained 48.7% C, 0.6% N, 0.22%P,1.2% K with C/N of 81.2; where as the sugarcane trash contained 51.2% C,0.42% N,0.18% P,0.72% K with C/N of 122.The Lignin content in sugarcane trash was more than that of paddy straw. After mulching one common irrigation of 6 cm was given to all the treatments and further irrigations were applied as per the respective main plot treatments.

2.3 Biomass of Weed and Crop yield

Weeds were removed from two different 1m^2 areas of each field at 60 DAT, oven dried after air drying for 2days and dry weight of the biomass was measured in terms of g m^{-2} by averaging the two locations in each plot.

An area of 1.8m x 1m (for 4rows of 1m length) was marked by fixing 4 number of sticks at the centre of each plot that included 4rows of 1m length which was left undisturbed until final harvest. Plants were cut from soil surface and pods were separated .All the samples were air dried and seeds were separated and air dry weights of seeds were recorded.

2.4 Soil sampling and Laboratory analysis

.Surface (0-15cm) soil samples collected after the harvest of second year rajmash crop were analysed after air drying for various soil properties such as pH(soil : water of 1:2 ratio), organic carbon (Walkley Black's rapid titration method), available N(Alkaline $KMnO_4$ method), available P(Bray's-1 extractable) and available K (Ammonium acetate extractable). Soil bulk density was determined by gravimetric method for which soil was sampled through manual coring up to 5 cm depth. For knowing the effect on biological properties, microbial respiration (Pelczar *et al*. 1993) and enzyme activities such as dehydrogenase (Casida *et al.*1964), urease (Tabatabai 1982) and acid phosphatase (Dick *et al.* 1996) were determined on air dried soil samples. Water use efficiency (WUE) was calculated from the yield and WR for each treatment.

2.5 Statistical Analysis

The results on crop yield, soil physical, chemical and microbiological parameters were then subjected to analysis of the variance (ANOVA) using least significant difference (LSD) test for comparing treatment effects on various parameters (Gomez and Gomez 1984).

3. Results and Discussion

3.1 Soil Properties

Soil samples collected immediately after harvest of the second crop were processed and analyzed for assessing changes in bulk density (BD), pH, soil organic carbon (SOC), available NPK, microbial respiration, activities of enzyme dehydrogenase, urease and phosphatase and the results were recorded in table 1 and 2.

3.1.1 Bulk Density (BD)

Within two years of continuous cropping neither the mulching nor the irrigation treatment had any significant effect on soil bulk density. When averaged over the irrigation treatment, lowest BD of 1.32 Mg m^{-3} was observed with paddy straw followed by 1.39 Mg $m^{-3}$with sugarcane trash,1.44 Mg m^{-3} in plastic mulch and highest of 1.46 Mg m^{-3} in the un mulched treatment as compared to the initial 1.40 Mg m^{-3}. When averaged over the mulching treatments the BD values measured 1.34, 1.36 and 1.44 Mg m^{-3} at 30, 40 and 60% depletion of soil moisture (DASM) respectively. With respect to porosity among mulched treatments lowest(42.50%) in plastic mulch as compared to 48.03% in paddy straw, 45.27% in sugarcane trash mulch. The unmulched soil also had low BD (42.17%). Khurshid *et al.,* (2006) and Glab and Kulig (2008) reported that mulching increased soil porosity and reduced soil compaction. In a study made earlier Thompson (1966) had however, showed no significant effect of sugarcane mulch on soil bulk density and porosity. Thus from the results of the present study it may be concluded that paddy straw is more effective than sugarcane trash and plastic mulch.

3.1.2 Soil pH

Within two years, there was significant increase in soil pH in organically mulched treatments. The pH increased from initial 5.78 to 5.98 with sugarcane trash and 5.78 to 6.09 with paddy straw. Increased pH in organically mulched soil has also been reported by Borthakur and

Bhattacharya (1992) and Shashidhar *et al*., (2009). This increase is attributed to liberation of base during the process of decay of the organic mulches (Shashidhar *et al.* (2009). In contrast, the pH remained unchanged (5.78) with plastic mulch. This also corroborated the above fact as plastic mulch had no decomposition effect. Irrigation at 50and 60% DASM also recorded significantly higher soil pH of 6.03 and 6.01 respectively than that at 30% DASM(5.79).This might be due to greater decomposition effect with less frequent irrigation and less leaching of bases.

3.1.3 Soil Organic Carbon (SOC)

Treatment with organic mulching maintained a higher level of organic carbon (0.74-0.79%) than the plastic mulch (0.70%) and unmulched treatment (0.68%). Between the two organic mulches higher value of 0.79% was recorded with paddy straw mulch which was 16.2% higher than the unmulched treatment when averaged over the irrigation levels. This is in agreement with results of Li Peng *et al,* (2004) who reported a decrease in soil organic carbon with plastic film and unmulched treatment. Irrigation treatments also significantly influenced the soil organic carbon. Irrigation at 30% DASM maintained highest SOC of 0.77% followed by 0.74% at 50% DASM and 0.67% at 60% DASM.This supported the result that at 50 and 60% DASM there is greater decomposition and more loss of carbon than that at more frequent irrigation with 30% DASM..

3.1.4 Available Nutrients

Results on soil available nitrogen, phosphorus and potassium showed that among the three types of mulching materials, paddy straw mulch recorded highest level of all the three primary nutrients.

3.1.4.1 Available Nitrogen (N)

With two years of mulching with paddy straw the available N content increased from the initial value of 248kg $ha^{-1}$to 307kg ha^{-1}. The increase was significantly higher than that with plastic mulch (272kg ha^{-1}) and no mulch (273kg ha^{-1}). Sugarcane trash with 285kg N $ha^{-1}$was however, at par with paddy straw. This might be due to the release of more N caused by decomposition and mineralization of both the organic materials which respectively contributed about 20kg and 15kg of total N/ha in one year in contrast to plastic mulch that did not add any N directly. Unlike the mulching treatments the irrigation treatments did not show any significant effect on available N content after two years of continuous cropping.

3.1.4.2 Available Phosphorus (P)

Unlike N availability that mostly depended on soil organic matter, availability of P depended both on organic matter mineralization and release from clay minerals through various mechanisms. Therefore its behavior is different from that of N in a soil system. Like N, highest mean available P of 37.60kg $ha^{-1}$was also recorded with paddy straw mulch. But unlike N it was significantly higher than both sugarcane trash (34.23kg ha^{-1}) and plastic mulch (34.46kg ha^{-1}) and no mulch (32.79kg ha^{-1}).Higher available P with paddy straw might be due to greater P addition through it and higher microbial activity. From the results however, it is clear that mulching increases the available P which might be due to the effect of mulching on soil temperature and moisture and creation of a favourable environment. Mulching significantly increases the soil temperature and moisture and the increase in temperature is more with black plastic than straw (Truax and Gagnon 1993). Like N, available P was not significantly influenced by the irrigation treatments. From the results however it is clear that with more frequent irrigation at the end of crop season less phosphorus was maintained.

3.1.4.3 Available Potassium (K)

In soil available K depends on all forms of K viz; mineral, fixed, exchangeable and solution K those are in dynamic equilibrium with one another. Addition of K either through fertilizer or through organic matter and other soil, plant and climatic factors also influence its availability. Organic mulches contribute to soil K through addition of K contained in them and indirectly through their effect on soil environment such as soil temperature and moisture. Among the mulched treatments paddy straw that contributed around 30kg K ha^{-1} to the soil recorded highest amount of available K (118kg ha^{-1}) .Plastic mulch that contained no K also maintained statistically same amount of K (115kg ha^{-1}) which might be due to creation of a favourable environment by increase of temperature (Sparks and Liebhardt, 1982) and moisture (Nye, 1966) releasing more K from soil. This is in agreement with the result reported by Truax and Gagnon (1993) that average soil K was higher under plastic mulch than no mulch and other organic mulches like paper and pine mulch. Available K (103kg ha^{-1}) with sugarcane trash was significantly lower than paddy straw mulch and plastic mulch and was at par with no mulch (97kg ha^{-1}). Similar to N and P, available K was also not influenced by the irrigation treatments.

3.1.5 Biological Properties

Results on effect of mulching and irrigation levels on soil microbial properties recorded in table 3 reveal that two years of mulching had significant positive effect on soil respiration, and activities of enzymes urease, phosphatase and dehydrogenase. In contrast to the effect on physical and chemical properties of soil as discussed above, paddy straw mulch and plastic mulch were equally efficient in improving the soil biological activity. Among the mulching treatments sugarcane trash had minimum effect and was almost at par with unmulched treatment with respect to their effect on respiration and phosphatase activity.

3.1.5.1 Soil Respiration

Highest mean soil respiration of 0.274mg CO_2 g^{-1} soil per day was observed with paddy straw mulch which was at par with plastic mulch (0.273mg) and 25.68% higher than no mulch (0.218mg). Sugarcane trash mulch (0.220mg CO_2 g^{-1} soil per day) which was at par with no mulch was most inefficient among the three mulching materials used in maintaining soil microbial respiration. Similar observations were also made with respect to three enzyme activities urease, phosphatase and dehydrogenase with the order paddy straw = plastic mulch > sugarcane trash > no mulch. The three irrigation treatments also were at par in their influence on the soil microbial properties studied. Thus because of maintenance of favourable soil physical, chemical and biological condition the nutrient availability was better with paddy straw mulch. This might be the reason why paddy straw mulch produced highest yield in both the years.

3.1.5.2Urease activity

Results on mean urease activity revealed that all mulched soils maintained significantly higher urease activity than the unmulched soil (78.7mg NH_4^+kg $^{-1}$soil per 2hrs). Both paddy straw and plastic mulch recorded the same (110mg NH_4^+kg $^{-1}$soil per 2hrs) mean activity which was significantly higher than that with sugarcane trash mulch(89.5110mg $NH_4^{+/}$kg $^{-1}$soil per 2hrs).All the three irrigation treatments did not significantly differ in their influence on urease. With same urease activity the soil under paddy straw mulch however maintained a higher level of alkaline $KMnO_4$ (mineralisable) than plastic mulch. This might be due to maintenance of higher organic matter in soil under 3t/ha of paddy straw mulch that decomposed during crop growing period resulting in more available N. The soil under sugarcane trash also had higher available N (285kg ha^{-1}) than the soil under plastic (273kg ha^{-1}) because of the same reason. Some authors suggested that enzyme activities were closely correlated to the total amount of carbon and nitrogen (Kheyrodin and Antoun, 2008).

3.1.5.3 Phosphatase activity

When averaged over the three irrigation treatments phosphatase activity varied from a lowest of 108mg p-nitrophenol found in the un-mulched control to 140mg p-nitrophenol kg^{-1} soil per hr found in soil under paddy straw mulch. Plastic mulch with 136mg activity was at par with straw mulch, but significantly higher than that with sugarcane mulch (117mg p-nitrophenol kg^{-1} soil per hr). Unlike urease, sugarcane trash mulch did not have any significant effect on this enzyme. However with respect to available P both sugarcane mulch and plastic mulch were at par and recorded 4-5% more P than un-mulched control. Paddy straw mulch with higher organic matter and highest phosphatase activity recorded highest available P in soil. Like urease activity the irrigation treatments were also at par in their influence on phosphatase activity.

3.1.5.4 Dehydrogenase activity

The mean value data on enzyme dehydrogenase showed that all the three mulched soils recorded significantly higher dehydrogenase activity than the unmulched control. Among the mulched treatments, paddy straw recorded highest activity of 251mg TPF kg^{-1} soil per 24hrs followed by plastic mulch with 247mg and sugarcane trash with 195mg. Irrigation treatments also did not differ in their influence on enzyme dehydrogenase.Thus mulching treatments were in the order :paddy straw = plastic mulch > sugarcane trash > no mulch with respect to their influence on soil microbial activity.

3.2 Weed Infestation

Weed infestation was studied by measuring dry weight of weeds per sq m at 60DAS of the crop grown during 2008-09. The mulching treatments differed significantly in weed infestation. The plastic mulch recorded the lowest biomass (15g m^{-2}) whereas the unmulched treatment gave highest biomass of 72g m^{-2}.Paddy straw mulch measured 32g m^{-2} as compared to 48g m^{-2} in sugarcane trash mulch signifying the sugarcane trash mulch to be ineffective in weed suppression (plate-1). Plastic mulch and paddy straw mulch were effective in control of weeds which is in agreement with the results of Ramakrishna *et al*.(2006) who worked on groundnut.

3.3 Crop yield

Results on effect of mulching and irrigation levels on grain yield of Rajmash (table 3) reveal that during 2007-08, grain yield of Rajmash (cv, *Chitra*) varied from 5.00 to 8.33 q ha^{-1} and was significantly influenced by the mulching treatments but not by different levels of irrigation. When averaged over the irrigation treatments paddy straw mulch produced highest yield of 7.26 q ha^{-1} which was significantly higher than the yields obtained in all other mulching treatments. During 2008-09 irrigation schedules like previous year, also had no significant effect and paddy straw mulch also produced highest yield of 13.69 q ha^{-1} which was however at par with plastic mulch (12.78 q ha^{-1}) and significantly superior to sugarcane trash (7.65q ha^{-1}) and no mulch (6.56q ha^{-1}) treatments. In contrast, Mahajan *et al.* (2007) had reported that black plastic was superior to rice straw mulch in increasing the yield of baby corn and field corn respectively. The yields of both the years when pooled were in the order: paddy straw mulch = plastic mulch > sugarcane mulch = no mulch. The results of two years thus showed that both paddy straw mulch and plastic mulch were almost at par but significantly superior to sugarcane mulch in influencing the grain yield. Thus sugarcane trash mulch with minimum effect was in no way different from the unmulched treatment. This might be due to the phyto-toxic effect of sugarcane trash leachate that contained phenolic acids such as vanilic acid, ferulic acid and syringic acid (Samprieto *et al*.,2005).Because of heavy amount of trash(3t ha^{-1}) added to the soil for mulching the phenolic acid concentration becomes high enough to inhibit the growth of young plants. These compounds can be leached from plant straws into soil (Souto *et al*.2001).This might also be due to more weed infestation and less nutrient availability. On the other hand, when averaged over the mulching treatments, irrigation at 30% depletion of ASM in 2007-08 and 2008-09 produced highest yields of 6.25 and 10.98q ha^{-1} respectively which however, were at par with irrigation at 50% and 60% depletion of ASM.

3.4 Water Use Efficiency (WUE)

Water use efficiency was derived from the crop yield and water requirement in different treatments in both the years. It varied from 20.67 to 29.66 kg $ha\text{-}cm^{-1}$ during 2007-08 and 28.21 to 57.06 kg $ha\text{-}cm^{-1}$ during 2008-09(table 3). Higher WUE measured during 2008-09 is due to higher yield at same level of water requirement. As evident from table 3, paddy straw mulch recorded maximum yield and highest WUE in both the years and the mean water use efficiency of two years was 37.68 kg $ha\text{-}cm^{-1}$ as compared to 33.87 kg $ha\text{-}cm^{-1}$ with plastic mulch. Lowest WUE of 26.81 kg $ha\text{-}cm^{-1}$ was recorded in un-mulched plots. With respect to WUE the irrigation treatments varied to a smaller extent and they were in the order 30% >50% >60%DASM.

Although total requirement of water at 60% DASM was more than that at 30% DASM, three numbers of less irrigation were required with the former as compared to the latter. Considering insignificant yield difference and reduced number of irrigation requirement , applying water at 60% DASM is suggested for winter rajmash grown under inter row mulching with paddy straw which is abundantly and easily available *in situ* as kharif rice grown in the same field is machine harvested leaving behind 3tonnes of paddy straw/ha. Inter row mulching with paddy straw provided a favourable soil environment with reduced weed growth, improved soil structure and higher status of nutrients .

3.5 Interaction Effect

Interaction effect of mulching treatments and irrigation levels was found to be non significant(Fig.1).The mean data of two year study revealed that the grain yield at all the three irrigation levels of 30%, 50% and 60% DASM in all the mulching treatments are statistically same. Further the study indicated that paddy straw mulch and plastic mulch even with less frequent irrigation (60%DASM) gave statistically higher yield than that with sugarcane trash mulch and no mulch with more frequent irrigation (30%DASM). This was perhaps due to better conservation of moisture and control of weeds (Mahajan *et al.* 2007)

4.0 Conclusion

Higher yield of rajmash (*Phaseolus vulgais*) can be obtained by mulching the soil with paddy straw at 20 days after sowing. Plastic mulch was also at par with paddy straw mulch and sugarcane mulching was most inefficient. As paddy is the dominant crop of the zone, availability of paddy straw is not a constraint. Crop yield with providing irrigation at 60% depletion of ASM was at par with that at 30% depletion and paddy straw mulch created more favourable soil conditions than other mulched and unmulched treatments by improving soil porosity, SOC, available nutrients and microbial activity measured in terms of urease, phosphatase and dehydrogenase. So inter row mulching of Rajmash crop with paddy straw @ 3 t ha^{-1} with irrigation at 60% depletion of soil moisture can be adopted as a practice in successfully growing the crop in water deficit areas of Hirakud command of Odisha.

5.0 Future Research

Future research however needs to be done to grow the crop with minimum tillage simply by dribbling the seeds into the soil with proper spacing as paddy straws after harvest are left on the field. This will save the cost on land preparation and spreading of straw.

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Table 1. Effect of mulching and Irrigation treatments on changes in some selective physical and chemical properties of surface soil after two years of Rajmash cultivation

Treatments	BD ($Mg\ m^{-3}$)	pH	SOC(%)	Alkaline $KMnO_4$- N ($kg\ ha^{-1}$)	Bray'sP ($kg\ ha^{-1}$)	NH_4OAc-K ($kg\ ha^{-1}$)
Effect of mulching treatments						
Sugarcane trash	1.39	5.98	0.74	285	34.23	103.33
Paddy straw	1.32	6.09	0.79	307	37.60	118.33
Plastic	1.46	5.78	0.70	272	34.46	115.56
No mulch	1.47	5.92	0.68	273	32.79	97.11
*P<0.05	NS	0.149	0.039	27	2.660	12.59
Effect of irrigation treatments						
30% DASM	1.34	5.79	0.77	283	33.29	110.00
50% DASM	1.36	6.03	0.74	292	35.55	109.08
60% DASM	1.44	6.01	0.67	277	35.47	106.67
*P<0.05	NS	0.132	0.038	NS	NS	NS
Initial	1.40	5.78	0.78	248	34.00	122.00

NS- Non significant , DASM- Depletion of available soil moisture

Table 2. Effect of mulching and Irrigation treatments on changes in microbial properties of surface soil after two years of Rajmash cultivation

Treatments	**Soil Respiration (mg CO_2 g^{-1}soil day $^{-1}$)**	**Urease Activity (mg NH_4^+ kg $^{-1}$soil 2h $^{-1}$)**	**Phosphatase activity (mg p nitrophenol kg ^{1}soil h $^{-1}$)**	**Dehydrogenase Activity (mg TPF kg-^{1} soil per 24hrs)**
Effect of mulching treatments				
Sugarcane trash	0.220	89.51	117	195
Paddy straw	0.274	110.60	140	251
Plastic	0.273	110.15	136	247
No mulch	0.218	78.73	108	157
*P<0.05	0.043	9.75	17	38
Effect of irrigation treatments				
30% DASM	0.235	94.69	121	219
50% DASM	0.264	99.48	133	230
60% DASM	0.242	97.58	122	188
*P<0.05	NS	NS	NS	NS
Initial	0.186	68.56	87	147

NS- Non significant , DASM- Depletion of available soil moisture

Table 3. Effect of mulching and Irrigation treatments on Rajmash (*Phaseolus vulgaris*) yield, water requirement andwater use efficiency

Treat	Seed yield (q ha^{-1})			Water requirement(cm)			Water use efficiency (kg $ha\text{-}cm^{-1}$)		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Effect of mulching treatments									
Sugarcane trash	6.37	7.65	7.01	28.29	27.34	27.82	22.50	38.64	30.57
Paddy straw	7.26	13.69	10.47	27.27	27.02	27.15	26.77	48.59	37.68
Plastic	6.30	12.78	9.39	27.59	27.03	27.31	22.93	44.81	33.87
No mulch	6.00	6.56	6.43	27.91	27.66	27.79	22.27	31.35	26.81
*P<0.05	0.83	3.01	1.92						
Effect of irrigation treatments									
30% DASM	6.25	10.98	8.62	24.89	23.28	24.14	25.16	46.18	35.67
50% DASM	6.58	9.92	8.25	29.48	29.28	29.38	22.48	39.59	31.22
60% DASM	6.61	9.62	8.12	28.92	29.14	29.03	22.86	36.76	29.81
*P<0.05	1.25	1.946	0.79						

DASM- Depletion of available soil moisture

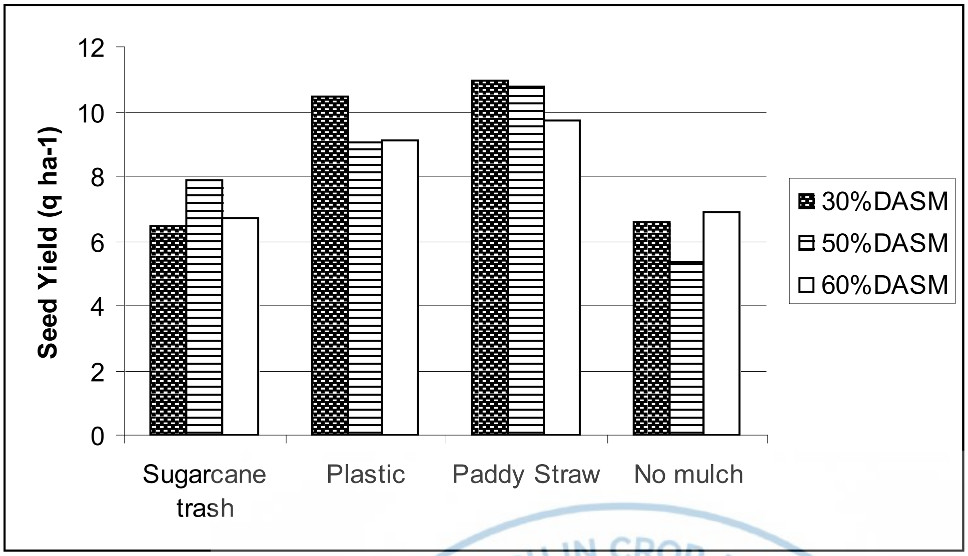

Figure 1.Interaction effect of mulching treatments and irrigation levels on grain yield of Rajmash (Mean of 2 years)

Plate No.1: Four mulching treatments of the experimental field with the Rajmash(cv: *Contender*) crop at early fruiting stage

The chemical blueprint: Deciphering Salinity, Sodicity, Toxicity Hazards in Irrigation water

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Abstract: Irrigation water quality refers to its suitability and sustainability for use in agricultural crop fields. The influence of water quality on the soil and plant growth is related to the chemical and physical properties of the soil, the salt tolerance of the crop growth, the climatic regime of the area and the method, frequency and the amount of irrigation water applied. Hence to formulate a comprehensive irrigation water classification scheme for agricultural crops different irrigation water quality parameters like electrical conductivity, total salt concentration, sodium hazard, boron toxicity, residual sodium carbonate, etc are to be considered conscientiously.

Key words: Irrigation water, salt concentration, sodium hazard, boron toxicity

Introduction

Irrigated agriculture is playing a major role in enhancing food and livelihood security of a country. Supply of fresh water which is an important input for the sustainable and economic development of agriculture are not enough to meet the requirement of all sectors of economy. Reduced water availability to agriculture from the present share of 85% of country's water resources to about 70-75% by 2020AD would affect the capacity of the country to meet the food production target, unless supplies are augmented from unconventional sources. For future agriculture there are no alternatives but to rely on non conventional sources for partial alleviation of the forecasted water scarcity. Among these sources extraction of marginal quality ground water and the waste water generated from urban and industrial activities have the potential to augment the water supplies. Many associated soil, plant and environmental problems come up when these sources of water are directly used for irrigation. For addressing these problems and to get more benefit from these sources of water, the first step is to understand how an irrigation water source affects the soil plant system. Therefore knowledge of irrigation water quality is critical to develop appropriate site and crop specific comprehensive short term and long term management programs.

Suitability of irrigation water

The suitability of irrigation water depends upon several factors such as water quality, soil type, plant characteristics, irrigation method, drainage, climate and local conditions. The integrated effect of these factors on the suitability of irrigation water (SI) can be expressed by the relationship given below;

$$SI = QSPCD$$

Where;

Q = quality of irrigation water, that is total salt concentration, relative proportion of cations

S = Soil type, texture, structure, permeability, fertility, calcium carbonate content, type of clay minerals, initial level of salinity and alkalinity before irrigation

P = Salt tolerance characteristics of the crop, its variety and growth stage

C = Climate that is, total rainfall, its distribution, and evaporation characteristics

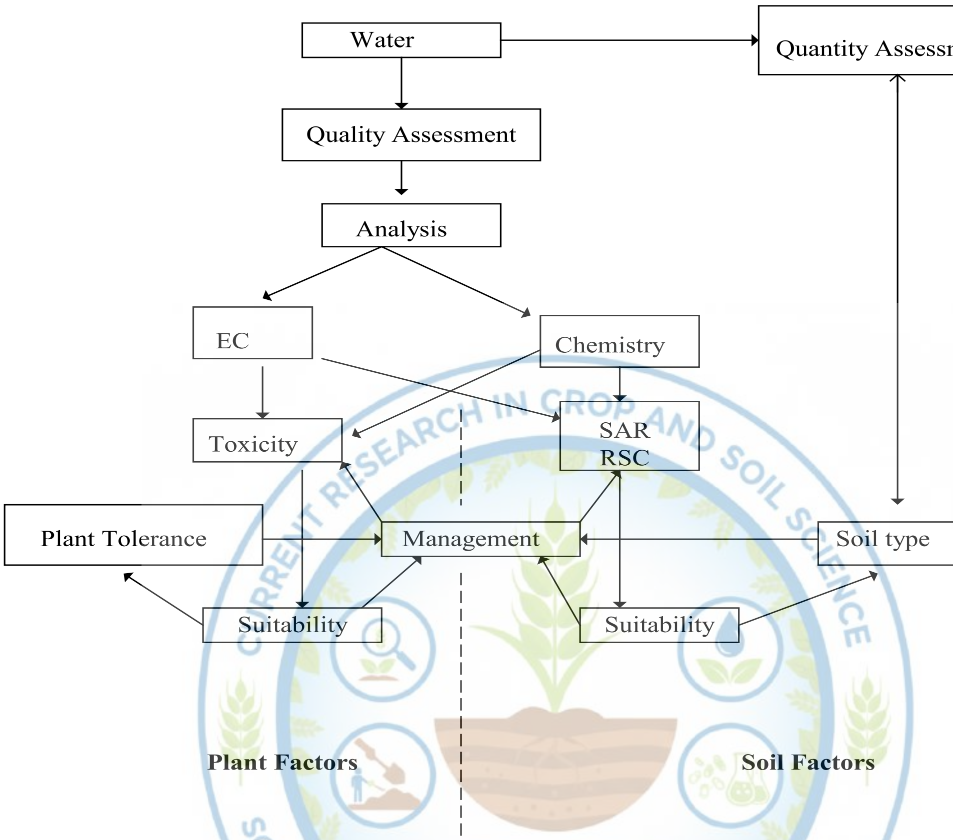
D = Drainage conditions, depth of water table, nature of soil profile, presence of hard pan or lime concretion and management practices

These factors act interactively such that a single suitable criterion is hard to be adopted for widely varying conditions. However Bureau of Indian Standards (BIS) has developed some general broad guidelines (IS: 11624-1986) for assessment of water quality which were reaffirmed in 2001 and 2009.

Water Quality Evaluation

Conceptually water quality refers to its suitability for a specific use and the criteria for judging water quality for different purposes are different. Specific uses have different quality needs and among all sectors of water use, agriculture is most sensitive to water scarcity and water quality.

The objective of water quality evaluation is to assess its suitability for irrigation and assist to cope with potential water quality problems that might reduce production through management. Basing on the experiences and measured responses certain parameters have emerged as indicators of irrigation water quality. These indicators are then organized into guidelines related to suitability for use. Numerous such guidelines are available covering many types of use. Figure 1 is a flow diagram suggesting a concept for assessing water quality. Plant tolerance allows a wide range of options as to suitable crops and this feeds back into management aspects which determine whether these crops are profitable or whether the yield losses due to salinity or toxicity are acceptable (Maas and Hoffman, 1977). Under soil factors where quality is marginal, there is a possibility of adding ameliorants to the soil or changing to another soil type to avoid problem.



Flow diagram of evaluation of water quality

Fig 1: Flow diagram of evaluation of water quality

Water Quality Guidelines

There have been a number of different water quality guidelines related to irrigated agriculture. Each has been useful but none has been entirely satisfactory because of the wide variability in field conditions. Water used for irrigation varies greatly in quality depending upon type and quality of dissolved salt. The suitability of water for irrigation is determined not only by the total amount of salt but also by the kind of salt. Various soil and cropping problems develop as the total salt content increases and special management practices are required to maintain acceptable crop yields. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long term use.

The problem that results vary in kind and degree that are modified by soil, climate and crop as well as by the skill and knowledge of the water use. As a result there is no set limit on water quality rather its suitability for use is determined by the conditions of use which affects accumulation of the water constituents and which may restricts crop yield. The soil problems that are most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity of ions and a group of other miscellaneous problems.

(i) ***Salinity***: It is related mainly to osmotic potential and its effect on crop growth. It is determined by salt concentration rather than specific constituents. The guideline indicates that it is necessary to consult detailed tolerance tables to determine plants which would not suffer unacceptable yield loss (Ayres and Westcott, 1976; Shainberg and Oster, 1978).

(ii) ***Sodicity***: The sodic (sodium) hazard is related to the detrimental effect of the exchangeable sodium percent (ESP) on soil structure and the direct toxic effect on sodium sensitive plants.

(iii) ***Toxicity***: This is the specification effects of solutes (excluding sodium) of a nutritional nature, e.g. boron, lithium, chlorine and certain heavy metals.

1. Salinity Problems

A salinity problem due to water quality occurs if salts from applied irrigation water accumulate in crop root zone beyond certain limits and yields are affected with shallow water tables, a salinity problem may also exist due to upward movement of salts from ground water as the water evaporates from the soil or used by the crop.

The total concentration of soluble salts in irrigation water can be adequately expressed in term of electrical conductivity (EC). The basic unit for EC is deci Siemen per meter (dS m^{-1}). The electrical conductivity values of irrigation water can also be converted into other reporting units (James et al., 1982) such as;

(i) EC (dS m^{-1}) × 640 = Total salt concentration, mg L^{-1} or ppm ……… (1)

(ii) EC (dS m^{-1}) × 0.36 = Osmotic pressure, bar ……… (2)

(iii) EC (dS m^{-1}) ×10 = Total cation or anion concentration, meq L^{-1} ……… (3)

Irrigation water classification for salinity hazard used as a guidelines as proposed by Richards (1954) is presented in Table 1. For assessing the suitability of particular irrigation water in a specified crop rotation, the salinity limits given in Table 2 may be adjusted/corrected for rainfall in the region.

Table2: USDA classification of irrigation water salinity

Salinity class and description		EC range(dSm^{-1})	Equivalent salt concentration (mg L^{-1})
C1	Low salinity water-good for most soils and crops	< 0.25	< 200
C2	Medium salinity water-some leaching for sensitive crops	0.25-0.75	200-500
C3	High salinity water tolerant crops and leaching required	0.75-2.25	500-1500
C4	Very high salinity water only for permeable soils and tolerant crops	> 2.25	> 1500

Source: (Richards, 1954)

Water quality rating for salinity hazard as proposed by workers in India is reported in Table 2. With appropriate management practices the hazards due to use of poor quality waters can be minimized for sustained production of crops in a given situation. Limits of salinity in irrigation water for achieving specified yield levels (relative) in various crops under different climatic and soil conditions have been given in Table 3. Hammed *et al.* (1966) stated that waters having EC value less than 1.5 dS m^{-1} are safe for irrigation, those having 1.5 to 3.0 dSm^{-1} are marginal and waters having EC values more than 3.0 dSm^{-1} are unsafe.

Table 3*:* Guidelines for using poor quality irrigation Water (Recommendation of AICRP – Saline Water, CSSRI, HAU and PAU, 1990)

Soil texture (% clay)	Crop tolerance	Upper limit of EC_{iw} (dS m^{-1}) in rainfall region (mm)		
		< 350	350-550	550-750
Fine (> 30)	Sensitive (S)	1.0	1.0	1.5
	Semi-tolerant (ST)	1.5	2.0	3.0
	Tolerant (T)	2.0	3.0	4.5
Moderately fine (20-30)	S	1.5	2.5	2.5
	ST	2.0	3.0	4.5
	T	4.0	6.0	8.0
Moderately coarse (10-20)	S	2.0	2.5	3.0
	ST	4.0	6.0	8.0
	T	6.0	8.0	10.0
Coarse (< 10)	S	--	3.0	3.0
	ST	6.0	7.5	9.0
	T	8.0	10.0	12.5

Selection of Crop(s)

Amongst the general guidelines for selecting crops and cropping sequences, tolerant or semi tolerant crops having low water requirement such as barley, wheat, mustard, pearl millet and sorghum (promising varieties are given in table 4) should be grown while crops with high water requirement such as rice, sugarcane and berseem should be avoided. In low rainfall area (having annual rainfall < 400 mm) if good quality canal water is unavailable, it is desirable to keep the fields fallow during kharif season. During rabi, only tolerant and semi tolerant crops like barley, wheat and mustard should be grown. In area having high rainfall (having annual rainfall > 400 mm) sorghum – wheat, guar- wheat, pearl millet- wheat and cotton- wheat rotations can be practiced, provided sowing of kharif crops is completed with rainwater or good quality canal water. Not more than 2 or 3 irrigations should be applied with sodic water during the kharif season. Sodic water should not be used to grow summer crops (Gupta, 2010).

Table 4: Promising varieties for alkali tolerance from CSSRI and other places

Crops	pH/ ESP	Varieties/ Genotype
Rice	9.4 – 10.2 9.4 – 9.8	CSR 10 CSR 13, CSR 23, CSR 27, CSR 36, CSR 30
Wheat	9.2 – 9.3	KRL 1-9, KRL 19, KRL 99, WH 157, Raj. 3077
Mustard	12 – 38 (ESP)	Pusa bold, Varuna, Kranti, CSR 52, CSR 54, CS 56
Chickpea	Upto 9.3	Karnal Chana 1
Barley	Upto9.3	CSB 1, CSB 2, CSB 3, DL 200, DL 348, Ratan, BH 97, AZAD
Dhaincha		CSD 137, CSD 123

Source: Gupta, 2010

Ideally it would be inferred that EC of irrigation water should be as low as possible, but the water which is completely free of soluble salts is never the best for irrigation. The water having EC less than 0.2 dSm-1 have no fertility value and are well known to create permeability problem in the preferably less than1.5 dS m^{-1} so that irrigated soil dose not even become saline and there is full choice to grow the crops (Gupta and Gupta, 2003).

2. Sodicity problems

Among the soluble constituents of irrigation water, sodium (Na) is considered to be most hazardous. Water which might be suitable under salinity classification may not be suitable, if sodium predominates. The effect of sodium is two fold. It affects the permeability of soil causing by swelling and dispersion of clay particles and clogging the soil pores and it may cause injury to crops specifically sensitive to sodium such as fruit crops. Irrigation water containing large amount of sodium is of concern due to absorbed sodium by plant roots which is transported to leaves where it can accumulated and cause injury (Begum and Rasul, 2009). The sodium adsorption ratio (SAR) has been proposed as a useful measure of sodium hazards of irrigation water (Richards, 1954). This parameter is defined by the relationship as;

$$SAR_{iw} = \frac{(Na^{+})}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{------------------------------------ (4)}$$

where, the ionic concentrations are expressed in miliequivalents per litre (meL^{-1}).

Based on SAR values of irrigation water, its suitability can be evaluated with the help of rating given in the Table 5. In practice many irrigation water contains sufficient quantities of sulphate and bicarbonate ions to produce precipitation of calcium sulphate and calcium carbonate that remove calcium from solution and hence markedly increase sodium hazards. SAR under this situation may not give the correct sodium hazard since it is the SAR of soil water (SARsw) value rather than the SAR of irrigation water (SARiw) value that affect the ESP of the soil and an eventually the soil permeability. Hence a new index called adjusted SAR (SAR_{adj}) is suggested by Rhoades (1969 a) and is calculated by using the following formula (Ayers and Westcot, 1976).

$$SAR_{adj} = SAR_{iw}(1 + (8.4 - pHc) \quad \text{--------------------------------------- (5)}$$

The term $(8.4 - pHc)$ reflects the tendency of the applied water to precipitate or dissolve $CaCO_3$. The pHc term is defined as the theoretical pH of irrigation water with a given calcium, magnesium and HCO_3^- + CO_3^- concentration, which is in equilibrium with solid $CaCO_3$. When $(8.4 - pHc) > 0$ calcium carbonate precipitates in the soil when the water is applied and when $(8.4 - pHc) < 0$, the irrigation water dissolves calcium carbonate if present in the soil. The term pHc is calculated from the equation;

$$pHc = (pk_2' + pk_c') + p(HCO_3^- + CO_3^{2-})/2 + p(Ca^{2+} + Mg^{2+}) \quad \text{------------------ (6)}$$

Where,

$(pk_2' - pk_c')$ is obtained from the sum of the concentration of $Ca^{2+} + Mg^{2+} + Na^{+}$ in meq L^{-1} as given in Table 6. pk_2' and pk_c' are the negative logarithms of the second dissociation constant of H_2CO_3 and the solubility-product constant of $CaCO_3$, respectively.

$p(Ca^{2+} + Mg^{2+})/2$ = negative log of concentration of calcium and magnesium in eq L^{-1}

$p(HCO_3^- + CO_3^{2-})$ = negative log of $HCO_3^- + CO_3^{2-}$ concentration in eq L^{-1}

Table 6: values of $pk_2' + pk_c'$ for respective salt concentration in irrigation water

Sum of salt concentration (meq L^{-1})	$pk'_2 + pk'_c$
0.05-0.49	2.0
0.50-1.50	2.1
1.51-6.0	2.2
5.10-20.0	2.3
20.10-30.0	2.4
30.10-80.0	2.5

Calculation of SAR_{adj}

Given;

Ca = 2.23 meq L^{-1}

Mg = 1.44 meq L^{-1}

Na = 7.73 meq L^{-1}

Sum = 11.79 meq L^{-1}

CO_3 = 0.42 meq L^{-1}

HCO_3 = 3.66 meq L^{-1}

Sum = 4.08 meq L^{-1}

From the above table and using the equation for pHc.

$(pk'_2 + pk'_c)$ = 2.3 (From table above)

$p(Ca^{2+} + Mg^{2+})/2$ = 2.7 (calculated)

$p(HCO_3^- + CO_3^-)$ = 2.4 (calculated)

Total = 7.4

Substituting the value of pHc, the SAR_{adj} will be;

$$SAR_{adj} = \frac{7.73\ (1+8.4-7.4)}{\sqrt{3.67/2}} = 11.3$$

With the help of values of SAR_{adj} quality of irrigation water for sodicity hazards can be evaluated using the guidelines given in Table 7.

In India, Gupta (1979) reported the following irrigation water suitability classification based on values of SAR_{adj}.

Table 7: Irrigation water and its suitability based on SAR_{adj} values

SAR_{adj}	Classification	Rating with suitability
< 10	S_1	Low: Suitable to black and alluvial soils, clay > 30% and fair to moderate drainage
10-20	S_2	Medium : Suitable to soils with clay 20-30 % and good drainage
20-30	S_3	High : suitable to soils with clay 10-20 % and good drainage
30-40	S_4	Very high : suitable to only light textured soils, clay < 10% and excellent drainage
> 40	S_5	unsuitable

However, Oster and Rhoades (1977), Oster and Schroer (1979) and Suarez (1981) carefully evaluated the adj. SAR procedure and concluded that it over predicts the sodium hazard. They suggested that, if used, the value obtained by that method should be further adjusted by a 0.5 factor to evaluate more correctly the effects of HCO_3 on calcium precipitation (adj. SAR × 0.5). Soon after irrigation, dissolution or precipitation may occur, changing the supply of calcium and establishing equilibrium at a new calcium concentration different to that in the applied water. Since the SAR_{adj} does not account for these changes a new term for this is adjusted R_{Na} ($Adj\ R_{Na}$) was suggested and calculated from the following equation (Suarez, 1981)

$$Adj\ R_{Na} = \frac{Na}{\sqrt{\frac{Ca_x + Mg}{2}}} \quad \text{-------------------------- (7)}$$

Where,

Na^+ = sodium in irrigation water, me L^{-1}

Ca_x^{2+} = a modified calcium concentration value taken form Table 6 in me L^{-1}. Ca_x^{2+} represents Ca^{2+} in the applied irrigation water but modified due to salinity of the applied water, its HCO_3^-/Ca^{2+} ratio (HCO_3^- and Ca^{2+} in me L^{-1} and the estimated partial pressure of CO_2 in the surface few millimeter of soil (pCO_2 = 0.007 atm).

Mg^{2+} = Magnesium in the irrigation water me L^{-1}

The $Adj\ R_{Na}$ obtained is used in place of the SAR or SAR_{adj} to more efficiently evaluate the potential of water to cause an infiltration problem if used for irrigation. In a study Hameed *et al* (2010) compared SAR, SAR_{adj} and $Adj\ R_{Na}$ of treated waste water and reported that SAR ranged from 1.43 to 3.19 (mean = 2.11), while SAR_{adj} and $Adj\ R_{Na}$ values ranged from 2.35 to 4.40 (mean = 3.12) and from 1.52 to 3.03 (mean = 2.03) respectively.

Residual sodium carbonate

In irrigation waters containing high concentrations of bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}) ions, there is a tendency for calcium and to a lesser extent magnesium to precipitate in the form of carbonates as the soil solution becomes more concentrated, thus leading to increase in SAR of soil solution and consequently increase in ESP of the soil. Eaton (1950) assumed that all calcium and magnesium would precipitate as carbonates and proposed the concept of "Residual Sodium Carbonates" (RSC) for evaluating high carbonate water.

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad \text{------------------------- (8)}$$

Where, the concentration of ions is expressed in meq L^{-1}.

Eaton proposed following irrigation water evaluation based on RSC values:

Table 8: Irrigation water evaluation based on RSC values

RSC value (meq L^{-1})	***Irrigation water evaluation***
< 1.25	Safe for irrigation purpose
1.25-2.5	Marginal suitability for irrigation purpose
> 2.5	Not suitable for irrigation purpose

The relative tolerance of few crops to application of high RSC is presented in table 9. It is observed that with increase in RSC levels there is a significant yield reduction irrespective of crops.

Table 9: Crop yields as affected by irrigation with alkali water in a sandy loan soil at Agra, India.

RSC (me/l)	***Crop yield (t/ha)***			
	Wheat	***Pea***	***Gram***	***Lentil***
Control	4.04	1.33	0.76	1.38
5	3.98	1.22	0.69	1.25
10	3.87	0.93	0.50	1.11
15	3.43	0.86	0.34	1.05

20	3.04	-	-	-
CD (5%)	0.20	0.34	0.22	0.15

Source : S.K. Gupta, 2010

In a recent study Hameed *et al* (2010) obtained negative RSC value in treated municipal waste water indicating no complete precipitation of calcium and magnesium.

3. Toxicity hazards

Toxicity may or may not be associated with salinity or soil permeability problems. Toxic elements that may cause concern under specific condition include boron, chlorides, sodium and other trace elements.

Boron, although an essential element, becomes toxic if present in excess even at relatively very low concentration of 0.6 mgL^{-1}. Toxicity occurs with the uptake of boron from the soil solution. The boron tends to accumulate in the leaves until it becomes toxic to the leaf tissue and results in the death of the plant. In arid regions, boron is considered the most harmful element in irrigation water. Boron is also present in irrigation water as unionized boric acid expressed as boron element (B) in mgL^{-1}. Sensitivity to boron encompasses a wide variety of field and tree crops, although fruit, nut and berry crops are particularly sensitive. On the basis of B content (mgL^{-1}) and the toxicity effect there are 5 classes of irrigation water (Bigger and Nielsen, 1972) as given in table 10.

Table 10: Classification of irrigation water based on boron (B) content

***Boron* (mgL^{-1})**	***Toxicity Hazard***
< 0.5	Safe for sensitive crop
0.5 – 1.0	Sensitive crops will show slight to moderate injury
1.0 - 2.0	Semi tolerant crops will show slight to moderate injury
2.0 -4.0	Tolerant crops will show slight to moderate injury
> 4.0	Hazardous for nearly all crops

Other trace elements

In some areas, toxic levels of selenium occur in well water. It has been reported that lithium in well water is toxic to citrus. Industrial pollution of natural water with copper, nickel, cadmium and other toxic heavy metals can also occur. These inputs to the environment are man made and can be controlled by cleaner technology and by strict guidelines (Peter *et al*., 2001). There are two important guidelines for irrigation water quality; 1. Even if toxicity levels of the element remain below accepted irrigation water quality standard, it accumulates in the soil of irrigated crop field if output is below input, 2.Excessive concentration in soil and water have adverse impacts on crop growth and development that lead to immediate hazard to the aquatic and terrestrial lives. Hence sustainability principles are required to minimize this accumulation of toxic elements in agricultural soils.

The accumulation of a given substance ($M_{accumulation}$) in irrigated land can be expressed;

$$M_{accumulation} = \sum_{i=1}^{n} \Delta M_i \quad \text{-------------} \quad (9)$$

Where,

ΔM_i = the change in concentration of the substance in the soil in a specific time interval (i), which can be explained by the simplified mass-balance equation;

$$\Delta M_i = M_{in} - M_{drain} - M_{grain} - M_{process}$$

Where,

M_{in} = the mass of the substance imported to the field through irrigation water, fertilizer, atmosphere or other sources.

M_{drain} = the mass exported from the field through surface and subsurface drainage.

M_{grain} = the mass taken up by crops and via the grain exported out of the system.

$M_{process}$ = relevant in the case of e.g. pesticides where a substance can disintegrate into other components due to temperature, sunlight exposure, bacterial activity etc., or in the case of microorganisms (e.g. helminthes and bacteria) where a die off will happen over time due to the same factors.

It is observed from the above equation that ΔMi must be equal or less than zero to avoid accumulation in the soil. It also indicates that to lower ΔM_i either a reduction in M_{in} or an increase in M_{drain} or M_{grain} has to be achieved. M_{drain} or M_{grain} can to a certain degree be controlled either by improved drainage or by specific crop selection. $M_{process}$ is on the other hand more dependent on the climate and soil conditions and therefore difficult to control. Guidelines concerning the maximum permissible levels of various trace elements in irrigation water have been reported in table 11 (FAO, 1985). Siddiqui (1995) also reported the same value for Zn, Mn, Pb, Ni, Co, and Cd to judge the suitability of irrigation water. Besides he fixed 0.2 mgL^{-1} for copper (Cu) and 0.5 mgL^{-1} for iron (Fe) as the maximum limit for irrigation.

Table 11: Recommended maximum concentration of Trace Elements in irrigation water (FAO, 1985)

Elements	***For water used continuously on all soils (mgL^{-1})***
Aluminium	5.0
Arsenic	0.1
Beryllium	0.1
Cadmium	0.01
Chromium	0.1
Cobalt	0.05
Fluorine	1.0
Iron	5.0
Lead	5.0
Lithium	2.5
Manganese	0.2
Molybdenum	0.01
Nickel	0.2
Selenium	0.02
Zinc	2.0

Table 12: FAO guidelines for evaluation of irrigation water quality

Sl No.	FAO guidelines for evaluation of irrigation water quality				
	Soil property affected	Units	Water quality guidelines		
			No problem	Increasing problem	Severe problem
1	Crop water availability	EC_{iw} (dS/m)	0.7	0.7 – 3.0	> 3.0
2	Permeability (Adj. SAR)	Montmorillonite	< 6.0	6.0 – 9.0	> 9.0
		Illite - Vermiculite	< 8.0	8.0- 16.0	> 16
		Kaolinite - Sexquioxide	< 16.0	16.0- 24.0	>24
3	Specific ion toxicity for sensitive crops	Sodium (Na) –Adj. SAR	< 3.0	3.0 – 9.0	>9.0
		Chloride (Cl) – me/L	< 4.0	4.0 – 10.0	> 10.0
		Boron (B)- mg/L	< 0.7	0.7 – 2.0	> 2.0
4	Miscellaneous effect for susceptible crops with sprinkler and drip	Nitrogen (NO_3^- or NH_4^+) – mg/L	< 5.0	5.0 – 30.0	> 30.0
		Bicarbonate(HCO_3^-) - me/L	< 1.5	1.5 – 8.5	> 8.5
5	pH (may cause imbalance in nutrient uptake)	pH	6.5 – 8.5		Very low or very high

Source: London, 1984

High concentration of heavy metals in irrigation water can result in death of crops, interfere with uptake of other essential nutrients or form objectionable deposits in fruits and render edible portion of plants toxic to human and grazing animals (*Aikman, 1983*).

In a study in Subernarekha command area, Kumar et al. (2015) reported that the Zn, Pb and Ni content were below the maximum concentration of irrigation water in well, tank, canal, borewell and river. However content of Co and Cd showed very high values. Higher content of Cu, Fe and Mn were found in well (0.123 mg L^{-1}) and tank (0.626 mgL^{-1}) and canal (0.192 mg L^{-1}), respectively.

Hydrogen Ion Activity (pH)

For assessing irrigation water quality very less attention has generally been paid to pH. The normal range for irrigation water as per *FAO (1985)* guidelines is 6.5-8.5. *Bichi and Bello (2013)* reported that the pH values in surface and ground water used for irrigation ranged from 6.71 to 8.07 and 6.20 to 6.71 respectively. Nazif *et al.* (2006) reported that the average pH of canal water and river water ranged from 8.1 to 8.3 and 8.4 to 8.9 respectively. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion (Ayers and Westcot, 1985 & Pescod, 1985).

The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate.

In a study Abdel-Ghaffar *et al.*, 1988 reported that municipality waste water contained a number of potentially toxic elements such as arsenic, chromium, copper, lead, mercury, zinc etc. Even if toxic materials were not present in concentrations likely to affect humans, they might well be at phyto-toxic levels, which would limit their agricultural use. Saraswat *et al.* 2005 suggested that continuous use of raw sewage water generally led to built up of metals and organic residues in the soils depending upon composition, rate and frequency of sewage-irrigation as well as characteristics of the soil. Sometimes built up of metals in agricultural soils may create phyto-toxicity to crops (Paul *et al.* 2006), which warrants judicious use of sewage and other waste water.

Effect of waste water use on soils

Study conducted by Raychoudhuri *et al.* (2014) on impact of waste water on surface soil showed an increase in Fe, Mn, Cr and Pb concentration by 13, 94, 72 and 71 per cent respectively. Accumulation of heavy metals due to waste water was conspicuous and the enrichment of heavy metals in the waste water irrigated soils were in the order, Fe > Zn > Mn = Cd > Cr > Cu. There is a number of different water quality guidelines associated with irrigated agriculture. Because of wide variability in crop and field condition, none is completely acceptable. The modified guideline by *Ayers and Westcot (1985)* was found to be the most reliable to predict the water quality for irrigation.

Water Quality Index (WQI)

Water quality index is a new tool for quantitative assessment of water quality in relation to a particular function. It is computed as;

$$WQI = \sum_{i=1}^{n} W_i \times q_i$$

Where;

W_i = Relative weight assigned to a particular quality parameter calculated on the basis of its relative importance as computed to other parameter.

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

Where;

w_i = the weight of each parameter and n is the number of parameters

q_i = the quality rating scale of each parameter is computed by dividing the observed value by its standard value as per the guidelines laid down in the BIS 10500, 1991 or FAO and multiplying with 100

$$q_i = \frac{c_i}{s_i} \times 100$$

The computed value of WQI is then interpreted using WQI rating classes. There are 4 rating classes of WQI for assessing ground water quality for irrigation purposes based on restrictions, viz, none, slight, moderate and severe with WQI values < 150, 151-300, 301-450 and > 450 respectively (Raychoudhury *et al*., 2014).

Special consideration for water quality guidelines as suggested by Paliwal (1972) and Ras *et al.* (1994) are as follows.

1. Use gypsum when saline waters (having SAR > 20 and Mg/Ca ratio > 3 and rich in silica) induce water stagnation during rainy season and crops grown are sensitive to it.
2. Leaving the field fallow during the rainy season is helpful when SAR > 20 and waters of higher salinity are used in low rainfall areas.
3. Additional phosphorus fertilization is beneficial, especially when Cl^{-}/SO_4^{2-} ratio in water is > 2.0
4. Canal water preferably be used at early growth stages including pre-sowing irrigation for conjunctive use with saline waters.
5. If saline water is to be used for seeding of crops, 20% extra seed rate and a quick post-sowing irrigation (within 2-3 days) will ensure better germination.
6. When $EC_{iw} < EC_e$ (0 - 45 cm soil at harvest of rabi crops), saline water irrigation just before the onset of monsoon will lower soil salinity and will raise the antecedent soil moisture for greater salt removal by rains.
7. Use of organic materials in saline environment enhances yields.
8. Accumulation of B, NO_3, Fe, Si, F, Se and heavy metals beyond critical limits proves toxic. Expert advice prior to the use of such waters may be obtained.
9. For soils having (i) shallow water table within 1.5 mm in kharif season and (ii) hard sub soil layers, the next lower EC w/alternate mode of irrigation canal/saline) is applicable.

Conclusion

The problems that result from the use of a particular irrigation water, vary both in kind and degree, and are modified by soil, climate and crop as well as by the skill and knowledge of the water user. As a result there is no set limit on water quality, rather its suitability for use is determined by the conditions of use which affects the accumulation of water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

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Bridging the Data Divide: A Review of Artificial Intelligence and Machine Learning in Advancing Soil Health and Precision Agriculture

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Abstract

The global challenges of climate change, soil degradation, and food security demand a fundamental shift in soil management practices. Traditional soil analysis methods are time-consuming, labor-intensive, and inadequate for delivering the real-time, large-scale data required in modern precision agriculture. This review examines the rapid integration of Artificial Intelligence (AI) and Machine Learning (ML) into soil science, highlighting recent advancements in monitoring, prediction, and decision support. AI applications are classified across four critical domains: Digital Soil Mapping (DSM), Soil Health Monitoring (SHM), Predictive Modeling, and Soil Conservation. These technologies leverage vast and diverse data sources to overcome long-standing limitations associated with conventional soil assessment. For example, advanced ML models achieve up to 92% accuracy in predicting Soil Organic Carbon (SOC) stocks and exhibit approximately 85% efficiency in mapping soil moisture patterns. Despite these promising developments, widespread AI adoption is hindered by challenges such as data standardization, the "black box" nature of complex models, and limited technological accessibility, particularly in resource-constrained regions. The future of AI in soil science lies in developing Explainable AI (XAI) frameworks, improving interoperable data systems, and fostering interdisciplinary collaboration to build sustainable, data-driven soil ecosystems.

Keywords: Artificial Intelligence, Machine Learning, Soil Health, Digital Soil Mapping, Precision Agriculture, Soil Organic Carbon.

1. Introduction

Soil stands as a non-renewable and fundamental natural resource, essential not only for supporting over **95%** of global food production but also for its vital role in climate change mitigation through carbon sequestration and the maintenance of overall ecosystem balance (Rahman & Das, 2025). However, the health of this resource is critically threatened. Global assessments indicate that more than **33%** of the Earth's land area is affected by moderate to severe degradation, encompassing challenges such as erosion, nutrient depletion, salinization, and contamination. This widespread degradation poses a direct threat to agricultural productivity and planetary sustainability, necessitating a fundamental shift in how soil is monitored, analyzed, and managed.

Historically, soil management has relied on conventional methods involving manual field sampling and time-consuming, costly laboratory testing. Although these techniques provide accurate point-in-time measurements, they are inherently slow, labor-intensive, and spatially limited. As a result, they fail to deliver the high-resolution, real-time insights required by modern agricultural practices particularly those aligned with Precision Agriculture (PA), which demands site-specific, sub-field level decision-making (Maraveas et al., 2022). Consequently, traditional practices often lead to inefficient resource use (e.g., fertilizers and water) and tend to be reactive rather than predictive.

The integration of Artificial Intelligence (AI) and its specialized subfields—Machine Learning (ML), Deep Learning (DL), Computer Vision (CV), and Expert Systems—has provided the technological advancement necessary to address these limitations. AI-driven approaches offer scalable, real-time, data-driven analysis capabilities that were previously unachievable (Awais et al., 2023; Babar et al., 2024). These technologies excel in interpreting large, complex, multi-source datasets, including:

- Proximal sensor/IoT networks (real-time measurements of soil temperature, moisture, and pH)
- Unmanned Aerial Vehicles (UAVs) and satellite remote sensing (high-resolution multispectral and hyperspectral imagery)
- Legacy soil databases and historical climate records (Heuvelink et al., 2021)

By integrating and analyzing these diverse data sources, AI models can identify complex, non-linear relationships between soil covariates and target soil properties, enabling highly accurate spatial predictions and predictive diagnostics.

This review synthesizes the current state of AI applications in soil science across four primary domains: Digital Soil Mapping (DSM), Soil Health Monitoring (SHM), Predictive Modeling, and Soil Conservation. It highlights key advancements, such as ML models achieving up to **92%** accuracy in predicting Soil Organic Carbon (SOC) stocks (Heuvelink et al., 2021) and **85%** efficiency in soil moisture mapping (Hyperspectral Remote Sensing and AI, 2025). Furthermore, the review critically evaluates existing barriers—including the need for data standardization, the challenge posed by the "black box" nature of complex AI models, and issues surrounding technological accessibility. These challenges underscore the importance of developing Explainable AI (XAI) frameworks and strengthening interdisciplinary collaboration to build sustainable and resilient soil ecosystems.

2. Methodology

A systematic review methodology was employed to identify, select, and synthesize relevant literature published between 2019 and 2025. Three major scientific databases—Scopus, Web of Science, and Google Scholar/related academic repositories—were searched to ensure comprehensive coverage. The search strategy used a combination of controlled vocabulary and Boolean operators with keywords such as *"Artificial Intelligence in soil science," "machine learning soil mapping," "deep learning agriculture," "soil health prediction," "soil moisture modelling,"* and *"AI-based soil diagnostics."*

Studies were included if they met the following criteria:

1. Applied AI, ML, DL, CV, or expert systems to soil-related processes.
2. Reported measurable outcomes (accuracy, efficiency, predictive performance).
3. Focused on agricultural, environmental, or soil resource management contexts.

Non-English papers, purely theoretical computer science studies without soil application, and duplicated records were excluded. The final dataset was categorized by AI technique, data source, and application domain (DSM, SHM, predictive modeling, conservation).

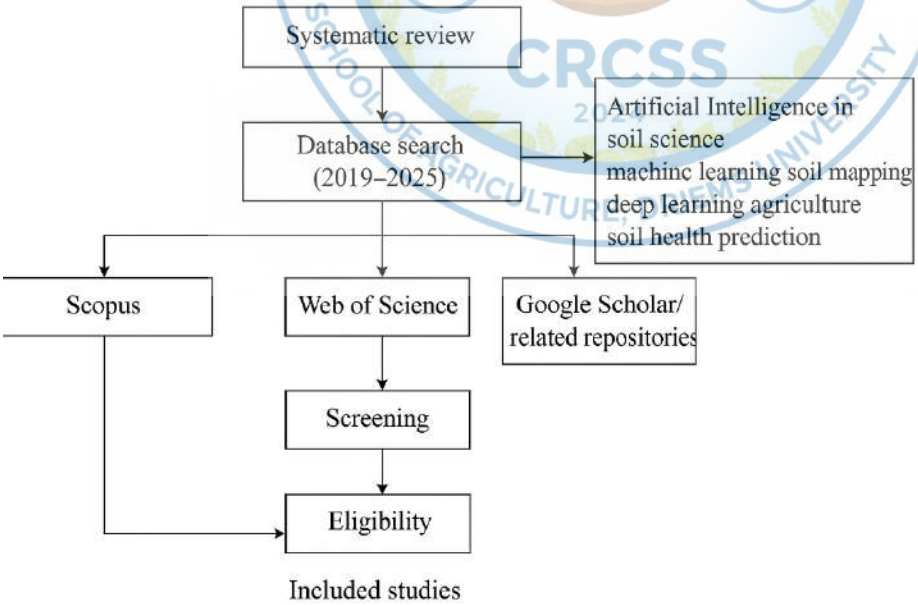

Fig.1. Methodology of data collection

2.1. Core AI Components

The review classified AI applications into four major methodological categories:

2.1a. Machine Learning (ML):

Algorithms such as Random Forests (RF), Support Vector Machines (SVM), and various Artificial Neural Networks (ANNs) were frequently used for predicting soil properties, including texture, SOC, moisture, and nutrient status (Poggio et al., 2021). ML models excel in handling nonlinear interactions among soil covariates.

2.1b. Deep Learning (DL):

Convolutional Neural Networks (CNNs) were widely applied for image-based soil texture and pore structure classification, while Long Short-Term Memory (LSTM) networks supported temporal forecasting tasks such as soil moisture, evapotranspiration, and temperature dynamics (Lavrukhin et al., 2021).

2.1c. Computer Vision (CV):

UAV- and ground-based imaging systems enabled automated detection of soil surface characteristics, erosion patterns, crusting, compaction zones, and nutrient deficiency symptoms through image segmentation and pattern recognition techniques.

2.1d. Expert Systems & Fuzzy Logic:

Rule-based systems incorporating pedological expertise and fuzzy logic were used in decision-support applications, particularly where uncertainty, imprecision, or qualitative descriptors are common (López et al., 2008).

2.2. Data Acquisition Sources

AI models in soil science rely on diverse, multi-scale data sources. This review categorized the major sources as follows:

2.2.1 Remote Sensing: Multispectral and hyperspectral satellite/UAV imagery provided spatially continuous datasets for large-area prediction of soil properties, including SOC, salinity, moisture, and texture (Gholizadeh et al., 2025).

2.2.2. Proximal Sensors / IoT Networks: In-field sensor networks measuring **soil moisture, temperature, pH, EC, and NPK levels** offered high-frequency, real-time observations essential for dynamic monitoring and predictive modelling (Ahmad et al., 2021).

2.2.3. **Legacy & Ground-Truth Data:** Soil profile databases, pedon descriptions, laboratory analyses, climate time-series, DEM-derived terrain attributes, and long-term land-use records were used to train, validate, and calibrate model predictions (Heuvelink et al., 2021).

3. Results and Discussion: Key Application Domains

3.1 Digital Soil Mapping (DSM)

AI has transformed DSM from manual mapping to automated, high-resolution spatial prediction.

3.1a. SOC Mapping: QRF and RF models achieve **2% accuracy**, combining DEM, climate layers, and spectral data (Heuvelink et al., 2021).

3.1b. Texture Prediction: CNNs and ANNs outperform conventional regression for predicting sand, silt, and clay content (Zhao et al., 2009).

3.2 Soil Health Monitoring (SHM)

AI enables continuous monitoring of dynamic soil parameters.

- Moisture and Temperature: LSTM-based forecasts support irrigation planning with 85% mapping efficiency.
- Nutrient & pH Estimation: Machine vision + colorimetric sensors automate NPK and pH diagnosis (Sindhu et al., 2018).
- Soil Contamination: ML models classify contaminant levels and health implications.

3.3 Predictive Modeling & Decision Support

- Yield Prediction: Combines soil, climate, and historic data for optimal crop recommendations (Hosseini et al., 2023).
- Variable Rate Technology (VRT): AI-based DSS improves fertilizer and irrigation efficiency by 20–25%.
- Erosion Risk: ML tools predict erosion, salinity, and degradation hotspots.

3.4 Soil Conservation and Remediation

- Management-Oriented Models: AI helps optimize nitrogen application, reduce leaching, and evaluate management scenarios (Li & Yost, 1999).
- Remediation Prediction: ML evaluates phytoremediation and bioremediation effectiveness.

4. Challenges and Future Directions

Challenge	Impact	Suggested Solution
Data Scarcity & Quality	Reduces model accuracy	Develop global, standardized open databases
Black Box Nature of ML	Limits trust in AI	Invest in Explainable AI (XAI)
Cost & Technological Access	Limits adoption by smallholders	Low-cost sensors, open-source AI tools
Integration & Scalability	Poor cross-region model transfer	Develop adaptable, region-specific models

Future Opportunities:

- NLP for digitizing legacy soil data
- Cognitive systems integrating sensing + prediction + automated action
- Fully autonomous soil management systems driven by AI

5. Conclusion

AI and ML have transformed soil science, enabling real-time, high-accuracy predictions and supporting precision agriculture. SOC prediction accuracy reaches **92%**, while soil moisture mapping achieves **85%** efficiency. The integration of AI enhances diagnostic speed, resource efficiency, and sustainability. Addressing challenges in data standardization, accessibility, and model transparency will unlock the full potential of AI-driven soil management globally.

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Knowledge and Operations Performed by Farm Women in Postharvest Management Activities

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Highlights

- Seed Collection Timing: 70% of respondents collect seeds just before sowing
- Seed Treatment Preferences: 84.2% purchase treated seeds; 36.84% use chemicals, while 26.31% prefer natural treatment methods.
- Seed Crop Storage: 58.3% store the same grain for future seeding
- Grain Storage Containers: 45% use bamboo baskets, 37.5% use gunny bags

Abstract

Postharvest management of agricultural produce was vital for food security and economic stability in rural areas, with farm women playing a key role. A study conducted in 2023 assessed the knowledge of farm women regarding postharvest grain management in Deoghar district, Jharkhand. The sample consisted of 120 farm women randomly selected from 8 villages using a lottery method. Data were collected through personal interviews. The study revealed that one-third of the women bought seeds before sowing, with 84.2% purchasing treated seeds. After harvest, 58.3% saved part of the crop for future seeds. About 65.8% of women were familiar with threshing machines, and 44.2% used them, mainly based on information from neighbors. Additionally, 60.0% used insecticides, and 27.5% applied Indigenous Technical Knowledge (ITK) for grain treatment before storage. During storage, 42.5% engaged in redrying, winnowing, and packing. Most farm women stored cereals for 1-2 seasons (72.5%), while 88.34% sold vegetables immediately. The findings indicated varied knowledge and practices, with reliance on treated seeds, neighbors' advice, and traditional methods. The study suggested that targeted training programs could help reduce food losses and improve food security by empowering farm women with better postharvest management skills.

Keyword Postharvest operation, Information, Storage, Treatment, Empowering, Training, Food security

Introduction

The postharvest management of agricultural produce is a critical aspect of farming that significantly influences both food security and economic stability in rural communities. Meeting the food requirements of a rapidly growing population emerges as a significant challenge for humanity (Kumar & Kalita, 2017). Significant postharvest losses in fruits and vegetables persist, primarily due to inadequate food processing capacity, insufficient infrastructure, and the weak financial status of most farmers. These losses intensify due to ineffective pre- and postharvest practices, along with limited access to appropriate processing and marketing systems (Etefa et al., 2023; Kumar et al., 2023). A study by (Gupta et al., 2024) indicates that farm women play an integral role in agricultural production and are often responsible for seed procurement, treatment, management, and storage. (Katumbi et al., 2021) find that although women farmers demonstrate greater awareness of postharvest hygiene compared to their male counterparts, they continue to rely on traditional handling practices due to insufficient infrastructure and lack of training opportunities. Although women predominantly manage postharvest operations, training programs tend to be directed toward men, leaving women with limited access to scientific knowledge and innovations. Their knowledge is often informal, experiential, and excluded from institutional training programs and technology transfer initiatives (Kaur et al., 2017; Ragasa et al., 2019). Methods and knowledge among farm women vary widely depending on local traditions, available resources, and their exposure to modern technologies. Understanding these practices is essential for identifying intervention points that can enhance efficiency, reduce postharvest losses, and improve overall food security. This approach not only strengthens the economic well-being of individual women but also contributes to broader community development (Das et al., 2023). Technological and logistical support enhances the shelf life of agricultural products, thereby increasing farmers' income (Kumar et al., 2022). Cultural gender norms continue to limit women's participation in agricultural training programs and hinder their ability to apply newly acquired knowledge (Mudege et al., 2016; Mudege et al., 2017). Postharvest management encompasses a range of activities performed after harvest, including the handling, processing, storage, and distribution of produce. Women's expertise, shaped by a blend of traditional knowledge and contemporary practices, directly impacts the quality, safety, and shelf life of agricultural goods, By systematically analyzing these components, this study aims to highlight the need for targeted training and support programs tailored to the specific needs of farm women, thereby contributing to the development of more effective postharvest management strategies. This research focuses on evaluating the knowledge and operational practices of farm women in postharvest management. Key aspects of the study include examining their understanding of seed procurement and treatment, the methods they use for grain storage, and the balance between traditional and modern techniques. In the Deoghar district of Jharkhand, India, farm women play a important role in managing postharvest activities, yet their knowledge and practices in this domain remain under-explored. This study seeks to fill this gap by critically evaluating the knowledge and operational practices of farm women in postharvest grain management.

Methodology

The study was conducted in the Deoghar district of Jharkhand, focusing on the Mohanpur and Madhupur blocks. These blocks were randomly selected using a simple random sampling method from a total of ten blocks. To ensure the sample was representative, two gram-panchayats were chosen from each selected block, and from each gram panchayat, two villages were randomly selected using the same sampling technique. From these villages, 15 women farmers were randomly selected as respondents, leading to a total of 120 participants in the study. Before finalizing the study variables and interview schedule, a pilot study was conducted. This helped refine the methodology and gather insights from about 20 additional respondents who were not part of the main sample. The data collection process involved both structured and semi-structured interview schedules, which were administered through face-to-face interviews. This method allowed for a flexible approach to capturing detailed information from the respondents. Once the data were collected, they went through a systematic process of coding, classification, analysis, and tabulation. To ensure the accuracy and meaningful interpretation of the data, statistical tools like frequency counts (for recording occurrences) and percentages (for showing relative proportions) were used. The study followed a descriptive research design, utilizing a survey method to collect comprehensive data, which allowed for a thorough examination and presentation of the findings. This approach enabled the researcher to draw meaningful conclusions and address the research questions effectively. Through this systematic process, the study provided valuable insights into the roles and challenges faced by women farmers in the selected areas. The use of statistical tools helped to quantify and present the data in a way that contributed to a better understanding of the issues under investigation. The findings highlighted key areas of knowledge and practices that could be further explored to improve the postharvest management skills of farm women in the region.

Results

Seed procurement and treatment practices play a vital role in crop productivity. This study explores women farmers' preferences regarding seed purchase timing, treatment methods, and procurement patterns. Understanding these aspects helps reveal the balance between traditional practices and scientific approaches in maintaining seed quality and ensuring agricultural success.

Aspects of seed treatment and procurement

The study reveals that the majority of farm women (70%) prefer to collect seeds just before sowing, indicating a practical approach that ensures seed freshness and suitability for the upcoming crop cycle. The majority of respondents (70%) preferred to buy seed before sowing the crops. This indicated that most believed the timing of this action was crucial right before planting the new crop. Some respondents (22.5%) favored different timing options, choosing to buy seeds immediately after the previous crop's harvest. This suggested that some respondents valued the importance of purchasing seeds as soon as the previous crop was harvested. The choice of timing was likely influenced by factors such as crop type, local agricultural practices, and individual preferences or circumstances. Regarding seed treatment, 36.84% used chemical methods, such as coating seeds with pesticides or fungicides to protect them from pests and diseases. Another

36.84% used untreated seeds, meaning they did not apply any treatment to the seeds before planting. A smaller percentage (26.31%) opted for natural methods of seed treatment, preferring to use non-synthetic substances or techniques such as bio-control agents or organic compounds to protect their seeds. These preferences reflected a mix of traditional, organic, and chemical approaches to managing seed quality and protection, influenced by individual practices and available resources.

Table 1: Distribution of respondents according to different aspects of seeds procurement and treatment

(n = 120)

Aspects	Percentage
Time for collection of seed	
Immediately after harvest of the previous crop	22.50
Just before sowing of the crop	70.00
Whenever it is available	07.50
Type of seed purchased	
Treated	84.20
Untreated	15.80
Types of treatment of untreated seeds	
Use chemical method for seed treatment	36.84
Use natural methods for seed treatment	26.31
Whether you use untreated seed	36.84
Treatment procedure of grown seed crops	
Crop kept for seed purpose is treated as special	25.80
It is the same grain crop, after harvesting some portion is kept separately for seed	58.30
Some plants are selected and seeds collected from them	06.70
Any other	09.20

Knowledge about a threshing machine

The majority of respondents (65.8%) were familiar with threshing machines, while a significant proportion (34.2%) were not familiar with this agricultural machinery used for separating grains from harvested crops. The most common source of information about threshing machines was interactions with neighbors, as 59.49% of respondents learned about them from their neighbors. This suggested that most respondents acquired knowledge from peer groups or local residents who were using or familiar with threshing machines. A smaller proportion (16.45%) obtained their knowledge about threshing machines from Krishi Vigyan Kendra (KVK), while 8.86% learned from a company. This indicated that a small number of respondents gained their knowledge from agricultural companies or manufacturers. Additionally, 11.39% of respondents acquired knowledge from an NGO. Regarding the use of threshing machines, the majority of respondents (55.8%) indicated that they did not have knowledge about how to operate them. On the other hand, 44.2% of respondents reported that they possessed the knowledge and skills to operate this agricultural machinery. This reflected a significant gap in the practical knowledge required to efficiently use threshing machines for separating grains, suggesting the need for more widespread training or access to resources to improve the use of such equipment.

Table 2: Distribution of respondents according to different aspects of threshing machine

(n = 120)

Aspects	**Percentage**
Knowledge about a threshing machine (Response)	
Yes	65.80
No	34.20
Source of knowledge about threshing machine	
KVK	16.45
NGO	11.39
Company	08.86
Neighbor	59.49
Others	03.79
Threshing machine used by farm women (Response)	
Yes	44.20

No	55.80

Operations performed and containers used for storage by farm women

The majority of respondents (60.0%) used insecticides as a pre-storage treatment method for grains. Insecticides are chemicals that help control or prevent insect infestations in stored grains, preserving their quality and preventing damage. Approximately one fourth (27.5%) of respondents relied on traditional or locally developed knowledge and practices for pre-storage treatment. Indigenous technical knowledge often involved traditional methods of grain preservation and protection from pests. Around 10.0% of respondents used fungicides as a pre-storage treatment method. Fungicides are chemicals used to control or prevent fungal growth on grains, helping to protect their quality during storage. A significant number of respondents (42.5%) performed "redrying, winnowing, and packing" operations on the stored seed. These operations included drying the grains if moisture levels increased, separating unwanted materials through winnowing, and repacking the grains to maintain their quality during storage. About 25.8% of respondents carried out "hydration and dehydration" operations on stored grain, indicating that they adjusted the moisture content of the stored grains by adding or removing moisture to preserve their quality. On the other hand, 17.5% of respondents did not perform any specific operations during grain storage, suggesting that they simply stored the grains without undertaking additional measures. Around 14.2% mentioned using pest control measures during storage. The choice of post-harvest operations appeared to be influenced by factors such as the type of grain, local practices, and individual preferences for preserving the quality of the grains. Regarding storage containers, 45.0% of respondents used "bamboo baskets" for grain storage. Bamboo baskets were popular due to their durability, ventilation properties, and easy availability in the village. Gunny bags were used by 37.5% of respondents, as they are commonly used for bulk storage of grains and other agricultural products. About 5.0% of respondents used cloth bags for smaller quantities of grains or seeds, while another 5.0% used earthen structures, such as clay containers, for grain storage. A smaller portion (2.5%) of respondents used metal bins for storage, likely due to their durability and ability to protect grains from pests and moisture. These findings indicated varied approaches to grain storage, with respondents using a combination of chemical, traditional, and practical methods to preserve their grains and maintain their quality. The choice of storage container and treatment methods were influenced by factors like availability, local knowledge, and the specific needs of the grains being stored.

Table 3: Distribution of respondents according to different aspects of storage of grains

(n = 120)

Aspects	**Percentage**
Methods of pre-storage treatment	
Indigenous Technical Knowledge	27.50

Fungicides	10.00
Inert material	02.50
Insecticides	60.00
Operation during storage	
Do not perform any operation	17.50
Hydration and dehydration of the stored grain	25.80
Redrying, winnowing and packing of the stored seed	42.50
Pest control measures	14.20
Containers used for storage of grains	
Bamboo basket	45.00
Cloth bag	05.00
Earthen structure	05.00
Gunny bag	37.50
Metal bin	02.50
Any special structure	05.00

Practices followed by farm women before storage of the grains

The majority of respondents (46.7%) prioritized storage spaces that were dry, cool, and well-ventilated to maintain the quality and prevent spoilage of stored grains. Factors like compactness were also important, as 20.8% of respondents preferred a "compact room" for storing grains. This indicated a preference for small, tightly sealed storage areas, which helped protect grains from pests and moisture. Additionally, some respondents considered the avoidance of damp places to ensure successful grain storage. Around 9.2% of respondents specifically sought "dry and cool" storage locations, indicating a preference for areas that were both dry and had a cool temperature to protect their grains from deterioration. These findings highlighted the importance of proper storage conditions in maintaining grain quality and minimizing the risk of spoilage.

Table 4: Respondents' distribution according to the checklist followed by farm women before storage (n = 120)

Checklist followed by farm women before storage	Percentage
Damp place	23.30
Dry and cool	09.20
Dry, cool and ventilated	46.70
Compact room	20.80

Duration of storage of crops practiced by farm women

The table provided showed the storage duration preferences for pulses, vegetables, and cereals. For pulses, the majority of respondents (58.3%) stored them for long durations, typically one or two seasons, while 20.8% stored them moderately. A smaller proportion (15.0%) stored pulses for a short time, and 3.3% used other methods. Only 2.5% of respondents sold pulses immediately. For vegetables, a significant majority (88.34%) preferred to sell them immediately due to their perishable nature. A smaller percentage (11.67%) stored vegetables moderately, and no respondents chose to store vegetables for a short time or for long periods. In the case of cereals, 72.5% of respondents stored them for long durations, one or two seasons, while 7.5% stored them moderately, and 15.8% stored them for a short time. Only 3.3% sold cereals immediately. These storage preferences highlighted the differences in how different types of crops were managed based on their perishability and market demand.

Table 5: Distribution of respondents according to the duration of storage

(n = 120)

Storage duration	Pulses	Vegetable	Cereals
	Percentage	Percentage	Percentage
Sell immediately	02.5	88.34	03.3
Store moderately	20.8	11.67	07.5
Store short time	15.0	00.00	15.8
Stores long/one season/two seasons	58.3	00.00	72.5
Any other	03.3	00.00	00.0

Discussion

The study reveals that the majority of farm women (70%) prefer to collect seeds just before sowing, my findings allenes with Erickson & Halford (2020) that majority of farmers collect seeds just before sowing, indicating a practical approach that ensures seed freshness and suitability for the upcoming crop cycle. Treatment procedure of grown seed crops concludes the majority, comprising (58.3%), follow the practice of keeping the same grain for seed purposes. This approach indicates that most respondents use a portion of their regular crop for seed purposes while keeping it separate after harvest of the crop. (6.7%) choose specific plants for seed collection. They prefer a selective approach to seed collection, possibly choosing plants with desirable traits for seed production. The choice of pre-storage treatment method may depend on factors such as the type of grains, local practices, and individual preferences for grain preservation and pest control. Through the present study found that (10%) of respondents use fungicides my findings oppose the findings of Kaur et al. (2017), they concluded that (86.67%) respondents used fungicides for storage. The operation performed during storage of grains my findings opposes the findings of Mwangi et al (2017), majority uses pest control measure to control whereas in my finding's women perform Redrying, winnowing and packing of the stored seed this shows that they perform traditional knowledge to control. Majority of the respondents plan to store cereal crops for an extended duration, often spanning one or two seasons or more, before using or selling them. The choice of storage duration may depend on various factors, including market conditions, perishability of the vegetables, type of cereal crops, transportation facility available, crop type, individual farming objectives, their needs etc. Pulse crops are used to be stored for long duration often spanning one or two seasons or more, before using or selling them and sell the produce as and when they require money. The majority of respondents prefer not to store vegetables for an extended period as it is perishable in nature

Conclusion

This study examines seed procurement, treatment, and storage practices among farm women in the Deoghar district. Key findings reveal a strong preference for purchasing seeds just before sowing, with most women choosing treated seeds. Despite this, many still use untreated seeds and apply a mix of chemical and natural treatments. For seed storage, most women use insecticides and traditional methods, favoring bamboo baskets and gunny bags. The use of threshing machines varies, with local knowledge playing a significant role. Farm women typically store cereals and pulses for extended periods, while vegetables are sold immediately. These insights highlight the impact of local practices and individual preferences on agricultural methods. The findings offer valuable information for improving seed management and storage practices. Support for seed treatment and storage education is essential, modern technologies should be encouraged, and resources should be provided to integrate effective practices while respecting local traditions.

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