ENHANCING GRAIN YIELD AND QUALITY THROUGH SOIL AMELIORATION AND FOLIAR NUTRITION IN RICE (*Oryza sativa* L.) IN VAIKOM KARI SOILS

by

SREELEKSHMI S

(2019-11-261)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"ENHANCING GRAIN YIELD AND QUALITY THROUGH SOIL AMELIORATION AND FOLIAR NUTRITION IN RICE (*Oryza sativa* L.) IN VAIKOM KARI SOILS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Enhancing grain yield and quality through soil amelioration and foliar nutrition in rice (*Oryza sativa* L.) in Vaikom kari soils"** is a record of research work done independently by Ms. Sreelekshmi S (2019-11-261) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Sreelekshmi S

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LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Per cent
@	-	at the rate of
B	-	Boron
^{o}C	-	Degree Celsius
BCR	-	Benefit / cost ratio
Ca	-	Calcium
CD	-	Critical difference
CEC	-	Cation exchange capacity
cm	-	Centimeter
cm^2	-	Centimeter square
Cu	-	Copper
$CuSO_4$	-	Copper sulphate
DAS	-	Days after sowing
dSm^{-1}	-	deci Siemens per meter
^{o}E	-	East
EC	-	Electrical conductivity
et al	-	And others
Fe	-	Iron
$FeSO_4$	-	Iron sulphate
Fig.	-	Figure
g	-	Gram
ha^{-1}	-	Per hectare
K	-	Potassium
K_2O	-	Potassium oxide
K_2SiO_3	-	Potassium silicate
KAU	-	Kerala Agricultural University
Kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
KNO_3	-	Potassium nitrate
L	-	Litre
m	-	Meter

Mg	-	Magnesium
mg g^{-1}	-	Milli gram per gram
mg kg^{-1}	-	milligram per kilogram
ml	-	Milli litre
mm	-	Milli meter
mmol g^{-1}	-	Milli moles per gram
Mn	-	Manganese
$MnSO_4$	-	Manganese sulphate
Mo	-	Molybdenum
MOP	-	Muriate of potash
MRP	-	Maximum retail price
MSP	-	Minimum support price
MT/ha	-	Metric tonnes per hectare
N	-	Nitrogen
NS	-	Not significant
OC	-	Organic carbon
P	-	Phosphorus
P_2O_5	-	Phosphorus pentoxide
pH	-	Soil reaction
PI	-	Panicle initiation
ppm	-	parts per million
RARS	-	Regional Agricultural Research Station
RDF	-	Recommended dose of fertilizers
Rs. ha^{-1}	-	Rupees per hectare
S	-	Sulphur
SE	-	Standard error
t ha^{-1}	-	Tonnes per hectare
viz.	-	namely
Zn	-	Zinc
$ZnSO_4$	-	Zinc sulphate

Dedicated to

Achan and Amma

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the major food crop grown all over the world. It can be grown on a variety of soils including silts, loams and gravels and can tolerate acidic as well as alkaline soils. It is the third largest produced crop in the world with an output of about 116.42 million tonnes. India is the second largest producer of rice with a production of 122.27 million tonnes from an area of 44 million ha (GOI, 2021). Rice is the most important food crop grown and consumed in Kerala. It occupies about 7.46 percent of the total cropped area of the state, and covers an area of 2.01 lakh ha with 6.26 lakh tones of annual production (GOK, 2021).

Kuttanad, known as “Granary” or “Rice Bowl” of Kerala, is a unique agricultural tract lying 0.6 to 2.2 m below MSL distributed in and around Vembanad Lake in Alappuzha, Kottayam and Pathanamthitta districts. Low lying areas of Kuttanad soils are highly acidic and saline in nature with high level of toxic salts. Several parts of this delta have subsoil layers containing pyrites which on oxidation produce severe acidity. Share of Kuttanad region to the state’s rice area is 15% and production is 18 % respectively. Rice cultivation in Kuttanad faces severe problems associated with waterlogging, severe acidity and iron and aluminium toxicities (Thampatti and Jose, 2000).

Based on geomorphology, soils, and salinity intrusion, the Kuttanad region is divided into six agronomic zones: Upper Kuttanad, Lower Kuttanad, North Kuttanad, Kayal lands, Vaikkom Kari, and Purakkad Kari. Based on acidity, salinity, texture and electro-chemical qualities, the soil type in Kuttanad is further divided into three distinct zones: Kayal lands (upland rice fields, 13000 ha.), Karappadams (wetland rice fields, 33000 ha.) and Kari lands (land buried with black coal like materials, 9000 ha).Paddy is Kuttanad's principal crop, and the traditional paddy crop season here is known as *puncha* (November - March).

Kari lands cover around 6075 hectares and are characterised by deep black soils. *'Kari'* literally means 'charcoal,' and these soils are unusually dark in colour and high in organic carbon, with deep buried, partly burned out large chunks of old timber species, most likely from the Pleistocene period.The *Kari* soils are found in the taluks,Vaikom and Kottayam in the Kottayam district (Vaikom *kari*), as well as Cherthala (Cherthala *Kari*) and Ambalapuzha (Purakad *Kari*) in the Alappuzha district. Vaikom *Kari* faces more severe yield constraints than Purakad *Kari*. They are acid sulphate soils that are black, peaty and heavy textured. Excessive acidity and nutrient disequilibrium throughout the year, as well as high salinity, particularly during periods of low rainfall, are important limiting factors for rice cultivation in these soils. In addition to lower pH, soil is also low in macronutrients such as N, P, K, Ca and Mg and high in S, Fe, Mn, Al and Na .Crop productivity in these soils are found to be low due to imbalance of nutrients in the soil and there is a scope to improve the productivity of these soils by different management practices. They are strongly to extremely acidic in nature which can be ameliorated by the application of liming materials.

Iron toxicity is a prevalent nutrient disorder of lowland rice grown on acid sulphate soils with a low cation exchange capacity (CEC), high acidity, and active Fe and low to moderately high in organic matter. Higher Fe^{2+} concentrations in the rhizosphere have antagonistic effects on the uptake of various essential nutrients, resulting in reduced yields. Rice production can be increased in acid sulphate soils by proper management practices.

Soil acidification is mostly restrained by application of lime in agricultural soils. Burnt lime (calcium oxide) produced from lime shell is commonly used for the liming purpose, but however, has the constraints of poor availability and high cost. Dolomite [$CaMg(CO_3)_2$] is a cheap and effective substitute for lime for improving acidic soils as it contains both calcium (Ca^{2+}) and magnesium (Mg^{2+}) which are generally deficient in the acid soils of Kerala . Dolomite dissolution releases calcium (Ca^{2+}) and magnesium (Mg^{2+}) into the soil solution, which increase base saturation by forming $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ respectively. Aluminium ($A1^{3+}$) ions are replaced by Ca and Mg ions and neutralised by OH ions at the same time. As a result, dolomite application raises the pH of acidic soils (Paradelo *et al*., 2015). Hence, the study includes two types of dolomite as treatments one which is ordinary industrial waste (17.16% Ca and 10.15% Mg) and other a granulated dolomite (23% Ca and 13% Mg) developed as a start up in collaboration with INVENT Social Incubation Program of IIT Kanpur.

The low pH combined with low aeration reduces the soil microbial activity affecting the availability of nutrients. The shallow water table with poor drainage enhances the problem of Fe and Al toxicity damaging the roots and hampering the nutrient uptake by plants. This necessitates foliar nutrition at critical growth stages especially at the panicle initiation stage. Recently, poor grain filling and grain discolouration were found to be associated with reduction in grain quality upsetting the smooth procurement of paddy. Low pH and high Fe toxicity causes deficiency of K which is essential for grain filling and K application through foliar spray may be beneficial to rice crop in this soil. Hence it is necessary to evaluate different sources of potassium fertilizers *viz*., potassium nitrate and potassium silicate as foliar spray on the growth, yield and agronomic efficiency of rice. Micronutrient deficiencies of B due to low pH, Cu due to the chelation by high organic carbon content and Zn due to Fe toxicity have also been found frequently in these soils.

Soil amelioration practices along with foliar nutrition of potassium fertilizers *viz.* potassium nitrate, potassium silicate and micronutrients are likely to enhance the grain yield, quality and productivity of rice in acid sulphate soils by correcting soil reaction and different nutrient deficiencies. Hence the present study on enhancing grain yield and quality through soil amelioration and foliar nutrition in rice in Vaikom *Kari* soils has been proposed with the following objectives.

- To augment the grain yield and quality of rice crops in Vaikom *Kari* soils through standardization of different soil amelioration practices.
- To manage soil acidity and standardization of foliar spray of K and different micronutrients for supplementing nutrients at PI stage.

Review of literature

2. REVIEW OF LITERATURE

The present investigation entitled "Enhancing grain yield and quality through soil amelioration practices and foliar nutrition in rice (*Oryza sativa* L.) in Vaikom *Kari* soils" was undertaken with an objective of augmenting the yield and quality of rice in Vaikom *Kari* soils through soil amelioration practices for managing soil acidity, and to supplement nutrition at panicle initiation stage through foliar application of K and micronutrients. Hence relevant literature of acid sulphate soils, effect of soil ameliorants on rice in acid soils and foliar nutrition of potassium and micronutrient fertilizers on rice are reviewed in this chapter.

2.1 ACID SULPHATE SOILS

The term "acid sulphate soils" was coined by Chenery (1954). He claims that drained soils have absorbed sulphate and a pale yellow colour Jarosite, as well as a pH less than 4.0 in water. When soils are drained or exposed to air owing to a dip in the water table, sulphides react with oxygen to produce sulphuric acid. Sulphide-bearing soils that have not been drained can also be found in situations where reclamation has been attempted.

Acid sulphate soils are problem soils suitable for various crops under controlled water logging that helps to keep reduced sulphide horizon by preventing pyrite oxidation (Dent, 1986). Acid sulphate soils are of three types *viz*. actual, potential and post active acid sulphate soils. Soils containing sulphuric acid formed by the oxidation of pyrites are termed as actual acid sulphate soils. Poorly drained soils which are rich in pyrite with the potential to produce sulphuric acid under drained and oxidised condition are known as potential acid sulphate soils. Soils in which acid have been leached away or neutralised so that microbiological activation and root development are no longer inhibited are known as post active acid sulphate soils (Breemen and Pons,1978).

Acid sulphate soils forms naturally under anaerobic conditions. These soils either contain sulphuric acid or have the capacity to produce it in sufficient amounts which significantly affect other soil parameters (Dent and Pons, 1995).

According to Yoshida (1981) and Sahrawat (2005), high S content can trigger the development of sulphides and organic acids in submerged rice soils, which can cause toxicity to rice plants. Acid sulphate soils are typically unsuitable for agricultural production unless they have been thoroughly ameliorated and their fertility has been increased Shamshuddin (2014).

Bian *et al*. (2013) reported that acid sulphate soils are deficient in nutrients, particularly P, which results in poor plant development, and their pH is low (3.5), containing hazardous levels of Fe and Al, both of which are harmful to rice crops.

Keene *et al*. (2004) pointed out that K deficiency in acid sulphate soils is linked with the formation of jarosite, a sulphide mineral oxidation product that functions as an endless sink for K in the upper sulphuric horizon, lowering available K for plant growth and Ca deficiency is a limiting factor for rice production in acid sulphate soils (Moore and Patrick, 1989).

Marschner (1991) reported that Al inhibits root growth in acid sulphate soils either by inhibiting cell division, cell elongation, or by both. Acid sulphate soils have in high quantities of Fe and Al and due to its excess levels they are toxic to plants including rice. (Panhwar *et al*., 2016).

Acid sulphate soils, which are abundant in Southeast Asia and virtually solely on its coastal plains, are one of the areas that can be used for rice production. (Anda *et al*., 2009). Langenhoff (1986) reported that acid sulphate soils covers an area of 0.4 million hectares in India along both the west and east coastal lines.

2.1.1 Acid sulphate soils of Kuttanad

The acid sulphate soils span an area of 14227.51 ha in Kerala's Kuttand region with total of 54000 ha wetlands. The acid sulphate soil series of Kuttanad includes Kallara, Ambalappuzha, Purakkad, Thakazhi, Thottappally, and Thuravur (Beena, 2005). Kallara series occupied largest area among different soil series.

Kari soils are the most problematic area in Kuttanad region for rice cultivation. The characterization of acidity in key wetlands of Kerala by Usha and Vargheese (2006) revealed the highest exchange acidity in *Kari* soils (16.4 cmols). Beena and Thampatti

(2013), reported that the Kuttanad soils are extremely acidic in nature showing a range of pH from 2.5 to 5.2 and compared to exchangeable acidity, potential acidity being very high in *Kari* soils ranging from 13.32 to 112.1 cmol kg^{-1}. Beena (2013) conducted an incubation experiment to confirm acid sulphate nature of Kuttanad soils that revealed potential acid sulphate condition of soil that increased with reduction in soil pH.

2.1.2 Physico-chemical characteristics of Kari soils

The lower pH of *Kari* soils is due to the acid sulphate nature and the presence of undecomposed organic matter in soil. These soils are dark brown to black in colour, rich in organic carbon, sandy to clayey in texture, with random deposits of lime shells and humus. (Chattopadhyay and Sidharthan, 1985) reported that *Kari* soils are highly acidic in nature despite of large deposit of lime shells in the soil. *Kari* soils are affected by severe acidity and periodic saline water inundation with constant accumulation of salts (Neenu *et al*., 2020).

Marykutty and Aiyer, (1987) reported that *Kallara* in Kerala has highly acidic *Kari* soils with a pH as low as 2.6. Kannan *et al*. (2014) reported that the OC content percentage in Kuttanad soils ranges from 2.79 to 7.70 %. Despite the high OC content of *Kari* soils, available N is deficient in the soil due to low microbial activity (Koruth *et al*., 2013). Devi (2017) reported that phosphorus levels in *Kari* soils are typically low due to the fixation of P by hydroxides of Fe and Al.

Kari soils was found to be deficient in available K (Nair and Money, 1972; Money and Sukumaran, 1973). Koruth *et al*., 2013 reported that, S is adequate in 96 per cent of Kuttanad soils, with the most of these soils having a high S content. Total S is more in *Kari* soils than the other two types, *Kayal* and *Karappadam* of Kuttanad soils. The deficiency of B in *Kari* soils was reported by Sasidharan and Ambikadevi (2013).

2.1.3 Iron toxicity and nutrient status in acid soils

Fe toxicity occurs in soils formed from acidic parent material like acid igneous rocks in Kerala soil which are high in Fe and Al sesquioxides (Ponnamperuma, 1972). Becker and Asch (2005) reported that low land rice production is mainly affected by Fe toxicity as the toxicity of Fe occurs only in flooded soils. Fe and Al toxicity is a widespread problem in acid sulphate soils of Kuttanad, resulting in 50 to 70% yield reduction in rice (Thampatti *et al*., 2005).

Lowland rice yields are said to be affected by Fe concentrations in the soil solution ranging from 10 to >2000 mg L^{-1}. Poor soil nutrient status is frequently linked to iron-induced yield decrease (Benckiser *et al*., 1984). Rice yields are extremely low on highly acidic soils due to the inhibitory effects of specific elements. A high nutrient concentration in the leaves, whether in the soil or in the plant, is not an indicator of high yield (Bridgit, 1999). According to John *et al*. (2001), toxicities of Fe, Al and Mn hinder crop productivity in laterites, and these nutrient imbalances must be corrected in order to continue sustained crop production. Bridgit and Potty (1992) found that high Fe levels in the leaf resulted in reduced chlorophyll 'a' content, which contributed to low yield. Higher Fe concentrations in the rhizosphere have an antagonistic effect on the uptake of essential nutrients, resulting in lower rice yields (Fageria *et al*., 2008). Basic cation deficiency and excessive saturation of soil CEC with H^+ and Al_3^+ ions are problems that limit agricultural yields in these heavily weathered soils. (Ryan *et al*., 2011; Nair *et al*., 2013).

Fageria and Rabelo (1987), reported that reduction in shoot dry weight is one of the most sensitive growth character in rice plants to Fe toxicity. Majumder *et al.* (1995) observed stunted growth, highly reduced tillering, an extended vegetative period, increased spikelet sterility, and lower grain yield in rice due to toxicity of Fe. Olaleye (2001) reported that increasing Fe levels reduced dry matter yields, tiller numbers per pot, and plant height considerably. Bridgit and Potty (2002) reported that iron toxicity in wetland rice is a yield limiting element which results in reduced long roots, less number of tillers and low dry matter resulting in low rice yield. Toxicity of iron reduces lowland rice yield by 12 to100 per cent based on genotype, intensity of Fe toxicity and nutrient status of the soil (Sahrawat, 2010).

Ottow *et al*. (1993) reported that Fe toxicity is a complex nutritional disorder in which high concentrations of Fe in the soil diminishes the availability of P, K and Zn to plants, resulting in deficiencies, and increases the availability of S resulting in H_2S toxicity. Fe^{2+} toxicity is a major constraint to long-term rice production, and it is the most prevalent micronutrient problem in wetland rice, along with Zn deficiency (Savithri *et al*., 1999; Dobermann and Fairhurst, 2000). Low soil pH and associated concerns such as Fe toxicity and inadequate availability of other nutrients are the important yield limiting factors related to rice soils of Kerala (Moossa *et al*., 2012). Deficiencies of P and K occur in acid soils affected by Fe toxicity than in soils without Fe toxicity (Wissuwa *et al.,* 2005; Suriyagoda *et al*., 2014).

Due to low pH and the prevalence of active forms of Fe and Al in acid soils, P becomes immobilised and unavailable to plants. Extreme soil acidity causes Fe and Al sesquioxides to fix P (Audebert and Sahrawat, 2000; Dixit, 2006). Soils with low pH (less than 5.5) are problematic due to severe deficiencies of phosphorus, calcium, magnesium and molybdenum and due to high toxicities of Fe and Al (Panda and Chamuah, 2002).

Soil acidity causes a decrease in basic cations like Ca and Mg, resulting in a shortage in these essential nutrients for plant growth. The majority of Ca in acid soils is soluble, but both soluble and exchangeable Ca decreases as soil pH drops. Furthermore, high concentrations of Al limit Ca bioavailability at low pH. (Haynes and Ludecke, 1981). Iron toxicity, along with Zn deficiency is the most common micronutrient disorder in wetland rice, and is one of the most serious constraints to rice production on acid soils. (Neue *et al*., 1998). Manganese, Zn and K deficiency increases with increasing availability of Fe (Fageria 1988; Jugsujinda and Patrick 1993), and the Fe uptake decreases with the application of potassium (Sahrawat *et al*., 1996).

With the use of balanced fertilizers, the nutrient stress related with iron toxicity in wetland rice can be reduced (Patra and Mohanty, 1994). Ramirez *et al.* (2002) reported that the application of fertilizers such as N, P, K, S and Zn mitigated the negative effects of iron toxicity. Fageria *et al*. (1995) reported the release of P ions from Fe and Al oxides increased soil P when pH climbed from 5.0 to 6.5. Increased pH with liming improves CEC in soils with pH dependent charges, and boost the ability to retain potassium (Ernani *et al*., 2012).

2 .2 EFFECT OF SOIL AMELIORANTS ON RICE IN ACID SOILS

Amelioration of acid soils can be done by chemical neutralization methods like application of lime, dolomite, calcite, magnesite etc. Liming is the most common agronomic procedure used to remediate acid sulphate soils for crop cultivation around the world. Suswanto *et al*. (2007) and Shazana *et al.* (2013) reported that the soil fertility restriction of acid sulphate soils can be substantially enhanced by using amendments such as dolomite limestone, basalt, and organic materials.

2.2.1 Effect of Lime

2.2.1.1 Effect on Soil Chemical Properties

Liming is the most common method used to neutralize the soil acidity and improves production capacity, increases the availability of nutrients, and reduce toxic element levels in the soil (Caires *et al*., 2001). Application of lime is the prevalent management practice which helps to increase the soil pH and to reduce the Al toxicity in acid sulphate soils (Lestari *et al*., 2016).

Improving the fertility of acid soils by the application of various liming materials is common practice to increase the crops productivity (Rengel, 2003). Pankova *et al*. (2009) suggested that liming on acid soils lowers the activity of Al and increases the P availability and also enhance the rate of N mineralization from organic materials. In acid soils, lime application can improve soil biological processes and, release of organically derived CO_2 through decomposition of organic matter. (Biasi *et al.*, 2008; Tamir *et al.*, 2011). Solubility of Fe, Al and other metals in the soil can be reduced by increasing the soil pH by liming (Haby, 2002) and increases the availability of nutrients *viz*., P, Ca, Mg and Mo effectiveness of fertilizers (Halim *et al.*, 2014). The yield benefits of liming can be ascribed to the increase in soil pH along with the associated improvement in nutrient availability, reduced Fe availability and many other attributes of soil fertility (Kumar *et al*., 2012).

Liming and lowering soil acidity are well known for increasing P availability, however, high lime application can also cause P fixation. (Rahman *et al.*, 2002). Shamshuddin *et al*. (2004) suggested that application of lime at a high rate of more than

4 t ha^{-1} under acid sulphate soils will help to maintain the critical pH value for rice (5.5-6.0). Rastija *et al*. (2014) found that liming improved the available P content in the acid soil. Significantly lower P concentrations was reported by Rose *et al*. (2016) and Vandamme *et al*. (2016) in grains of crops suffering from P deficiency because P level in rice grain reflects the soil P status.

The beneficial functions of lime for crop growth can also be linked to better Ca nutrition, soil structure improvement, and pH neutralisation, all of which lead to an increase in P availability (Curtin and Syers 2001). As liming raises the Ca concentration in the soil solution, cation adsorption, such as K, can be influenced (Bolan, 2003). Merino *et al*. (2010) found that Ca plays a critical role in reducing pH and Al toxicity, as well as in enhancing physiological and biochemical processes in plants through aluminium- calcium interactions. The Ca ions present in liming materials is readily adsorbed to soil particles and organic matter and the carbonates in turn react with H^+ ions in solution that lead to increase in soil pH (Buni, 2015). Lime raises soil pH and precipitates active Al and Fe as insoluble hydroxy-Al and hydroxy-Fe, respectively (Haling *et al*., 2010). Hence it is commonly utilised as a standard amendment to ameliorate acid sulphate soils for agricultural production (Shazana *et al.,* 2013).

Patil and Ananthanarayana, (1989) reported that increase in exchangeable Ca was directly proportional to the increase in lime level. Liming increased the base saturation and reduced Al saturation and thus increases the Mg concentration in soil solution. Application of lime increased Mg adequately. Liming of acidic red and lateritic soil not only alleviates soil acidity-related issues, but also increases Ca availability and uptake (Samui and Mandal, 2003). Lime is a source of Ca and Mg that also reduces the amount of acetate extractable Fe in soils. (Seng *et al*., 2006). Shetty *et al.* (2012) and Azman *et al*. (2014) also reported that the application of lime decreases Fe and Al concentration and will increase the Ca and Mg content in the soil. Sulphur concentration in rice crop after 60 days of growth as well as in grain and straw after harvest were significantly reduced by liming (Karan *et al*., 2014).

2.2.1.2 Effect on growth, yield and quality of rice

Soil amelioration with lime significantly increased the rice yield components such as number of panicles, grains per panicle and thousand grain weight (Chang and Sung, 2004). Devi (2017) found that liming materials considerably improved grain yield and yield attributes such as panicle number and reduced sterility percentage over control. Suswanto *et al*. (2007) reported that rice production on acid sulphate soils can be improved by the application of lime along with judicious application of fertilizers. Rattanapichai *et al*. (2013) also reported that combined application of lime along with chemical fertilizers can increase rice productivity. Liming along with recommended dose of chemical fertilizers enhanced yields by 37% in paddy (Attanandana and Vacharotayan, 1986) and 49 per cent in crops (Sharma and Sarkar, 2005).

2.2.2 Dolomite

2.2.2.1 Effect on soil chemical properties

In rice soils, dolomite with 56% of CaO and 40% of MgO was used to improve pH and available P. (Rahman *et al.*, 2002). The results of an incubation experiment by Rosilawati *et al.* (2014) found that on acid sulphate soil the application of dolomite increased the soil pH by increasing the doses applied. Similar results were also obtained by Wijanarko and Taufiq (2016).

Rastija *et al*. (2014) pointed out that liming with dolomite had a significant impact on soil chemical characteristics and it also raised the pH levels. Reducing the acidity of soil resulted in the enhancement of available P in the soil. Dolomite application at high rates raised the P availability by 8% in the soils with high P content and 45% in the soils with poor available P. Mowidu *et al*. (2017) reported that dolomite application can increase the soil pH and thus release phosphates from Al and Fe ions. Dolomite application in both field and pot experiment decreased the soil Fe concentration by increasing soil pH and P availability (Suriyagoda *et al*., 2017).

Application of dolomite significantly increased the Ca and Mg contents in leaves as dolomite is a good source of these nutrients (Soratto and Crusciol, 2008). Similar results were also found by Duarte *et al*. (1999). Dolomite application is used as a management intervention in various cropping systems and as a magnesium source when an increase in soil pH and efficiency of phosphorus fertiliser use are required (Takijima *et al*. 1970); Wijewardena ,2005). Stevens *et al*. (2005) found that in soils that are deficient in Mg, dolomite can be used to reduce soil acidity and to enhance the soil Mg content.

2.2.2.2 Effect on growth, yield and quality of rice

Varghese and Money (1965) conducted a pot culture experiment to study and found that fertiliser application, along with application of Ca and Mg, enhanced grain yield and nitrogen content. In Mg deficient soils, Mg application in the form of $MgSO_4$, magnesite, or dolomite increased rice grain and straw yield significantly according to Biswas *et al*. (2013). Koruth *et al*. (2013) stated that application of Mg as basal dose was very significant increased the grain and straw yield of rice in Mg deficient soils. Suriyagoda *et al*. (2017) reported that application of dolomite to lowland rice fields, affected by Fe toxicity, will improve plant height, shoot dry weight, and root dry weight and grain yield by increasing plant P and K contents and decreasing Fe content. In acidic soils, the application of dolomite along with recommended dose of fertilizers resulted in higher grain and straw yield and higher returns under rice cultivation. Mansingh *et al*. (2019)

2.3 EFFECT OF FOLIAR APPLICATION

Foliar application is a fastest method to provide elements required in plants as the nutrients are absorbed very quickly, compared plant root absorptions. (Hashemy *et al*., 1998). Latha and Nadanassababady (2003) also pointed out foliar fertilisation to be a significant method as it is very easy and rapid. Fageria *et al*. (2009) also found that crops respond to soil-applied fertilisers in five to six days, whereas foliar fertilisers respond faster within 48 hours.

Jamal *et al*. (2006) reported that foliar application of nutrients is preferred as it gives better and quicker results than the soil application. Alam *et al*. (2010) also reported the same, as foliar application could be considered only as a supplement to soil application of fertilizers.

Foliar spray of nutrients enhances root growth and nutrients flow from terminal leaves to depth roots, promoting root absorption of the same nutrient or additional nutrients (El-Fouly and El-Sayed, 1997). Dixon (2003) revealed that foliar feeding is more efficient than soil application in the following ways as N was six times more efficient, boron was four times more efficient, Mn was thirty times more efficient, zinc and phosphorus was twenty times more efficient, and Mo was fourteen times more efficient. Liew (1988) claimed that application of micronutrients as foliar spray is six to twenty times more efficient than soil application on various soil types. According to Girma *et al*. (2007), foliar spray is a visible and cost-effective technique to boost nutrient uptake.

Foliar spraying of nutrients is an established practice in crop production which help to increase the yield and quality of crops (Roemheld and El-Fouly, 1999). Hasewaga *et al*. (2000) reported that foliar nutrition has a significant effect on rice growth and yield. A study by Lin and Zhu (2000) revealed that application of fertilizers as foliar spray at flowering stage enhanced the productivity of rice crop. Ahamad and Jabeen (2005) reported that foliar nutrition increased the grain yield and decreased the amount of fertilizers applied as soil application. Ali *et al*. (2005) found that the metabolic activity of plant was increased by foliar nutrition. Foliar nutrition increased nutrient uptake throughout critical growth stages, leading to increased physiological activity and yield (Kundu and Sarkar, 2009). Application of nutrients as foliar spray is an efficient way to increase the yield and quality of crops (Roemheld and El-Fouly, 1999; Sarkar *et al*., 2007). Bhuyan *et al*. (2012), reported that foliar application of N during late growth stages reduced sterility and boosted thousand grain weight and yield of rice crop. Jagathijothi *et al*. (2012) found that foliar nutrients increase the photosynthetic rate and translocation of carbohydrates and in turn it also increases the dry matter production. Rani *et al*. (2014) found that combined fertilizer application at recommended doses with foliar spray of NPK significantly increased the grain yield in rice. According to Mohan *et al*. (2017) foliar nutrition in correct quantity with RDF increases yield and yield attributes in rice.

2.4.1 Effect of foliar spray of potassium fertilizers

Potassium is an essential and required nutrient for plant growth and development. It also helps in photosynthesis, distribution of carbohydrates, and synthesis of starch in storage organs, which results in increased grain yield (Imas and Magen, 2007; White *et al*., 2010). Utilization of K by plants through foliar nutrition is well known and is practiced in different agriculturally advanced countries (Ali *et al*., 2007). Yang *et al*. (2003) stated that in rice producing soils, K is one of the limiting factors for enhancing rice yield. Singh *et al*. (2013) reported that application of K fertilizers increased rice and wheat yields irrespective of different soil texture, soil K content, climate and irrigation.Ye *et al*. (2019) stated that with the increase of K application, growth condition of rice crop is improved and in turn it flowered earlier.

Foliar nutrition of K may be beneficial when uptake of K through the root zone is low mainly due to the competition of cation in saline or sodic soils with high content of Na (Weinbaum *et al*., 2001). According to Ebrahimi *et al*. (2012) potassium application as foliar spray and as soil intake is the best method under salinity conditions. It plays essential roles in stomata movement, energy transfer, phloem transport, cation-anion balance and stress resistance (Wang *et al*., 2013 and Salami and Saadat, 2013).

Narang *et al*. (1997) recorded effects of K fertilisation on rice and wheat under maximum yield research strategies and found that foliar K application increased grain production. Ali *et al*. (2005) reported significant increase in rice yield with foliar application of K using different K sources over control where no K was applied. According to him foliar spray of K_2SO_4 at different concentrations enhanced the yield components of rice and increased the uptake of K by rice grain and straw. Kundu *et al*. (2020) reported that foliar spray of K salts resulted in increased plant height, chlorophyll content, grain yield and nutrient uptake by rice. There was a significant increase in number of grains per panicle and the panicle numbers after the application of K fertilizers (Ye *et al*., 2019).

2.4.1.1 Foliar spray of potassium nitrate

Foliar spray of potassium nitrate at critical stages of crop production increase the growth attributes of rice which tend to the overall improvement in plant growth, vigour and photosynthates production of leading to increased availability, absorption and translocation of nutrients in rice. Nitrogen and K supplied in the form of KNO_3 improves the factors affected by high salinity and also correct deficiencies of both n and K. The N absorbed at PI stage increased the number of spikelet number and that absorbed at maturity helps in better filling of grains (De Datta, 1981). Potassium nitrate is an important nutrient for the production of boro rice. It plays a key role in increasing the tillering capacity of plant, which leads to increased production (Ali *et al*., 2005). Foliar nutrition of KNO_3 had greater effect on vegetative growth than other applications (Marchand and Bourrie, 1999). Foliar application of potassium nitrate had significant influence on grain protein and grain yield (Ahmad and Jabeen, 2005). Bhuyan *et al*. (2012) stated that foliar spray of N fertilizers at late growth stages resulted in reduced sterility percentage enhanced thousand grain weight and increased the yield in rice. Even though there are different methods of fertilizer application, foliar application of KNO_3 is the better method compared to others (Son *et al*., 2012).

The foliar spray of KNO_3 reduces the harmful effects of salts and in turn increases the production of rice (Ahmad and Jabeen, 2005). The grain yield and straw yield of rice was increased with foliar nutrition of 0.5% KNO_3 solution at flowering stage of the crop (Sarkar and Bandopadhyay, 1991). Ravi *et al*. (2007) found that foliar spray of 0.5 % KNO_3 resulted a significant increase in rice yield over control. Son *et al*. (2012) found increased yield and net income responses from one to three foliar spray of KNO_3 with spring and summer rice grown on soils with low exchangeable K. Foliar nutrition of KNO_3 also increased the number of panicles per m^2, numbers of grains per panicle, 1000 grain weight, and decreased the percentage of unfilled grains. Arif *et al*., (2010); and Zain *et al*. (2014) found that foliar application of potassium nitrate was effective in increased growth and production of rice. Surya (2015) conducted an experiment in wetland rice and recorded the highest grain and straw yield by flag leaf nutrition with 0.5% KNO_3.

Sarkar and Mukhopadyay (1990) investigated the response of rice cultivars to foliar application of KNO_3 and found that foliar spray with KNO_3 solution at 1.5 % at flowering stage significantly enhanced the grain yield of high yielding and traditional cultivars compared to control cultivars. Foliar application of 0.4% calcium nitrate followed by 0.5% potassium nitrate during 50% flowering stage improved the growth characters and yield attributes which in turn resulted in higher rice grain yield (Kundu and Sarkar, 2009). Mahajan *et al*. (2012) claimed that rice grain yield can be improved by a single spray of 1 % potassium nitrate at flowering stage and there was no advantages in yield found with two sprays of 1% potassium nitrate compared to single spray of 1% potassium nitrate. Foliar application of KNO_3 at 1.5 per cent and 2.0 per cent solutions on 40 and 60 days after planting of rice increased the net returns and also enhanced the rice yield. (Khan *et al*., 2012). Jothi *et al*. (2019) opined that foliar spray of 2% KNO_3 at tillering, panicle initiation and flowering stages could be recommended as alternative K management strategy against soil application of K at 50 kg/ha for higher productivity, agronomic efficiency and benefit cost ratio of rice under sodic soil condition. Foliar KNO_3 application had significant effect on the yield performances of BRRI dhan 28 and application of KNO_3 at 0.25 kg ha^{-1} recorded the highest grain yield when applied at the panicle initiation (PI) stage of boro rice (Hasan *et al*., 2020).

2.4.1.2 Foliar spray of potassium silicate

Rice is known as Si accumulator (Takahashi *et al*., 1990) and huge amounts of Si are required for the healthy and productive growth of rice (Savant *et al*., 1997; Singh *et al*., 2005). Rice's growth and grain yield can be promoted by silicon application (Okuda and Takahashi, 1962). Ma and Takahashi (2002), reported that adequate uptake of Si increases the tolerance of agronomic crops particularly rice to both biotic stress and abiotic stress. Some studies revealed that the soil application of Si at the root zone may significantly enhance the rice yield (Epstein, 1999; Prychid *et al.*, 2003). Deposition of Si increases the strength and rigidity of cell walls, and enhances resistance in plants (Epstein 1994, Epstein, 1999; Ma and Takahashi 2002). (Korndorfer *et al*., 2001) reported that effects of Si on yield are based on the deposition of silicon under the leaf epidermis which results a physical mechanism of defense, reduces the lodging, and enhances photosynthesis capacity and minimum transpiration losses.

Silicon solution has the ability to reduce various impacts of plant diseases which is clearly elucidated in case of rice blast (Kim *et al*., 2002).

Silicon content in the plant affects plant growth, quality of the crop, photosynthesis stimulation, reduction of transpiration and increased plant resistance to biotic stresses (Lu and Cao, 2001; Raven, 2003 and Savvas *et al*., 2002). Jinhong *et al*. (2002) concluded that Si has increased the N, P and K concentrations in both shoots and grains of rice. Silicon is considered as an important fertilizer for improving vegetative growth and development and also nutrition of optimum amount of Si is required for cell development and for its differentiation (Liang *et al*., 2005). Silicon is an essential element to enhance and sustain rice productivity (Sudhakar *et al*., 2006). Application of Si to plants develops photosynthetic efficiency of leaf, enhance growth parameters and increase the grain yield in cereal crops particularly in rice (Shashidhar *et al*., 2008). Gholami and Falah (2013) stated that application of Si improved the growth parameters, enhanced yield, yield attributes and quality of rice crops. According to Chalmardi *et al*. (2014), application of silicon helps to mitigate the detrimental effects of Fe toxicity by lowering plant Fe concentrations and increasing antioxidant enzyme activity. Yogendra *et al*. (2014) found that with application of calcium silicate at 2 t ha^{-1} along with the application of N at 100 kg ha^{-1} increased the grain yield and straw yield significantly. Malav *et al*. (2015) revealed that Si application in soil up to 200 mg kg^{-1} significantly enhanced rice grain and straw yield over control.

Concentration of nutrients and its uptake were significantly affected with the foliar treatment of Si (Abou-Baker *et al*., 2011). Foliar application of Si at 0.5 % obtained maximum grain protein and grain diameter whereas silicon at 1 % solution produced the highest number of productive tillers, straw yield, thousand grain weight, and grain yield and grain starch. (Ahamad *et al*., 2013). Shah *et al*. (2020) observed that foliar application of potassium silicate at the rate of 1% at different growth stages such as tillering stage, PI stage and grain formation stage significantly influenced the growth parameters and yield attributes in rice such as panicle length, panicle weight, number of grains per panicle and weight of grains per panicle, grain yield and straw yield, as well as gross return, net return and benefit cost ratio over control. Foliar application of Si increased the percentage of filled grains and as an impact the grain yield also increased. Foliar nutrition of Si is economically and environmentally efficient to enhance the rice yield and also in providing sufficient food for the increasing world population (Dehaghi *et al*., 2018). Nagula *et al*. (2015) reported that application of boron and silicon fertilizers through soil and foliar obtained the highest plant height and number of tillers. Gladis (2015) observed that the application of 0.5% K_2SiO_3 + 0.5% borax was very effective in reducing the toxicity of Fe, Mn and Al in the soil and significantly enhanced the Si content and uptake by the plant, and in turn improves the rice yield.

2.4.2 Effect of foliar spray of micronutrients

Foliar application of Zn, Cu and B has been shown to be similarly or even more effective in overcoming micronutrient deficiency as compared to soil application (Ali *et al*., 2009; Hussanin *et al*., 2012). Lahijani *et al*. (2020) reported that micronutrients delivered through the leaf have a significant impact on rice yield and yield components, it can also reduce the postponement time, which is critical for rice plants during their rapid growth phase. A single leaf spraying of essential micronutrients has a considerable impact on rice yield. Mohan *et al*. (2017) reported that foliar application of nutrients in an optimum quantity with recommended doses of fertilizer help to improve the growth characters of the rice crop. Foliar nutrition of Zn, B and S along with recommended dose of fertilizers in rice increased growth parameters and protein content of rice crop.

Micronutrient application as foliar spray under saline soil conditions is favourable for rice growth and yield (Zayed *et al*., 2011). Foliar nutrition of micronutrients enhanced the yield, yield components and protein content of rice, wheat, maize, sorghum and barley (Boorboori *et al*., 2012).

Adequate B nutrition is essential for high yield and quality of crops (Brown and Shelp, 1997). Both soil and foliar application of B found to be helpful in increasing plant growth and yield in rice (Sakal *et al*., 2002). Jena *et al*. (2006) revealed that application of boron to rice increased the yield and decreased the panicle sterility. Boron deficiency is one of the most common factor seen in rice growing soils. Even though being tolerant, rice plants suffering with B deficiency results in significant yield loss (Cakmak and Romheld, 1997; Rashid *et al*., 2009). According to Rao *et al*. (2013), boron application increased the number of grains while decreased the number of unfilled spikelets.

El-Magid *et al*. (2000) found that application of NPK along with foliar application of various micronutrient combination such as Fe, Mn, Cu, Zn, B, and Mo enhanced the rice grain yield. Shueadshen (1991) reported that foliar nutrition of 0.1 per cent of Zn, Fe, Co, B and Mn at tillering stage increased the number of spikelets per panicle and grain yield while lowering the spikelet sterility. Asad and Rafique (2002) studied the effect of various micronutrients such as Fe, Mn, Zn, Cu and B and a commercial micronutrient mixture and the result revealed that the application of various micronutrients had a significant influence on grain yield, straw yield and dry matter of wheat. Patel *et al.* (2008), reported that foliar application of micronutrient mixture at 1 % (containing Fe - 4 %, Mn -1 %, Zn - 6 %, Cu - 0.5 % and B - 0.5 %) at 30, 40 and 50 days after sowing recorded the highest plant height, number of tillers, shoot and grain weight and increased micronutrients uptake. Agostinho *et al*. (2017) reported that application of B at the rate of 1.0 % as foliar application and the combine application of both 1.5 % Si and 1.0 % B at the rate of can produce better yield.

Foliar spray of micronutrients with 1% of Fe, Cu and B and 2% of Zn and Mn, on wheat enhanced the plants height, number of grains per spike, biological yield, harvest index, thousand grain weight, grain yield and straw yield (Khan *et al*., 2010). Foliage application of micronutrients is beneficial for growth and yield of rice under saline soil conditions. Combined foliar application of Zn, Fe and Mn significantly improved the growth characters, yield and yield attributes of rice (Zayed *et al*., 2011). Samanta *et al*. (2017) proposed that application of micronutrients such as Mo and B as foliar spray at active tillering and PI stages of rice had intense effect on yield and yield attributes of hybrid rice. Esfahani *et al*. (2014) revealed that in rice crop, the highest number of grains per panicle was obtained when a mixture of Fe+Zn and the Fe+Zn+Si were applied as foliar spray and the highest thousand grain weight was recorded with foliar spray of Zn + Si and also the combined application of these elements recorded the highest biomass weight and grain yield.

2.5 EFFECT OF NUTRIENTS ON PEST AND DISEASE

Plant nutrition is an important component of disease control (Huber and Wilhelm, 1988). Application of K profoundly improves plant tolerance to infection by most fungal pathogens (Amtmann *et al*., 2008). Fertilization of soils deficient in available K reduces the pressure from diseases such as stem rot and sheath spot in rice (Williams and Smith, 2001). Potassium improves the rice tolerance to adverse climatic conditions, lodging, insect pests and diseases (Tiwari, 2002). Singh *et al*. (2003) stated that K imparts resistance against diseases and high concentrations of K ions in the cell sap will restricts insect attack. Vaithilingam and Baskaran (1985) examined the mechanism of resistance induced to insects in rice with increased application of K. Application of K decreases leaf blight severity and enhance the grain yields in wheat (Sharma and Duveiller ,2004; Sharma *et al.*, 2005).

Buck *et al*. (2008) found that foliar application of potassium silicate reduced the incidence of blast disease on rice. Abad-Ashtiani *et al*. (2012) reported that silicon fertilization is effective in controlling and reducing the rice blast severity. Application of Si is an effective method to reduce and to control the rice blast disease (Datnoff *et al*., 1991; Seebold *et al*., 2001; Hayasaka *et al*., 2005). Silicon fertilization have significantly lowered the development of blast disease in rice plants (Qin, 1979; Zang, 1989). Rezende *et al*. (2009) found that foliar spray of silicon can reduce the intensity of brown spot in rice. Guevel *et al*. (2007) studied the foliar and root applications of different Si-based formulations for powdery mildew control in wheat.

Micronutrient disorders of Zn, Mn, B, Cu and Fe are widespread in India and correction of these nutritional disorders resulted in resistance to plant diseases (Agrios, 2005). The effect of micronutrients on reducing severity of diseases can be attributed with physiology and biochemistry of plants (Marschner, 1995). Micronutrient concentrations in plants are important in host ability to resist or tolerate infectious pathogens. Graham and Webb (1991) reported that application of Zn lowered the disease severity, by the toxic effect of Zn on the pathogen. Mn helps in controlling number of diseases as it plays an important role in lignin biosynthesis, phenol biosynthesis and photosynthesis.

Materials and methods

3. MATERIALS AND METHODS

An experiment entitled "Enhancing grain yield and quality through soil amelioration and foliar nutrition in Rice (*Oryza sativa* L.) in Vaikom *Kari* soils" was carried out during *puncha* season (October 2020 to February 2021), at farmer's field in Vechoor area of Kottayam district of Kerala. The objective of the experiment was to augment the grain yield and quality of rice crops in Vaikom *Kari* soils through standardization of different soil amelioration practices to manage soil acidity and standardization of foliar spray of K and different micronutrients for supplementing nutrition at PI stage. Relevant details of methodologies adopted, materials used and practices employed at the time of research are described in this chapter.

3.1. MATERIALS

3.1.1 Experimental Site

The experiment was carried out in the field of Sri. Suresh Babu at Vechoor panchayat in Kottayam district during *Puncha* season (oct-feb) 2020-21. It is located at 9°44'56.02''N latitude, 76°23'51.18"E longitude and an altitude of about 3 m above MSL.

3.1.2 Soil

The soil of the experimental field which falls in the order Entisol (GoK, 1999) was sandy clay loam in texture, extremely acidic in reaction, with high OC and low available N and available P. Initial soil samples were collected from 15 cm depth of the experimental site and analysed for the chemical properties and is presented in Table 2.

3.1.3 Climate

The climate of experimental site was classified as humid tropical. Data on weather parameters were obtained from the Class B Agromet Observatory at Regional Agricultural Research Station, Kumarakom, Kottayam. The average maximum temperature was 32.73 ^{o}C and minimum temperature was 20.86 ^{o}C. Abstract of weather data is given in Table 2. The mean values of weather parameters recorded during the crop period (October to February) are furnished in Fig. 1.

3.1.4 Cropping Season

The field experiment was conducted during October 2020 to February 2021 (*puncha* in Kuttanad).

Table 1. Abstract of weather data during experimental period

Weather element	Range	Mean
Maximum temperature(^oC)	29.35 - 34.30	32.73
Minimum temperature(^oC)	18.50 - 22.10	20.86
Rainfall(mm)	78.64 - 82.86	80.44

Table 2. Chemical properties of soil in the experimental site

Sl.no.	Soil parameters	Unit	Content	Rating
1	pH	-	4.28	Extremely acidic
2	EC	dS m^{-1}	0.70	Low
3	Organic carbon	%	3.93	High
4	Available Nitrogen	kg ha^{-1}	188.16	Low
5	Available Phosphorus	kg ha^{-1}	9.08	Low
6	Available Potassium	kg ha^{-1}	210.88	Medium
7	Available Calcium	mg kg^{-1}	301.56	High
8	Available Magnesium	mg kg^{-1}	84	Low
9	Available Sulphur	mg kg^{-1}	365	High
10	Available Iron	mg kg^{-1}	351	Toxic
11	Available Manganese	mg kg^{-1}	2.01	High
12	Available Zinc	mg kg^{-1}	6.88	High
13	Available Copper	mg kg^{-1}	3.58	High
14	Available Boron	mg kg^{-1}	0.36	Low
15	Available Sodium	mg kg^{-1}	220.73	High

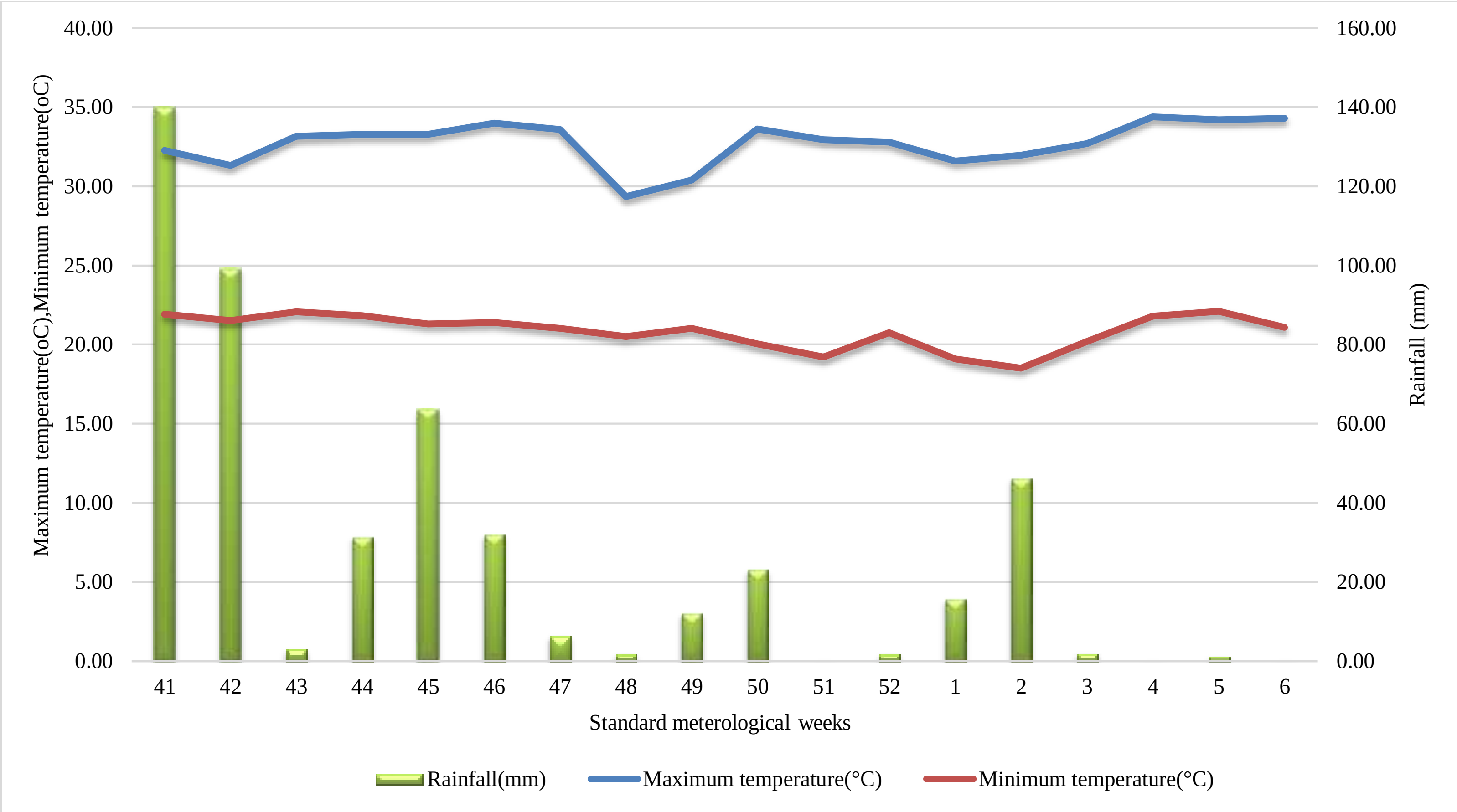

Fig. 1. Weather data prevailed during the crop season in standard weeks

3.1.5 Crop Variety

The rice variety Uma (MO-16) was used for the study. It is having red and medium bold grains and is a medium duration variety with duration of 115 to120 days. It is non-lodging and resistant to brown plant hopper. It is suited for all the three seasons and is best suited for the additional crop season of Kuttanad (KAU, 2011).

3.1.6 Soil ameliorants

Ordinary dolomite (17.16 % Ca and 10.15% Mg) and Granulated dolomite (23 % Ca and 13 % Mg) were used as soil ameliorants for the correction of acidity and applied as per treatments.

3.1.7 Manures and Fertilizers

Urea (46% N), rajphos (20% P_2O_5) and muriate of potash (60% K_2O) were used as the sources of N, P, and K for soil application. Water soluble potassium nitrate (13:0:45), potassium silicate (34% K_2O) and micronutrient solution were used for foliar nutrition as per treatments.

3.1.8 Micronutrient solution

Micronutrient solution formulated at College of Agriculture, Padannakkad under Kerala Agricultural University was used for the experiment. It is a combination of two solutions, in which one litre of solution A contains $ZnSO_4.7H_2O$ (50 g), $CuSO_4.5H_2O$ (20 g), $FeSO_4.7H_2O$ (10 g), H_3BO_3 (10 g), $MnSO_4.H_2O$ (0.5g) and $(NH_4)_6Mo_7O_{24}.4H_2O$ (0.5g) and solution B contains organic chelate.

3.2 METHODS

3.2.1 Design

Design	: Randomised Block design (RBD)
Number of treatments	: 15
Number of replications	: 3
Plot size	: 20 m^2
Spacing	: 20 cm x 10 cm

3.2.2 Treatments

Factor A- Dolomite (soil application; basal + 30 DAS application) (D)

1. D_0- without dolomite application.

2. D_1-Dolomite (ordinary) @500 kg ha^{-1}

3. D_2-Granulated dolomite @500 kg ha^{-1}

Factor B - Foliar nutrition (N)

1. N_0 - without foliar application.

2. N_1- FS* of K_2NO_3 (1%) at PI++ stage.

3. N_2- FS of K_2SiO_3 (1%) at PI stage.

4. N_3- FS of KNO_3 (1%) + Micronutrient solution (0.5%) at PI stage.

5. N_4- FS of K_2SiO_3 (1%) +Micronutrient solution (0.5%) at PI stage.

Treatment combinations

T_1 - Without dolomite application +Without foliar application.

T_2 - Without dolomite application + FS of KNO_3 (1%) at PI stage.

T_3 - Without dolomite application + FS of K_2SiO_3 (1%) at PI stage.

T_4 - Without dolomite application + FS of KNO_3 (1%) + Micronutrient solution (0.5%) at PI stage.

T_5 - Without dolomite application + FS of K_2SiO_3 (1%) +Micronutrient solution (0.5%) at PI stage.

T_6 - Dolomite (ordinary) @500 kg ha^{-1} + Without foliar application.

T_7 - Dolomite (ordinary) @500 kg ha^{-1} + FS of KNO_3 (1%) at PI stage.

T_8 - Dolomite (ordinary) @500 kg ha^{-1} + FS of K_2SiO_3 (1%) at PI stage.

T_9- Dolomite (ordinary) @500 kg ha^{-1}+ FS of KNO_3 (1%) + Micronutrient solution (0.5%) at PI stage.

T_{10} - Dolomite (ordinary) @500 kg ha^{-1}+ FS of K_2SiO_3 (1%) +Micronutrient solution (0.5%) at PI stage.

T_{11}- Granular dolomite @500 kg ha^{-1} +Without foliar application.

T_{12} - Granular dolomite @500kg ha^{-1} + FS of KNO_3 (1%) at PI stage.

T_{13} - Granular dolomite @500 kg ha^{-1} + FS of K_2SiO_3 (1%) at PI stage.

T_{14} - Granular dolomite @500 kg ha^{-1} + FS of KNO_3 (1%) + Micronutrient solution (0.5%) at PI stage.

T_{15} - Granular dolomite @500 kg ha^{-1} + FS of K_2SiO_3 (1%) +Micronutrient solution (0.5%) at PI stage.

*FS-foliar spray, ++ PI- panicle initiation stage.

$R_1 T_2$	$R_1 T_{14}$	$R_1 T_8$	$R_1 T_1$	$R_1 T_7$
$R_1 T_9$	$R_1 T_3$	$R_1 T_{15}$	$R_1 T_{12}$	$R_1 T_5$
$R_1 T_{11}$	$R_1 T_{10}$	$R_1 T_4$	$R_1 T_{13}$	$R_1 T_6$
$R_2 T_6$	$R_2 T_{13}$	$R_2 T_{10}$	$R_2 T_2$	$R_2 T_{14}$
$R_2 T_3$	$R_2 T_7$	$R_2 T_1$	$R_2 T_{11}$	$R_2 T_8$
$R_2 T_{12}$	$R_2 T_4$	$R_2 T_{15}$	$R_2 T_9$	$R_2 T_5$
$R_3 T_{14}$	$R_3 T_7$	$R_3 T_3$	$R_3 T_{10}$	$R_3 T_{12}$
$R_3 T_8$	$R_3 T_1$	$R_3 T_{14}$	$R_3 T_4$	$R_3 T_6$
$R_3 T_2$	$R_3 T_{13}$	$R_3 T_9$	$R_3 T_{11}$	$R_3 T_5$

Fig. 2. Layout of the experimental field

The data on growth characters and soil analysis are not influenced by foliar nutrition at panicle initiation stage of crop. Hence the effect of foliar nutrition and the interaction effect of main treatments are not relevant on the same and was assessed in simple RBD with three treatments *viz.* levels of dolomite application same as mentioned above (D_0, D_1, D_2) and fifteen replications.

3.3 Field Experiment

3.3.1 Land Preparation

The experimental field was ploughed, puddled and laid out as per the technical programme. Soil samples were collected from the field for initial analysis. Proper irrigation facilities and drainage channels were provided.

3.3.2 Application of Soil Ameliorants

Ordinary dolomite and granulated dolomite @ 500 kg ha^{-1} were applied in two splits of 300 kg as basal dose and 200 kg at 30 DAS.

3.3.3 Application of Fertilizers

Nitrogen, phosphorus and potassium fertilizers @ 90:45:45 kg ha^{-1} were applied uniformly in all plots. Full dose of P as rajphos was applied as basal application along with ploughing. Nitrogen was applied through urea and K was applied through muriate of potash in three equal splits at 20 DAS, at tillering stage and at panicle initiation stage. Potassium nitrate and potassium silicate @ 1 % and micronutrient solution @ 0.5% were given as foliar spray as per treatment.

3.3.4 Seeds and Sowing

Seeds of rice var. Uma was soaked in water overnight, and kept for germination for 24 hours in gunny bag. The pre-germinated seeds were dibbled using seed drum at a spacing of 20 cm x 10 cm. The seeds are sown on 07.10.2020.

3.3.5 After cultivation

Post emergent herbicide Affinity (Carfentrazone Ethyl 40% DF) @ 4 g *a.i.* ha^{-1} + 0.2% surfactant was sprayed at 15 DAS and gap filling, thinning and hand weeding were done at 30 DAS.

3.3.6 Plant Protection

The incidence of stem borer was noticed at PI stage of the crop which was controlled by soil application of Fertera (chlorantraniliprole 0.4% GR). Rice blast and brown leaf spot symptoms were also observed in the field.

3.3.7 Harvest

The crop was harvested manually on 08.02.2021. The observation plants were harvested separately. Each plot was harvested individually, threshed, winnowed and dried separately. The weight of grains from each plot was recorded.

3.4 OBSERVATIONS

Five plant samples were chosen at random from each plot avoiding the border rows within the plots and labelled as observation plants for recording biometric data.

3.4.1 Growth Characters

3.4.1.1 Plant Height (cm)

Plant height was recorded at different growth stages such as maximum tillering (MT), Panicle initiation (PI) and harvest stages. The height was measured from the base of the plant at ground level to the tip of the longest leaf or ear head and expressed in centimetres.

3.4.1.2 Leaf Area Index

Leaf area index (LAI) was calculated at maximum tillering and Panicle initiation stages by using the formula proposed by Watson (1947).

$$\text{LAI} = \frac{\text{Total functional leaf area per plant (cm}^2\text{)}}{\text{Land area occupied per plant (cm}^2\text{)}}$$

3.4.1.3 Number of Tillers

Total number of tillers was recorded from the observation plants at MT, PI and harvest stages, average was worked out and recorded as number of tillers m^{-2}.

3.4.1.4 Total Dry Matter Production (TDMP)

The observation plants from each plot were uprooted at harvest and fresh weight was recorded. Uprooted plants were washed and separated into grain and straw, initially shade dried and later oven dried at 60^{o}C to a constant weight. The average values were recorded and used for computing total dry matter production and expressed in t ha^{-1}.

3.4.2 Yield and Yield Attributes

3.4.2.1 Number of Productive Tillers

Number of productive tillers in observation plants was counted at harvest and expressed as number of productive tillers m^{-2}.

3.4.2.2 Thousand Grain Weight

Thousand grains were counted from sample grains of each individual plot and the weight was recorded in g.

3.4.2.3 Percentage of filled grains

Percentage of filled grains was calculated using the formula,

$$\text{Percentage of filled grains} = \frac{\text{Number of filled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.4.2.4 Grain Yield

After harvesting, threshed and cleaned grains were dried to 14 per cent moisture level and grain yield per individual plot was recorded and expressed in t ha^{-1}.

3.4.2.5 Straw Yield

Straw harvested from each individual plot was dried to a constant weight and the weight was expressed as t ha^{-1}.

3.4.2.6 Harvest Index (HI)

HI was calculated using the equation suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield (grain yield t ha}^{-1}\text{)}}{\text{Biological yield [(grain yield + straw yield) t ha}^{-1}\text{]}}$$

3.4.3 Soil Analysis

A composite soil sample was collected at a depth of 0-15 cm from the experimental field before the experiment. After the experiment soil samples were collected from each individual plot at PI stage and harvest. Samples were air dried, grinded and sieved through 2 mm sieve and preserved for analysis. Analysis for OC, available macronutrients, micro nutrients and Na was carried out using standard procedures. Procedures followed for soil analysis is presented in Table 3.

3.4.4 Plant analysis

3.4.4.1 Nutrient Content of Grain and Straw

Plant samples were collected at harvest, separated into grain and straw, oven dried at 60^{o}C to a constant weight and analysed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and Na. Procedures followed for plant analysis is presented in Table 4.

3.4.5 Uptake of nutrients

Uptake of N, P, K, Ca, Mg and S by grain and straw was computed by multiplying nutrient content of each part with respective dry matter production in kg ha^{-1}. The total uptake of nutrients was also recorded and expressed in kg ha^{-1}.

3.5 PEST AND DISEASE INCIDENCE

Incidence of pest and disease was recorded from each experimental plot throughout the cropping period.

3.6 ECONOMIC ANALYSIS

Cost of cultivation was calculated considering the prevailing market price of inputs and MSP of paddy during the cropping periods.

3.6.1 Gross return

Gross return was calculated using the market price of grain and straw. For calculating gross returns marketable yield is considered instead of total yield.

3.6.2 Net returns

The net return per hectare under each treatment was obtained by subtracting cost of cultivation from gross returns.

3.6.3 Benefit cost ratio (BCR)

Benefit cost ratio is the ratio of gross returns to the total cost of cultivation.

$$BCR = \frac{\text{Gross return ha}^{-1}\text{ (Rs)}}{\text{Cost of cultivation ha}^{-1}\text{ (Rs)}}$$

3.7 STATISTICAL ANALYSIS

The data collected from the field experiments was statistically analyzed by using analysis of variance (ANOVA) for Factorial RBD. It was then tested for its significance using GRAPES software for drawing conclusion.

Table 3. Procedures followed for soil analysis

Sl.no	Parameters	Method	Reference
1	pH	pH meter (1:2.5 soil water suspension)	Jackson (1973)
2	EC	Conductivity meter (1:2.5 soil water suspension)	Jackson (1973)
3	Organic carbon	Chromic acid wet oxidation method	Walkley and Black (1934)
4	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
5	Available P	Bray No. 1 extraction and and spectrophotometer estimation	Bray and Kurtz (1945) and Jackson (1973)
6	Available K	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)
7	Available Ca	Versanate titration method	Hesse (1971)
8	Available Mg	Versanate titration method	Hesse (1971)
9	Available S	Calcium chloride extraction and turbidimetry and estimation using spectrophotometer	Tabatabai (1982)
10	Available Fe	HCl extraction and estimation using Atomic absorption spectroscopy	Sims and Johnson (1991)
11	Available Mn	HCl extraction and estimation using Atomic absorption spectroscopy	Sims and Johnson (1991)
12	Available Zn	HCl extraction and estimation using Atomic absorption spectroscopy	Emmel *et al*. (1977)
13	Available Cu	HCl extraction and estimation using Atomic absorption spectroscopy	Emmel *et al*. (1977)
14	Available B	Hot water extraction and spectrophotometer estimation	Bingham (1982)
15	Exchangeable Na	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)

Table 4. Procedures followed for plant analysis

Sl.no.	**Parameters**	**Procedure of analysis**	**Reference**
1	Total N	Single acid (H_2SO_4) digestion followed by distillation	Jackson (1973)
2	Total P	Di-acid digestion followed by vanado molybdo-phosphoric yellow colour method	Jackson (1973)
3	Total K	Di-acid digestion followed by flame photometry	Piper (1967)
4	Total Ca	Di-acid digestion followed by Atomic Absorption Spectroscopy	Issac and Kerber (1971)
5	Total Mg	Di-acid digestion followed by Atomic Absorption Spectroscopy	Issac and Kerber (1971)
6	Total S	Di-acid digestion followed by $CaCl_2$ turbidimetry and spectrophotometer estimation	Bhargava and Raghupathi (1995)
7	Total Fe	Di-acid digestion followed by Atomic Absorption Spectroscopy	Lindsay and Norvell (1978)
8	Total Mn	Di-acid digestion followed by Atomic Absorption Spectroscopy	Lindsay and Norvell (1978)
9	Total Zn	Di-acid digestion followed by Atomic Absorption Spectroscopy	Lindsay and Norvell (1978)
10	Total Cu	Di-acid digestion followed by Atomic Absorption Spectroscopy	Lindsay and Norvell (1978)
11	Total B	Dry ashing and azomethine yellow colour method followed by spectrophotometer estimation	Gaines and Mitchel (1979) and Bingham (1982)
12	Total Na	Di-acid digestion followed by flame photometry	Piper (1967)

Plate 1. Field layout

Plate 2. Sowing

Plate 3. Gap filling

Plate 4. Dolomite application

Plate 5. Maximum tillering stage

Plate 6. Panicle initiation stage

Plate 7. Foliar nutrition at PI stage

Plate 8. Harvesting stage

Plate 9. Harvesting

Plate 10. Harvested paddy

Plate 11. Threshing

Plate 12. General view of the experimental plot at 30 DAS

Plate 13. General view of the experimental plot at harvesting stage

Results

4. RESULTS

A field experiment entitled "Enhancing grain yield and quality through soil amelioration and foliar nutrition in Rice (*Oryza sativa L.*) in Vaikom *Kari* soils" was conducted in farmer's field at Vechoor, during *pucha* season of October 2020 to February 2021 to augment grain yield and quality of rice crops in *Vaikom kari* soils. The results that are obtained from the experiment were statistically analysed and presented in this chapter.

4.1 GROWTH CHARACTERS

Growth characters such as plant height (cm), number of tillers (m^2), leaf area index and total dry matter production (t ha^{-1}) were recorded during different growth stages of crop. The data on growth characters were not influenced by foliar nutrition at PI stage of crop. Hence the effect of foliar nutrition and the interaction effect of main treatments are not relevant on the same except in total dry matter production (t ha^{-1}).

4.1.1 Plant height (cm)

The mean data on plant height recorded at different growth stages *viz*. MT, PI and harvesting stages are given in Table 5. Effect of dolomite application on plant height was not significant at maximum tillering stage. Application of granulated dolomite as basal + 30 DAS (D_2) recorded the highest values (89 cm and 103.73 cm respectively) at PI and harvest stages compared to other treatments.

4.1.2 Number of tillers (m^{-2})

Data on treatment effect of dolomite application on number of tillers are presented in Table 5.The data on number of tillers showed significant difference between the treatments. Granulated dolomite application as basal + 30 DAS (D_2) recorded the highest number of tillers m^{-2} at MT and PI stages (562.16 and 779.04 respectively) which was on par with ordinary dolomite application as basal + 30 DAS (D_1).

4.1.3 Leaf Area Index (LAI)

Dolomite application showed significant effect on LAI at MT and PI stages and are presented in Table 5. The data on LAI at MT and PI stages were found to be the highest (5.47 and 6.33 respectively) with application of granulated dolomite as basal +30 DAS (D_2) and was on par with ordinary dolomite application (D_1) at PI stage.

Table 5. Effect of soil amelioration practices on growth characters

Treatment	Plant height (cm)			No of tillers m^{-2}		LAI	
	MT	PI	Harvest	MT	PI	MT	PI
T1	67.33	78.20	100.66	428.84	548.88	4.76	5.27
T2	65.93	82.80	98.73	515.50	750.97	5.32	6.32
T3	69.13	89.00	103.73	562.16	779.04	5.47	6.33
SEm (±)	1.03	1.99	0.73	21.03	32.35	0.07	0.03
CD(0.05)	NS	5.72	2.11	61.33	93.73	0.20	0.08

4.1.4 Total dry matter production (TDMP)

Data on influence of soil amelioration, foliar nutrition and their interaction effects on total dry matter production are given in Table 6. The data on TDMP was recorded during harvesting stage. Application of granulated dolomite as basal + 30 DAS recorded significantly higher dry matter production (15.05 t ha^{-1}) than the other treatments.

Foliar application of potassium nitrate at 1% gave the highest dry matter production (14.96 kg ha^{-1}) which was on par with all other treatments except treatment without foliar application.

4.2 YIELD AND YIELD ATTRIBUTES

Soil amelioration, foliar nutrition and their interaction effects influenced the yield and yield attributes of rice such as number of productive tillers m^{-2}, thousand grain weight (g) and percentage of filled grains (%) which are given in Table 7. The mean data on grain yield, straw yield and harvest index recorded are also presented in Table 7.

4.2.1 Number of productive tillers

Number of productive tillers m^{-2} was significantly influenced by soil amelioration, foliar nutrition and their interaction (Table 7). Number of productive tillers was significantly higher (564.38) in granulated dolomite as basal + 30 DAS (D_2) compared to D_0 and $D_{1.}$

Foliar nutrition and the interaction of main treatments failed to produce a significant effect on number of productive tillers m^{-2}.

4.2.2 Percentage of filled grains (%)

The influence of soil amelioration practices and foliar nutrition on filled grain percentage is shown in Table 7. Treatment with granulated dolomite as basal + 30 DAS (D_2) registered higher percentage (89.32%) of filled grains. In case of foliar nutrition, application of potassium nitrate (1%) obtained the highest percentage (89.04 %) of filled grains which was on par to all other treatments except treatment without foliar application.

Effect of main treatment interactions were not significant on filled grain percentage.

4.2.3 Thousand grain weight (g)

Treatment effect of thousand grain weight with respect to soil amelioration, foliar nutrition and their interaction are given in Table 7. Thousand grain weight was the highest in D_2 (28.35 g) with granulated dolomite as basal + 30 DAS compared to D_0 and $D_{1.}$

In case of foliar application higher 1000 grain weight was recorded in N_1 (28.56 g) which was on par with N_3 (28.42 g) compared to other treatments.

Thousand grain weight was not significantly influenced by the interaction of soil amelioration practices and foliar nutrition.

Table 6. Effect of soil amelioration, foliar nutrition and their interaction effects on total dry matter production at harvest (t ha^{-1})

Treatments	Grain dry matter yield (t ha^{-1})	Straw dry matter yield (t ha^{-1})	Total dry matter yield (t ha^{-1})
Dolomite Application			
D_0	5.65	7.12	12.78
D_1	6.07	6.84	12.91
D_2	6.50	8.54	15.05
SEm (±)	0.196	0.305	0.45
CD($P < 0.05$)	0.569	0.884	1.32
Foliar nutrition			
N_0	5.18	6.32	11.50
N_1	6.40	8.56	14.96
N_2	6.08	7.55	13.64
N_3	6.43	7.77	14.21
N_4	6.29	7.31	13.60
SEm (±)	0.254	0.394	0.590
CD($P < 0.05$)	0.735	1.141	1.710
Interaction effects			
D_0N_0	4.64	5.56	10.21
D_0N_1	5.85	8.10	13.95
D_0N_2	5.72	7.16	12.89
D_0N_3	6.13	7.26	13.39
D_0N_4	5.92	7.53	13.46
D_1N_0	5.23	5.89	11.12
D_1N_1	6.36	8.48	14.85
D_1N_2	6.08	7.46	13.55
D_1N_3	6.45	6.72	13.17
D_1N_4	6.23	5.65	11.88
D_2N_0	5.66	7.50	13.16
D_2N_1	6.98	9.11	16.09
D_2N_2	6.45	8.02	14.47
D_2N_3	6.72	9.35	16.08
D_2N_4	6.71	8.76	15.47
SEm (±)	0.439	0.682	1.02
CD(0.05)	NS	NS	NS

Table 7. Effect of dolomite application, foliar nutrition and their interaction effects on yield attributes and yield

Treatments	Productive tillers m^{-2}	Percentage of filled grains (%)	Thousand grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
Dolomite Application						
D_0	413.41	87.19	25.94	5.86	7.09	0.44
D_1	488.84	87.81	27.19	6.38	7.41	0.47
D_2	564.38	89.32	28.35	6.79	8.78	0.43
SEm (±)	23.48	0.492	0.247	0.185	0.331	0.008
CD(0.05)	68.03	1.42	0.716	0.535	0.959	0.023
Foliar nutrition						
N_0	485.34	86.10	25.09	5.47	6.58	0.456
N_1	503.65	89.04	28.56	6.63	8.91	0.429
N_2	455.51	88.49	27.11	6.29	7.81	0.447
N_3	499.95	88.59	28.42	6.76	7.94	0.464
N_4	499.95	88.30	26.62	6.57	7.57	0.472
SEm (±)	30.32	0.635	0.319	0.238	0.427	0.010
CD(0.05)	NS	1.83	0.924	0.691	1.23	NS
Interaction effects						
D_0N_0	445.03	85.80	23.54	4.83	5.85	0.45
D_0N_1	388.85	88.07	25.83	6.21	8.50	0.43
D_0N_2	399.96	87.47	26.98	5.80	7.51	0.44
D_0N_3	411.07	87.87	26.00	6.33	7.40	0.46
D_0N_4	422.18	86.74	27.39	6.14	7.81	0.44
D_1N_0	422.18	83.71	25.37	5.50	6.08	0.47
D_1N_1	555.50	89.09	27.18	6.55	8.75	0.42
D_1N_2	411.07	88.33	28.99	6.30	7.70	0.45
D_1N_3	566.61	88.96	26.53	6.91	7.01	0.50
D_1N_4	488.84	88.95	27.88	6.65	5.93	0.53
D_2N_0	588.83	88.79	26.38	6.08	7.83	0.44
D_2N_1	566.61	89.98	28.33	7.13	9.48	0.43
D_2N_2	555.50	89.69	29.71	6.76	8.21	0.45
D_2N_3	522.17	88.94	27.35	7.05	9.40	0.43
D_2N_4	588.83	89.21	29.98	6.93	8.96	0.44
SEm (±)	52.51	1.10	0.553	0.413	0.74	0.018
CD(0.05)	NS	NS	NS	NS	NS	NS

4.2.4 Grain yield (t ha^{-1})

The influence of soil amelioration, foliar nutrition and their interaction effect on grain yield are presented in Table 7. The effect of dolomite application was found to be significant among treatments. Granulated dolomite as basal + 30 DAS (D_2) registered the highest (6.79 t ha^{-1}) grain yield which was on par with D_1 and the lowest grain yield (5.86 t ha^{-1}) was recorded for treatment without dolomite application (D_0).

Foliar spray of 1% potassium nitrate + 0.5% micronutrient solution (N_3) obtained higher yield (6.76 t ha^{-1}) which was on par with all other treatments except treatment without foliar application (N_0) which recorded the lowest grain yield (5.47 t ha^{-1}).

No significant difference was observed on grain yield with regard to interaction of dolomite application with foliar nutrition.

4.2.5 Straw yield (t ha^{-1})

The straw yield after harvest was recorded and given in the Table 7. The straw yield was significantly influenced by soil amelioration practices. The highest straw yield was obtained by the treatment with granulated dolomite as basal + 30 DAS (8.78 t ha^{-1}**)** and the lowest straw yield was obtained for treatment without dolomite application.

With regard to foliar nutrition, foliar spray of KNO_3 at 1% recorded higher straw yield (8.91 t ha^{-1}) which was on par with N_3 and the lowest yield was recorded for N_0.

Interaction effect of soil amelioration and foliar nutrition was not significant with respect to straw yield.

4.2.6 Harvest index

Harvest index was significantly influenced by soil amelioration practices (Table 7) and was not influenced by foliar nutrition and their interaction effects. Ordinary dolomite application as basal+30 DAS obtained highest HI (0.47) compared to other treatments.

4.3 SOIL ANALYSIS

The data on chemical properties of the soil analysed at PI stage and after harvest are presented in Tables 8 to 12. The soil characteristics were not influenced by foliar nutrition at PI stage of crop, hence the effect of foliar nutrition and the interaction effect of main treatments are not relevant for the same.

4.3.1 Soil pH

The data presented in Table 8 reveals that pH was significantly influenced by soil amelioration practices. Soil pH gradually increased from the initial value of 4.28 (Table 4) in all the treatments at PI stage. The highest pH (5.40) was obtained on application of granulated dolomite as basal + 30 DAS (D_2) and the lowest pH (4.38) was obtained in D_0.

After harvest the soil pH declined in all the treatments. At harvest also the highest pH was obtained for D_2 (4.26) and the lowest pH was obtained in D_0 (3.13).

4.3.2 Electrical conductivity

The soil EC was significantly influenced by soil amelioration practices. EC decreased at panicle initiation stage and increased at harvest stage from the initial value 0.70 dS m^{-1} (Table 4) as seen in Table 8. The treatment without dolomite application (D_0) recorded the highest EC at both panicle initiation and harvest stages (0.71 dS m^{-1} and 1.80 dS m^{-1} respectively) compared to D_1 and D_2.

4.3.3 Organic carbon

Soil amelioration practices had a significant influence on OC content both at panicle initiation and harvesting stages (Table 8). Initial value obtained was 3.93% (Table 4) which increased at PI stage and decreased at harvesting stage. The highest OC content (4.26% and 3.31% respectively) was recorded with granulated dolomite as basal + 30 DAS (D_2), at both PI and harvest stage compared to D_0 and D_1.

Table 8. Effect of soil amelioration practices on pH, EC and OC in soil at PI stage

Treatment	pH		EC (dS m^{-1})		OC (%)	
	PI	Harvest	PI	Harvest	PI	Harvest
D_0	4.38	3.13	0.71	1.80	3.18	2.19
D_1	5.06	4.09	0.55	1.71	3.91	3.15
D_2	5.40	4.26	0.47	1.51	4.26	3.31
SEm (±)	0.03	0.02	0.01	0.01	0.05	0.01
CD(0.05)	0.09	0.07	0.02	0.05	0.16	0.05

4.3.4 Available N

The data on available N in the soil are given in Table 9. The available N was significantly influenced by soil amelioration practices at PI stage. Application of granulated dolomite as basal + 30 DAS recorded the highest N content of soil (369.58 kg ha^{-1}) compared to D_0 and D_1.

Different soil amelioration practices did not have any significant influence on available N content of soil at harvest stage.

4.3.5 Available P

Available P content of the soil was significantly influenced by soil amelioration practices at panicle initiation stage (Table 9). The highest soil available P (16.05 kg ha^{-1}) was obtained with granulated dolomite as basal + 30 DAS (D_2) which was on par with ordinary dolomite as basal + 30 DAS (D_1).

It can be seen from Table 9 that the soil amelioration practices failed to express significant effect on available P content of soil at harvest.

4.3.6 Available K

Data on available K status of the soil as influenced by soil amelioration practices are given in Table 9. Soil amelioration practices had significant effect on soil available K at PI and harvest stages. Granulated dolomite as basal + 30 DAS recorded significantly higher status (404.71 kg ha^{-1} and 246.38 kg ha^{-1}) of available K which was on par with ordinary dolomite application at both the stages.

Table 9. Effect of soil amelioration practices on N, P and K in soil at PI and harvest stages.

Treatment	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	PI	Harvest	PI	Harvest	PI	Harvest
D_0	303.05	250.88	11.58	6.71	321.97	185.82
D_1	354.86	275.96	16.05	7.07	372.06	244.18
D_2	369.58	257.15	14.75	6.56	404.71	246.38
SEm (±)	4.88	19.88	0.42	0.42	17.25	13.48
CD(0.05)	14.13	NS	1.22	NS	49.97	39.07

4.3.7 Available Ca

The data obtained for soil available Ca are depicted in Table 10. At PI stage, application of granulated dolomite as basal + 30 DAS recorded the highest available Ca content in soil (576 mg kg^{-1}) compared to other treatments. At harvest, soil available Ca content was less compared to PI stage and D_2 obtained the highest (424 mg kg^{-1}) calcium content which was on par with D_1.

4.3.8 Available Mg

Available Mg content was significantly influenced by soil amelioration practices as seen in Table 10. The initial Mg content (84 mg kg^{-1}) in soil was very low and it increased during cropping period. At PI stage the highest soil Mg content (131.70 mg kg^{-1}) was obtained in treatment with application of granulated dolomite as basal + 30 DAS (D_2) and at harvesting stage (113.53 mg kg^{-1}), it was on par with D_1.

4.3.9 Available S

Data on effect of soil amelioration practices on available sulphur in the soil is shown in Table 10. The soil was initially higher in S (301.5 mg kg^{-1}) which gradually decreased during cropping period. The treatment without dolomite application recorded significantly higher content of soil available sulphur at both PI and harvesting stages (177.04 mg kg^{-1} and 227.06 mg kg^{-1} respectively) which was on par with treatment with ordinary dolomite application as basal + 30 DAS. Granulated dolomite as basal+30 DAS registered significantly lower values at PI and harvest stages.

Table 10. Effect of soil amelioration practices on Ca, Mg and S in soil at PI and harvest stages

Treatment	Ca (mg kg^{-1})		Mg (mg kg^{-1})		S (mg kg^{-1})	
	PI	Harvest	PI	Harvest	PI	Harvest
D_0	444.31	341.33	110.98	95.86	177.04	227.06
D_1	543.30	408.00	120.65	106.36	173.05	212.73
D_2	576.00	424.00	131.70	113.53	158.92	191.73
SEm (±)	6.73	19.08	2.81	4.14	4.06	7.12
CD(0.05)	19.49	55.56	8.15	8.15	11.77	20.62

4.3.10 Available Fe

Data on available Fe content in the soil as influenced by soil amelioration practices are furnished in Table 11. The soil was with high iron toxicity. The soil available Fe content decreased due to soil amelioration practices. The treatment without dolomite application was superior with respect to soil available Fe at both PI and harvesting stages (411.99 mg kg^{-1} and 333.20 mg kg^{-1}) compared to other treatments. Granulated dolomite as basal + 30 DAS registered significantly lower values at both the stages.

4.3.11 Available Mn

The data on available Mn status as influenced by soil amelioration practices is depicted in Table 11. Significantly higher soil Mn content (3.74 mg kg^{-1}) was recorded by the treatment with ordinary dolomite as basal+30 DAS (D_1) which was on par with D_2 at harvesting stage. No significant effect of soil amelioration practices on available Mn status of soil was noticed at PI stage.

4.3.12 Available Zn

The data on available Zn content in soil is given in Table 11. Effect of soil amelioration practices was found to be non - significant on soil available zinc content at both PI and harvest stages.

4.3.13 Available Cu

Available Cu content also showed similar trend as in Zn (Table 12). Soil amelioration practices failed to express significant effect on soil available Cu at both PI and harvesting stages.

Table 11. Effect of soil amelioration practices on Fe, Mn and Zn in soil at PI and harvest stages

Treatment	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})	
	PI	Harvest	PI	Harvest	PI	Harvest
D_0	333.20	411.99	2.60	3.44	2.93	6.01
D_1	312.13	335.32	2.72	3.74	3.17	6.53
D_2	283.46	325.03	2.70	3.72	3.20	6.57
SEm (±)	4.57	7.74	0.12	0.089	0.10	022
CD(0.05)	13.25	22.42	NS	0.258	NS	NS

4.3.14 Available B

Available B content in the soil was significantly influenced by soil amelioration practices as presented in Table 12. Granulated dolomite as basal + 30 DAS (D_2) recorded the highest soil available B (0.550 mg kg^{-1}) at PI stage and at harvest the available B status was on par with D_1 (0.430 mg kg^{-1}and 0.410 mg kg^{-1}respectively). The lowest available B was obtained for treatment without dolomite application (D_0).

4.3.15 Available Na

Table 12 depicts the effect of soil amelioration practices on available Na content in soil. The sodium content in the soil decreased from the initial value (220.73 mg kg^{-1}) at all the stages. At both PI and harvesting stage treatment without dolomite application (D_0) obtained the highest value (211.79 mg kg^{-1} and 209.87 mg kg^{-1} respectively) compared to all other treatments.

Table 12.Effect of soil amelioration practices on Cu, B and Na in soil at PI and harvest stages

Treatment	Cu (mg kg^{-1})		B (mg kg^{-1})		Na (mg kg^{-1})	
	PI	Harvest	PI	Harvest	PI	Harvest
D_0	0.95	1.88	0.460	0.353	211.79	209.87
D_1	0.95	1.99	0.480	0.410	175.27	175.87
D_2	1.03	2.04	0.550	0.430	183.81	174.31
SEm (±)	0.05	0.07	0.02	0.018	5.90	5.54
CD(0.05)	NS	NS	0.06	0.053	17.10	16.07

4.4 PLANT ANALYSIS

4.4.1. Nutrient Content in Grain and Straw at Harvest

Nutrient status of grain and straw at harvest stage as influenced by soil amelioration, foliar nutrition and their interaction effects are presented in Table 13, 14, 15 and 16.

4.4.1.1 Nitrogen

The N content in grain and straw was analysed at harvest and the values are presented in Table 13.

Nitrogen content in grain responded significantly to soil amelioration practices and higher N content was recorded in D_2 (1.79%) which was on par with D_1. With regard to N content in straw no significant difference was observed between soil amelioration practices.

Foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) recorded the highest N content in grain (2.30%) and foliar nutrition of 1% potassium nitrate (N_1) and N_3 obtained significantly higher N content in straw (1.94 % and 1.93%, respectively). Significantly lower N content was obtained in N_0 for both grain and straw.

Among the treatment combinations, granulated dolomite as basal + 30 DAS along with potassium nitrate (1%) + micronutrient solution (0.5%) (D_2N_3) recorded higher N content in grain (2.71 %) which was on par with D_2N_4, D_1N_3 and D_1N_1 and ordinary dolomite as basal + 30 DAS along with N_3 (D_1N_3) obtained the highest N content in straw (2.25 %).

4.4.1.2 Phosphorus

Phosphorus content of grain and straw was significantly influenced by soil amelioration practices, foliar nutrition and their interaction and data are given in Table 13. Among soil amelioration practices, the highest P content in grain was observed with D_2 (0.345 %), which was on par with D_1 (0.344 %) and in straw, the highest P content was observed with D_0.

In grain, foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) recorded the highest P content (0.347%) which was on par with N_0 and was significantly superior to other treatments. Maximum P content in straw (0.208%) was observed with foliar nutrition of (1%) potassium nitrate (N_1).

Among treatment combinations, D_1N_1 recorded higher P content in grain (0.376%) which was on par with D_2N_3 and in straw higher P content was obtained in D_0N_1 (0.247 %).

4.4.1.3 Potassium

Potassium content in grain and straw was significantly influenced by individual treatments and their interactions (Table 13). In grain and straw, higher K content (1.31% and 1.79% respectively) was recorded in D_2 compared to other treatments.

Foliar application of 1% potassium nitrate (N_1) recorded the highest K content in both grain and straw (1.49 % and 1.86 % respectively).

Significant interaction effects between soil amelioration practices and foliar nutrition on K content was observed. Significantly higher K content in grain (1.77 %) was recorded by application of granulated dolomite as basal + 30 DAS along with foliar application of 1 % potassium nitrate (D_2N_1) and in straw, treatment with application of ordinary dolomite along with foliar spray of 1 % potassium silicate (D_1N_2) obtained the highest (1.99%) K content which was on par with D_2N_1, D_2N_2, D_2N_3 and D_2N_4.

4.4.1.4 Calcium

Soil amelioration practices, foliar nutrition and their interaction significantly influenced the Ca content in grain and straw (Table 14). The highest Ca content in both grain and straw was obtained by application of granulated dolomite as basal + 30 DAS (0.266% and 0.287% respectively).Foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) registered higher Ca content in both grain and straw (0.267% and 0.288%) which was on par with foliar application of (1%) potassium nitrate (N_1) and was significantly superior to other treatments.

Application of granulated dolomite as basal + 30 DAS along with foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (D_2N_3) obtained highest Ca content in grain (0.329 %) which was on par with D_2N_2 and D_1N_1. In straw, granulated dolomite as basal+30 DAS along with foliar nutrition of potassium silicate (1%) (D_2N_2) recorded higher Ca content (0.330%) which was on par with D_2N_3 and D_1N_1.

4.4.1.5 Magnesium

Treatment effect on Mg with respect to soil amelioration practices, foliar nutrition and their interaction is depicted in Table 14. Magnesium content in both grain and straw was significantly enhanced by granulated dolomite as basal + 30DAS (0.150% and 0.195 % respectively) compared to D_1 and D_0. Maximum Mg content in grain (0.155%) was recorded in treatment with foliar nutrition of 1 % potassium nitrate (N_1) which was on par with application of potassium silicate (1%) + micronutrient solution (0.5%) (N_4). In straw also, N_1 obtained the highest Mg content (0.184%) which was on par with N_0 and N_4.

Application of granulated dolomite as basal + 30 DAS along with foliar application of potassium silicate (1%) (D_2N_2) significantly enhanced the Mg content of grain (0.186%) and Mg content in straw was increased (0.213%) by the application of granulated dolomite as basal +30 DAS along with foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) followed by D_2N_2, D_2N_0, D_1N_4 and D_1N_1.

Table 13. Effect of dolomite application, foliar nutrition and their interaction effects on N, P and K content in grain and straw after harvest (%)

	N (%)		P (%)		K (%)	
Dolomite Application	Grain	Straw	Grain	Straw	Grain	Straw
D_0	1.22	1.34	0.329	0.185	1.11	1.60
D_1	1.72	1.43	0.344	0.173	1.19	1.67
D_2	1.79	1.51	0.345	0.163	1.31	1.79
SEm (±)	0.097	0.081	0.003	0.002	0.017	0.026
CD(0.05)	0.282	NS	0.010	0.007	0.049	0.075
Foliar nutrition						
N_0	0.97	0.85	0.346	0.171	1.00	1.41
N_1	1.92	1.94	0.335	0.208	1.49	1.86
N_2	1.02	1.19	0.331	0.158	1.14	1.75
N_3	2.30	1.93	0.347	0.172	1.27	1.69
N_4	1.66	1.25	0.337	0.160	1.13	1.73
SEm (±)	0.126	0.104	0.003	0.003	0.022	0.034
CD(0.05)	0.365	0.303	0.008	0.009	0.009	0.097
Interaction effects						
D_0N_0	0.81	0.60	0.353	0.167	0.97	1.29
D_0N_1	1.73	1.76	0.289	0.247	1.28	1.63
D_0N_2	0.37	0.85	0.329	0.168	1.30	1.72
D_0N_3	1.83	1.87	0.340	0.182	1.40	1.70
D_0N_4	1.37	1.62	0.335	0.163	1.11	1.65
D_1N_0	0.77	1.10	0.329	0.179	0.93	1.51
D_1N_1	2.24	1.86	0.376	0.204	1.41	1.64
D_1N_2	1.98	1.02	0.350	0.154	1.27	1.99
D_1N_3	2.36	2.25	0.341	0.168	1.22	1.62
D_1N_4	1.23	0.94	0.325	0.160	1.14	1.60
D_2N_0	1.34	0.85	0.356	0.166	1.11	1.43
D_2N_1	1.79	2.16	0.339	0.171	1.77	1.98
D_2N_2	0.71	1.69	0.314	0.151	0.85	1.85
D_2N_3	2.71	1.68	0.361	0.167	1.11	1.74
D_2N_4	2.39	1.20	0.353	0.157	1.14	1.93
SEm (±)	0.200	0.181	0.006	0.005	0.038	0.158
CD(0.05)	0.591	0.524	0.016	0.015	0.109	0.169

Table 14. Effect of dolomite application, foliar nutrition and their interaction effects on Ca, Mg and S in grain and straw after harvest (%)

	Ca (%)		Mg (%)		S (%)	
Dolomite Application	Grain	Straw	Grain	Straw	Grain	Straw
D_0	0.168	0.205	0.131	0.155	0.206	0.327
D_1	0.245	0.275	0.136	0.167	0.240	0.263
D_2	0.266	0.287	0.150	0.195	0.217	0.281
SEm (±)	0.004	0.003	0.002	0.004	0.035	0.009
CD(0.05)	0.012	0.010	0.004	0.011	NS	0.027
Foliar nutrition						
N_0	0.213	0.250	0.144	0.176	0.183	0.303
N_1	0.260	0.282	0.155	0.184	0.247	0.302
N_2	0.237	0.263	0.138	0.164	0.227	0.209
N_3	0.267	0.288	0.109	0.164	0.223	0.335
N_4	0.153	0.197	0.151	0.173	0.225	0.302
SEm (±)	0.005	0.004	0.002	0.005	0.035	0.015
CD(0.05)	0.016	0.013	0.006	0.015	0.012	0.045
Interaction effects						
D_0N_0	0.183	0.207	0.115	0.150	0.152	0.288
D_0N_1	0.222	0.250	0.159	0.177	0.290	0.435
D_0N_2	0.145	0.170	0.147	0.170	0.213	0.267
D_0N_3	0.206	0.240	0.098	0.120	0.157	0.350
D_0N_4	0.104	0.160	0.137	0.160	0.220	0.293
D_1N_0	0.241	0.290	0.142	0.177	0.238	0.303
D_1N_1	0.303	0.317	0.159	0.190	0.233	0.388
D_1N_2	0.261	0.290	0.081	0.117	0.237	0.168
D_1N_3	0.283	0.303	0.135	0.160	0.273	0.260
D_1N_4	0.147	0.177	0.169	0.193	0.216	0.193
D_2N_0	0.225	0.253	0.174	0.200	0.160	0.318
D_2N_1	0.264	0.280	0.147	0.187	0.218	0.082
D_2N_2	0.315	0.330	0.186	0.207	0.230	0.192
D_2N_3	0.329	0.320	0.098	0.213	0.238	0.395
D_2N_4	0.220	0.253	0.147	0.167	0.238	0.420
SEm (±)	0.009	0.008	0.003	0.009	0.021	0.027
CD(0.05)	0.027	0.022	0.01	0.025	0.061	0.077

4.4.1.6 Sulphur

The mean data on S content of grain and straw are presented in Table 14. No significant effect on S content in grain was seen by soil amelioration practices. In straw, treatment without dolomite application (D_0) recorded the highest (0.327%) S content compared to other treatments. Foliar nutrition of 1 % potassium nitrate (N_1) obtained higher S content in grain (0.247%) and in case of straw foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) recorded the highest (0.335%) S content followed by all other treatments except N_2.

Among interaction effects, treatment without dolomite application along with foliar nutrition of potassium nitrate (1%) recorded the highest S content (0.290% and 0.435% respectively) in both grain and straw and in straw it was on par with D_2N_4, D_2N_3 and D_1N_1.

4.4.1.7 Iron

The Fe content in grain and straw was significantly influenced by soil amelioration, foliar nutrition and their interaction and data are presented in Table 15. The treatment without dolomite application obtained the highest Fe content in both grain and straw (250.46 mg kg^{-1} and 581.93 mg kg^{-1} respectively) and in grain which was on par with D_1. Foliar nutrition of potassium nitrate (1%) registered the highest Fe content in both grain and straw (256.33 mg kg^{-1} and 655.60 mg kg^{-1} respectively) compared to all other treatments.

Among interaction effects, application of granulated dolomite as basal+30 DAS along with foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (D_2N_3) recorded the highest Fe content (293 mg $kg^{-1}$and 944.33 mg kg^{-1} respectively) in both grain and straw and in straw it was on par with D_1N_1 and D_0N_4.

4.4.1.8 Manganese

Manganese content in grain and straw was significantly influenced by soil amelioration practices, foliar nutrition and their interactions and are presented in Table 15. The higher Mn content in grain (15.14 mg kg^{-1}) was obtained by application of ordinary dolomite as basal + 30 DAS and was on par with D_2, and in straw application of granulated dolomite as basal + 30 DAS recorded the highest (12.68 mg kg^{-1}) Mn content. Foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) recorded the highest (15.53 mg $kg^{-1}$and 14.66 mg kg^{-1} respectively) Mn content in both grain and straw compared to other treatments.

Application of granulated dolomite as basal + 30 DAS along with foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (D_2N_3) obtained highest Mn (16.32 mg kg^{-1}) content in grain which was on par with D_2N_4 and D_1N_3. In straw foliar nutrition of potassium silicate (1%) + micronutrient solution (0.5%) recorded highest (16.01 mg kg^{-1}) Mn content which was on par with D_2N_3

4.4.1.9 Zinc

Zinc content of grain and straw was significantly influenced by soil amelioration practices, foliar nutrition and their interaction (Table 15). Among soil amelioration practices treatment without dolomite obtained the highest Zn content in grain (52.22 mg kg^{-1}) and in straw, application of dolomite as basal + 30 DAS recorded the highest Zn content (55.56 mg kg^{-1}).Foliar nutrition of potassium silicate (1%) + micronutrient solution (0.5%) (N_4) obtained highest Zn content (50.27 mg $kg^{-1}$and 62 mg kg^{-1} respectively) in both grain and straw compared to other treatments.

Treatment without dolomite application along with potassium silicate (1%) + micronutrient solution (0.5%) (D_0N_4) showed the highest Zn content (61.70 mg kg^{-1}) in grain and granulated dolomite as basal + 30 DAS along with FS of potassium silicate (1%) + micronutrient solution (0.5%) (D_2N_4) showed the highest Zn content (74.56 mg kg^{-1}) in straw which was significantly superior to all other treatments.

4.4.1.10 Copper

Data on the effect of soil amelioration practices, foliar nutrition and their interaction effects on Cu content in grain and straw are given in Table 14. The highest Cu content in grain (9.72 mg kg^{-1}) was obtained by treatment without dolomite application compared to other treatments. Significant effect was not observed in Cu content in straw with respect to soil amelioration practices. Foliar nutrition and their interaction with soil amelioration practices did not influence the Cu content in grain significantly.

No major influence of soil amelioration practices, foliar nutrition and their interaction were observed in Cu content in straw.

4.4.1.11 Boron

The effect of soil amelioration, foliar nutrition and their interaction effects on B content in grain and straw are shown in Table 15. No significant effects were found on B content in grain due to soil amelioration practices, foliar nutrition and their interaction.

The effect of soil amelioration practices and foliar nutrition significantly influenced the B content in straw. Application of granulated dolomite as basal + 30 DAS obtained the highest (19.73 mg kg^{-1}) B content. In case of foliar nutrition, N_3 significantly enhanced the B content (20.44 mg kg^{-1}) followed by N_4. Interaction effects of main treatments were not significant.

4.4.1.12 Sodium

Soil amelioration practices, foliar nutrition and their interactions significantly influenced Na contents in grain and straw (Table 15). Sodium content in grain was highest (418.73 mg kg^{-1}) in application of granulated dolomite as basal+30 DAS and was on par with D_1. In straw, application of ordinary dolomite as basal + 30 DAS obtained highest (7047.60 mg kg^{-1}) Na content. With regard to foliar nutrition, in grain, foliar spray of potassium silicate (1%) was significantly superior (445.66 mg kg^{-1}) to other treatments and in straw N_4 obtained the highest Na content (7908.67 mg kg^{-1}) which was on par with N_1.

Among interactions, treatment with no dolomite along with potassium silicate (1%) (D_0N_2) obtained the highest (604.66 mg kg^{-1}) Na content in grain and in straw ordinary dolomite as basal+30 DAS along with of potassium silicate (1%) + micronutrient solution (0.5%) (D_1N_4) recorded the highest (9939.33 mg kg^{-1}) Na content.

Table 15. Effect of dolomite application, foliar nutrition and their interaction effects on Fe, Mn and Zn in grain and straw after harvest (mg kg^{-1})

	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})	
Dolomite Application	Grain	Straw	Grain	Straw	Grain	Straw
D_0	250.46	581.93	13.26	10.97	52.22	40.95
D_1	241.20	492.80	15.14	12.31	33.11	45.21
D_2	233.33	472.93	14.86	12.68	33.34	55.56
SEm (±)	3.53	9.47	0.093	0.089	0.23	0.59
CD(P < 0.05)	10.25	27.44	0.271	0.258	0.68	1.73
Foliar nutrition						
N_0	235.77	504.11	13.23	10.97	36.92	39.51
N_1	256.33	713.66	13.72	12.31	36.85	45.41
N_2	220.55	403.88	14.73	12.68	32.71	37.04
N_3	254.11	609.44	15.53	14.66	41.02	52.24
N_4	241.55	593.11	14.89	14.19	50.27	62.00
SEm (±)	4.56	12.23	0.121	0.115	0.30	0.77
CD(0.05)	13.23	35.43	0.350	0.333	0.88	2.23
Interaction effects						
D_0N_0	241.33	283.33	11.03	10.11	45.26	37.10
D_0N_1	266.00	806.33	12.68	11.24	46.73	36.20
D_0N_2	237.00	447.66	15.35	12.04	38.73	28.46
D_0N_3	218.66	408.33	14.18	13.16	58.66	37.46
D_0N_4	289.33	419.00	13.07	12.35	61.70	65.53
D_1N_0	211.66	563.33	15.39	11.54	30.46	43.80
D_1N_1	291.00	487.66	14.12	13.12	32.83	43.80
D_1N_2	228.00	371.00	14.68	12.89	27.10	38.36
D_1N_3	250.66	475.66	16.10	15.15	31.03	54.20
D_1N_4	224.66	566.33	15.42	14.21	44.13	45.90
D_2N_0	254.33	665.66	13.28	11.27	35.03	37.63
D_2N_1	212.00	847.00	14.36	12.57	31.00	56.23
D_2N_2	196.66	393.00	14.18	13.11	32.30	44.30
D_2N_3	293.00	944.33	16.32	15.67	33.36	65.06
D_2N_4	210.66	794.00	16.19	16.01	35.00	74.56
SEm (±)	7.91	21.18	0.209	0.199	0.52	1.33
CD(0.05)	22.92	61.37	0.609	0.577	1.53	3.87

Table 16. Effect of dolomite application, foliar nutrition and their interaction effects on Cu, B and Na in grain and straw after harvest (mg kg^{-1})

	Cu (mg kg^{-1})		B (mg kg^{-1})		Na (mg kg^{-1})	
Dolomite Application	Grain	Straw	Grain	Straw	Grain	Straw
D_0	9.72	6.27	17.06	18.33	418.73	4,875.40
D_1	6.40	5.21	16.93	18.66	387.20	7,047.60
D_2	5.66	5.67	16.60	19.73	356.53	6,531.93
SEm (±)	0.53	0.49	1.05	0.316	10.985	167.11
CD(0.05)	1.56	NS	NS	0.916	31.821	484.10
Foliar nutrition						
N_0	7.63	4.51	15.77	18.22	390.33	5,235.89
N_1	7.72	6.32	16.66	18.77	354.22	7,361.67
N_2	7.29	5.33	16.66	18.11	445.66	3,653.22
N_3	6.67	6.95	17.44	20.44	359.00	6,598.78
N_4	7.00	5.46	17.77	19.00	388.22	7,908.67
SEm (±)	0.69	0.64	1.35	0.40	14.18	215.73
CD(0.05)	NS	NS	NS	1.18	41.08	624.97
Interaction effects						
D_0N_0	11.60	6.01	16.00	17.66	405.66	3,093.33
D_0N_1	8.46	6.05	17.00	17.33	432.00	8,016.00
D_0N_2	11.73	5.43	17.00	18.66	604.66	2,981.00
D_0N_3	7.69	7.69	17.00	19.33	406.33	5,210.33
D_0N_4	9.14	6.17	18.33	18.66	327.00	5,076.33
D_1N_0	5.99	4.74	16.00	18.00	348.66	8,831.67
D_1N_1	7.87	6.28	16.33	18.66	368.66	5,345.67
D_1N_2	5.50	5.20	17.33	17.33	367.33	4,698.00
D_1N_3	6.43	5.23	17.00	20.00	365.00	7,652.33
D_1N_4	6.24	4.60	18.00	19.33	333.00	9,939.33
D_2N_0	5.31	2.77	15.33	19.00	416.66	3,782.67
D_2N_1	6.84	6.64	16.66	20.33	262.00	8,723.33
D_2N_2	4.63	5.38	15.66	18.33	365.00	3,280.67
D_2N_3	5.89	7.94	18.33	22.00	305.66	6,933.67
D_2N_4	5.63	5.62	17.00	19.00	504.66	9,939.33
SEm (±)	1.20	1.11	2.35	0.70	24.56	430.23
CD(0.05)	NS	NS	NS	NS	71.15	1,252.79

4.5 UPTAKE OF NUTRIENTS

4.5.1 Nutrient uptake by grain and straw

Mean data on uptake of nutrients such as N, P, K, Ca, Mg and S by grain and straw are depicted in Table 17 and Table18.

4.5.1.1 Nitrogen uptake

Application of granulated dolomite as basal + 30 DAS increased the uptake of nitrogen (117.48 kg ha^{-1} and 131.60 kg ha^{-1}) by grain and straw significantly (Table 17). In grain it was on par with ordinary dolomite application as basal + 30 DAS. Foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) recorded the highest (149.41 kg ha^{-1}) N uptake by grain and in straw, foliar spray of potassium nitrate (1%) alone recorded higher (164.79 kg ha^{-1}) uptake of N which was on par with N_3.

Among the interaction, application of granulated dolomite as basal + 30 DAS along with (1%) potassium nitrate + (0.5%) micronutrient solution (D_2N_3) recorded higher N uptake (182.96 kg ha^{-1}) by grain. In straw higher N uptake (196.77 kg ha^{-1}) was obtained by application of granulated dolomite as basal + 30 DAS along with of potassium nitrate (1%) alone.

4.5.1.2 Phosphorus uptake

The mean data on P uptake (Table 17) showed that higher P uptake by grain and straw (22.43 kg $ha^{-1}$and 13.91 kg ha^{-1}respectively) was obtained with granulated dolomite as basal + 30 DAS (D2) which was on par with D_1 in grain and D_0 in straw.

Application of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) as foliar nutrition recorded higher (22.37 kg ha^{-1}) P uptake by grain which was on par with all other treatments except treatment without foliar nutrition. In straw, foliar nutrition of potassium nitrate (1%) recorded the highest (17.64 kg ha^{-1}) P uptake compared to all other treatments. Effect of interaction did not differ significantly with respect to P uptake by both grain and straw.

4.5.1.3 Potassium uptake

The effect of soil amelioration, foliar nutrition and their interaction effects on K uptake in grain and straw is presented in Table 17. Uptake of K by straw was found the highest (153.95 kg ha^{-1}) in application of granulated dolomite as basal + 30 DAS. Soil amelioration practices failed to produce significant effect on uptake of potassium in grain.

Foliar nutrition of potassium nitrate (1%) obtained higher (94.42 kg ha^{-1} and 150.85 kg ha^{-1} respectively) K uptake by grain and straw and in straw (150.85kg ha^{-1}) it was on par with N_2 and N_3. Among interaction effects, the highest uptake of K (103.60 kg ha^{-1}) by grain was observed in treatment with granulated dolomite application along with potassium nitrate (1%) followed by D_1N_1 and D_0N_1 and interaction effects were not significant on K uptake by straw.

4.5.1.4 Calcium uptake

Calcium uptake by grains and straw was significantly influenced by soil amelioration practices, foliar nutrition and their interaction (Table 18). Calcium uptake by grain and straw was significantly higher (18.73 kg $ha^{-1}$and 24.60 kg ha^{-1} respectively) in granulated dolomite application as basal + 30 DAS (D_2) compared to other treatments.

Higher Ca uptake (18.53 kg ha^{-1}) by grain was obtained with foliar nutrition of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) which was on par with N_1 and uptake of calcium (24.21 kg ha^{-1}) by straw was higher by the application of potassium nitrate (1%) alone and was on par with N_3.

In case of interaction, application of granulated dolomite as basal + 30 DAS along with potassium nitrate (1%) +micronutrient solution (0.5%) (D_2N_3) recorded higher (21.49 kg ha^{-1} and 29.90kg ha^{-1}respectively) Ca uptake by grain and straw.

4.5.1.5 Magnesium uptake

Magnesium uptake by grain and straw (Table 18) was found to be significantly superior (9.71 kg ha^{-1} and 16.63 kg ha^{-1} respectively) in the application of granulated dolomite as basal +30 DAS (D_2). Foliar nutrition of potassium nitrate (1%) alone (N_1) recorded higher (9.90 kg $ha^{-1}$and 15.85 kg ha^{-1} respectively) Mg uptake by grain and straw and in grain it was on par with N_4 and in straw N_1 was superior in Mg uptake.

Among interaction effects, granulated dolomite as basal + 30 DAS along with potassium silicate (1%) (D_2N_2) recorded the highest (12 kg ha^{-1}) Mg uptake by grain which was on par with D_1N_4. Application of potassium nitrate (1%) + micronutrient solution (0.5%) (D_2N_3) as foliar nutrition obtained significantly higher (19.94 kg ha^{-1}) Mg uptake by straw which was on par with D_2N_2 and D_2N_1 compared to all other treatments.

4.5.1.6 Sulphur uptake

Sulphur uptake by grain and straw was significantly influenced by soil amelioration practices, foliar nutrition and their interaction (Table 18). Ordinary dolomite application as basal+30 DAS recorded higher (14.45 kg ha^{-1}) uptake of S by grain which was on par with D_2. Higher S uptake by straw was (24.15 kg ha^{-1}) obtained by application of granulated dolomite as basal + 30 DAS (D_2) and was on par with $D_{0.}$

Foliar nutrition with potassium nitrate (1%) alone (N_1) recorded the highest sulphur uptake by grain (15.65 kg ha^{-1}) and significantly higher uptake of S (26.45 kg ha^{-1}) by straw was obtained by application of potassium nitrate (1%) + micronutrient solution (0.5%) (N_3) which was on par with N_1 and N_4.

Application of ordinary dolomite as basal + 30 DAS along with potassium nitrate (1%) micronutrient solution (0.5%) (D_1N_3) registered higher (17.53 kg ha^{-1}) S uptake by grain and in straw, higher S uptake (37.02 kg ha^{-1}) was recorded by application of granulated dolomite as basal + 30 DAS along with potassium nitrate (1%) + micronutrient solution (0.5%) (D_2N_3) followed by D_2N_4, D_1N_1 and D_0N_1.

Table 17. Effect of dolomite application, foliar nutrition and their interaction effects on uptake of N, P and K in grain and straw after harvest (kg ha^{-1})

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
Dolomite Application	Grain	Straw	Grain	Straw	Grain	Straw
D_0	71.36	97.23	18.55	13.35	72.94	115.34
D_1	106.49	101.34	20.96	11.86	73.12	125.35
D_2	117.48	131.61	22.43	13.91	75.04	153.95
SEm (±)	6.74	6.88	0.687	0.57	2.34	5.59
CD(0.05)	19.53	19.95	1.991	1.65	NS	16.19
Foliar nutrition						
N_0	51.89	54.54	17.95	10.72	52.06	89.68
N_1	123.07	164.79	21.50	17.64	94.42	150.85
N_2	61.73	89.85	20.17	11.86	69.23	140.37
N_3	149.41	148.98	22.37	13.31	81.84	131.88
N_4	106.11	92.15	21.24	11.68	70.88	128.29
SEm (±)	8.70	8.89	0.887	0.73	3.02	7.21
CD(0.05)	25.21	25.75	2.57	2.13	8.76	20.90
Interaction effects						
D_0N_0	37.47	33.32	16.38	9.25	45.09	72.24
D_0N_1	101.64	139.13	16.92	20.00	89.69	132.80
D_0N_2	21.32	57.843	18.82	12.02	74.61	123.80
D_0N_3	112.83	135.58	20.84	13.21	86.31	123.53
D_0N_4	83.54	120.31	19.79	12.29	65.33	124.37
D_1N_0	41.78	66.82	17.29	10.44	48.14	89.13
D_1N_1	142.68	158.48	23.93	17.34	89.91	139.45
D_1N_2	121.44	75.46	21.34	11.42	77.66	148.76
D_1N_3	152.45	153.05	21.97	11.15	79.28	108.91
D_1N_4	74.10	52.90	20.26	8.98	70.59	90.50
D_2N_0	76.43	63.48	20.19	12.48	62.95	107.67
D_2N_1	124.88	196.77	23.66	15.59	103.60	180.32
D_2N_2	42.44	136.25	20.34	12.14	55.42	148.57
D_2N_3	182.96	158.33	24.30	15.57	79.94	163.21
D_2N_4	160.70	103.237	23.673	13.76	76.74	170.02
SEm (±)	15.07	15.40	1.53	1.27	5.24	12.49
CD(0.05)	43.68	44.61	NS	NS	NS	NS

Table 18. Effect of dolomite application, foliar nutrition and their interaction effects on uptake of Ca, Mg and S in grain and straw after harvest (kg ha^{-1})

Treatments	Ca uptake (kg ha^{-1})		Mg uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
Dolomite Application	Grain	Straw	Grain	Straw	Grain	Straw
D_0	11.62	14.67	7.44	11.11	11.70	23.42
D_1	16.69	19.17	8.28	11.32	14.45	18.16
D_2	18.73	24.60	9.71	16.63	14.25	24.15
SEm (±)	049	0.73	0.303	0.58	0.59	1.18
CD(0.05)	1.42	2.12	0.87	1.69	1.72	3.42
Foliar nutrition						
N_0	13.04	15.85	7.54	11.23	9.47	19.37
N_1	18.11	24.21	9.90	15.85	15.65	25.16
N_2	16.24	20.11	8.46	12.51	13.77	15.63
N_3	18.53	22.47	6.97	13.03	14.42	26.45
N_4	12.484	14.760	9.51	12.50	14.02	22.96
SEm (±)	0.63	0.94	0.39	0.75	0.76	1.52
CD(0.05)	1.83	2.746	1.13	2.19	0.22	4.42
Interaction effects						
D_0N_0	9.59	11.49	5.33	8.32	7.03	16.03
D_0N_1	14.65	20.26	9.30	14.39	16.99	35.09
D_0N_2	9.78	12.27	8.43	12.27	12.24	18.90
D_0N_3	14.59	17.22	6.00	8.51	9.54	25.21
D_0N_4	9.50	12.12	8.13	12.08	12.69	21.86
D_1N_0	15.13	17.05	7.43	10.33	12.18	18.17
D_1N_1	20.17	26.87	10.16	16.11	14.81	32.89
D_1N_2	17.68	21.63	4.96	8.65	14.34	12.51
D_1N_3	19.52	20.30	8.33	10.64	17.53	17.11
D_1N_4	10.95	10.01	10.53	10.90	13.39	10.15
D_2N_0	14.39	19.03	9.86	15.03	9.19	23.91
D_2N_1	19.53	25.51	10.23	17.05	15.16	17.49
D_2N_2	21.26	26.43	12.00	16.61	14.73	15.48
D_2N_3	21.49	29.90	6.60	19.94	16.19	37.02
D_2N_4	16.99	22.15	9.86	14.51	15.97	36.88
SEm (±)	1.10	1.64	0.68	1.31	1.33	2.64
CD(0.05)	3.18	4.75	1.96	3.79	3.85	7.66

4.6 DISEASE AND PEST INCIDENCE

Sheath rot caused by the fungus *Sarocladium oryzae* and Brown spot by *Helminthosporium oryzae* were the major diseases observed in the plants during the cropping period. Grain discoloration due to iron toxicity was also noticed in the field. The major pests noticed in the experimental field were white stem borer (*Scripophaga innotata*), and rice bug (*Leptocorisa acuta*).

4.7 ECONOMIC ANALYSIS

The economics of cultivation is presented in Table 19. The highest gross income was obtained by the treatment D_2N_1 (Rs 213900 ha^{-1}). The maximum net return (Rs 123788 ha $^{-1}$) and maximum BCR (2.48) were obtained by the treatment D_1N_3.

Table 19. Effect of different treatments on economics of cultivation

Treatments	**Cost of cultivation (Rs ha^{-1})**	**Gross income (Rs ha^{-1})**	**Net income (Rs ha^{-1})**	**BCR**
D_0N_0	77512	144900	67388	1.86
D_0N_1	78512	186300	107788	2.37
D_0N_2	81512	174000	92488	2.13
D_0N_3	81012	189900	108888	2.34
D_0N_4	84012	184200	100188	2.19
D_1N_0	80012	165000	84988	2.06
D_1N_1	81012	196500	115488	2.42
D_1N_2	84012	189000	104988	2.24
D_1N_3	83512	207300	123788	2.48
D_1N_4	86512	199500	112988	2.30
D_2N_0	91512	182400	90888	1.99
D_2N_1	92512	213900	121388	2.31
D_2N_2	95512	202800	107288	2.12
D_2N_3	95012	211500	116488	2.22
D_2N_4	98012	207900	109888	2.12

Plate 14. Brown spot

Plate 15. Sheath rot

Plate 16. Grain discolouration

Plate 17. Stem borer attack

Discussion

5. DISCUSSION

An investigation entitled "Enhancing grain yield and quality through soil amelioration and foliar nutrition in Rice (*Oryza sativa* L.) in *Vaikom Kari* soils" was undertaken during *puncha* season (2020-21) to augment grain yield and quality of rice crop in *Vaikom Kari* soils, and the results of the experimental research presented in previous chapter are discussed below.

5.1 GROWTH CHARACTERS

5.1.1 Effect of soil amelioration practices on plant height, number of tillers and LAI

Soil amelioration practices had a significant effect on growth characters of rice at all the growth stages. This is evident from the higher values of plant height, number of tillers and LAI registered by dolomite applied plots as seen in Table 5 and Fig .3, Fig.4 and Fig. 5. Application of dolomite significantly influenced the plant height at both PI and harvesting stages and it was non-significant at maximum tillering stage. The highest value of plant height was obtained in treatment with granulated dolomite application as basal + 30 DAS and the lowest was obtained in treatment without dolomite application. LAI and number of tillers was also significantly superior in treatments with granulated dolomite application at both MT and PI stages and the lowest was recorded in treatment with no dolomite application. Increase in plant height and number of tillers resulted in more number of leaves which in turn resulted in higher LAI. The increased plant height, maximum number of tillers and the highest LAI on treatment with granulated dolomite might be due to the action of dolomite reducing the Fe and Al toxicity of soil which resulted in improved plant growth. Dolomite reduces the soil pH as well as provide additional supply of Ca and Mg which improves the growth characters. This is evident from the findings of Aslam *et al*. (2002), who reported the improved growth characteristics such as tillering capacity and shoot lengths and root lengths by an external supply of Ca resulting in higher yield of rice. Bose *et al.* (2011), stated that Mg is an essential element for various physiological and biochemical processes which affect the development and growth and also ameliorate

Al phytotoxicity. Similar results were also reported by Suswanto *et al*. (2007); Soltani *et al*. (2016) and Elisa *et al*. (2016).

5.1.2 Effect of soil amelioration and foliar nutrition on total dry matter production

The data of results revealed that dry matter production at harvest was influenced by the treatments. The application of granulated dolomite as basal and at 30 DAS recorded higher dry matter production than ordinary dolomite and no dolomite application and foliar application of 1% KNO_3 gave the highest dry matter production which was on par with all other treatments except treatment without foliar application. Interaction of main treatments were not significant on TDMP. The plant growth characters such as plant height, number of tillers and more number of leaves are favourably influenced by dolomite application which might have contributed to higher dry matter production. Higher leaf area for photosynthesis along with more number of tillers increased the growth of the plant and hence obtained higher dry matter production. Foliar application of potassium fertilizers might have increased the chlorophyll content and grain yield which resulted in higher TDMP. In *Kari* soils the plants suffer from poor root health during PI stage. In case of treatment without foliar nutrition the uptake of nutrients especially N and K during critical stage of plant growth might have been affected resulting in lower grain yield, straw yield and TDMP. Potassium is a major element which involved in enzyme activation which controls metabolic reactions, helps in uptake and translocation of photosynthates and in turn resulted in accumulation of dry matter in plants. Jagathijothi *et al*. (2012) observed that foliar nutrients tend to increase the rate of photosynthesis and carbohydrate translocation which in turn increased the dry matter production.

5.2 YIELD AND YIELD ATTRIBUTES

5.2.1 Effect of soil amelioration and foliar nutrition on yield attributes

Results of the study revealed that various yield attributes such as number of productive tillers m^{-2}, percentage of filled grains and thousand grain weight were significantly influenced by soil amelioration practices and by foliar nutrition. The interaction of treatments failed to produce significant effect on yield attributes. Number of productive tillers, percentage of filled grains and thousand grain weight was

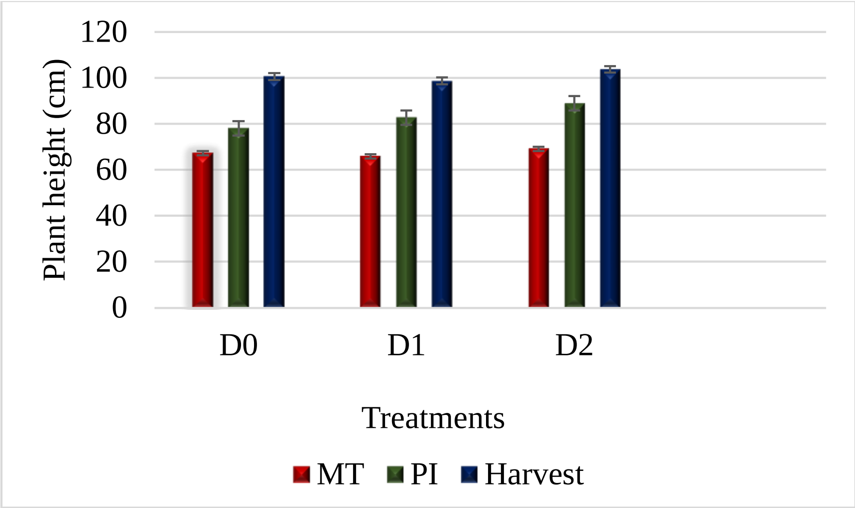

Fig.3 Effect of soil amelioration practices on plant height

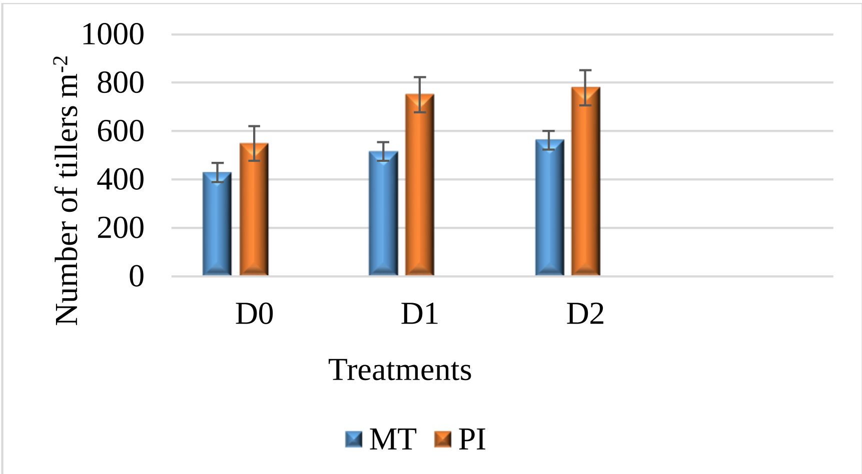

Fig.4 Effect of soil amelioration practices on number of tillers m^{-2}

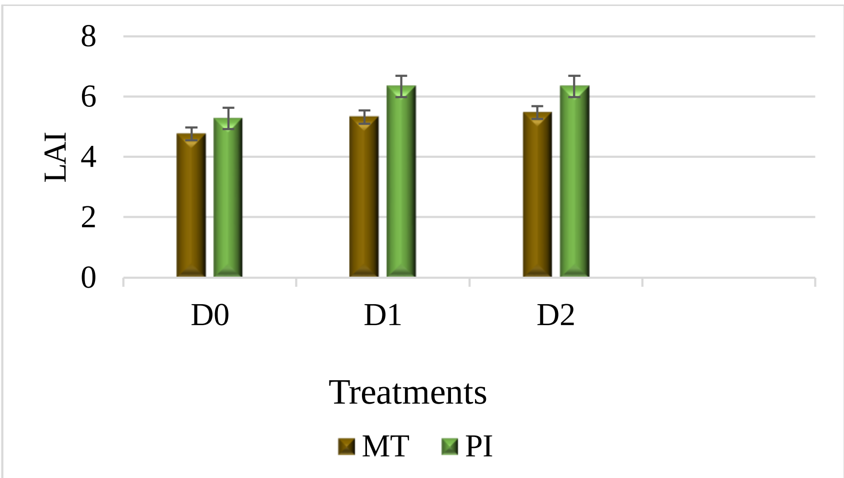

Fig.5 Effect of soil amelioration practices on LAI

significantly higher in treatment with application of granulated dolomite as basal and 30 DAS (D_2) compared to D_0 and D_1. Higher value of yield attributes in dolomite treated plots might be due to the increase in soil pH which resulted in increased availability of nutrients, reduction in Fe availability and many other attributes of soil fertility. The same result was obtained by Mansingh *et al*. (2019) and Kumar e*t al*. (2012). Among foliar nutrition, FS of 1% KNO_3 recorded the highest percentage of filled grains and thousand grain weight and it was on par with all other treatments except treatment without foliar application in case of filled grain percentage. Foliar application of N and K might have increased the availability of those nutrients and increased the absorption and the translocation of nutrients to the rice grain. Similar results were also reported by Jagathjothi *et al*. (2012). This was also in agreement with the result of Son *et al*. (2012) who reported that foliar nutrition of KNO_3 increased the number of panicles per m^2, numbers of grains per panicle, 1000 grain weight, and decreased the percentage of unfilled grain. These findings are also supported by Ali *et al*. (2007). Foliar application did not show any significant influence in case of productive tillers m^{-2}.

5.2.2 Effect of soil amelioration and foliar nutrition on yield and harvest index

The data of grain yield, straw yield and HI of rice significantly influenced by different treatments is shown in Table 7 and Fig. 6. Granulated dolomite as basal and 30 DAS (D_2) registered higher grain yield which was on par with ordinary dolomite application (D_1) and the lowest grain yield was recorded for treatment without dolomite application (D_0). Foliar spray of 1% KNO_3 + 0.5% micronutrient solution (N_3) obtained higher grain yield which was on par with all other treatments except treatment with no foliar application (N_0) which recorded the lowest grain yield. The increased grain yield by dolomite application might be due to the ameliorating effect of dolomite which reduced Fe and Al toxicity and increased the Ca and Mg content which also enhanced the soil conditions for better growth. The supply of magnesium in Mg deficient soils is also a factor that enhanced the grain yield. Similar results were also reported by Martin *et al*. (1988), Biswas *et al*. (2013), Elisa *et al*. (2016) and Soltani *et al*. (2016). Higher yield of treatments with foliar spray of KNO_3 or combined spray of KNO_3 and micronutrient solution might be due to improved growth characters and yield attributes which in turn resulted in higher rice grain yield. Application of potassium fertilizers also helps in photosynthesis, carbohydrates distribution, and synthesis of starch in storage organs, which results in increased grain yield (Imas and Magen, 2007; White *et al*., 2010). Foliar nutrition of K may be beneficial when uptake of potassium through the root zone is low mainly due to the competition of cation in saline or sodic soils with high content of Na (Weinbaum *et al*., 2001). Devi (2017) opined that application of N and K as foliar spray is especially important in *Kari* soils deficient in available nitrogen and high in iron and calcium that are antagonistic to potassium. Micronutrient fertilization helps to increase enzymatic reactions and hormone productions which results in increased yield. Similar results were noted by El-Magid *et al*. (2000); Zayed *et al*. (2011) and Shueadshen (1991). Results of increased grain yield due to application of potassium nitrate fertilizers were also reported by Ahmad and Jabeen (2005), Ravi *et al*. (2007) and Khan *et al*. (2012).

The highest straw yield was obtained by the treatment with granulated dolomite as basal and 30 DAS and the lowest straw yield was obtained for treatment without dolomite application. In case of foliar nutrition, FS of 1% KNO_3 recorded higher straw yield which was on par with 1% KNO3 + 0.5 % micronutrient solution and the lowest yield was recorded for treatment with no foliar nutrition. Higher straw yield might be due to the increased plant growth by the action of dolomite and N. Similar results were also reported by Sarkar and Bandopadhyay (1991) and Surya (2015). Interaction effect of soil amelioration and foliar nutrition was not significant in case of both grain yield and straw yield.

Harvest index was significantly influenced by soil amelioration practices and was not influenced by foliar nutrition and their interaction effects. Ordinary dolomite application as basal and 30 DAS obtained the highest HI compared to granulated dolomite application and treatment with no dolomite application. Higher HI is in accordance with grain yield and straw yield.

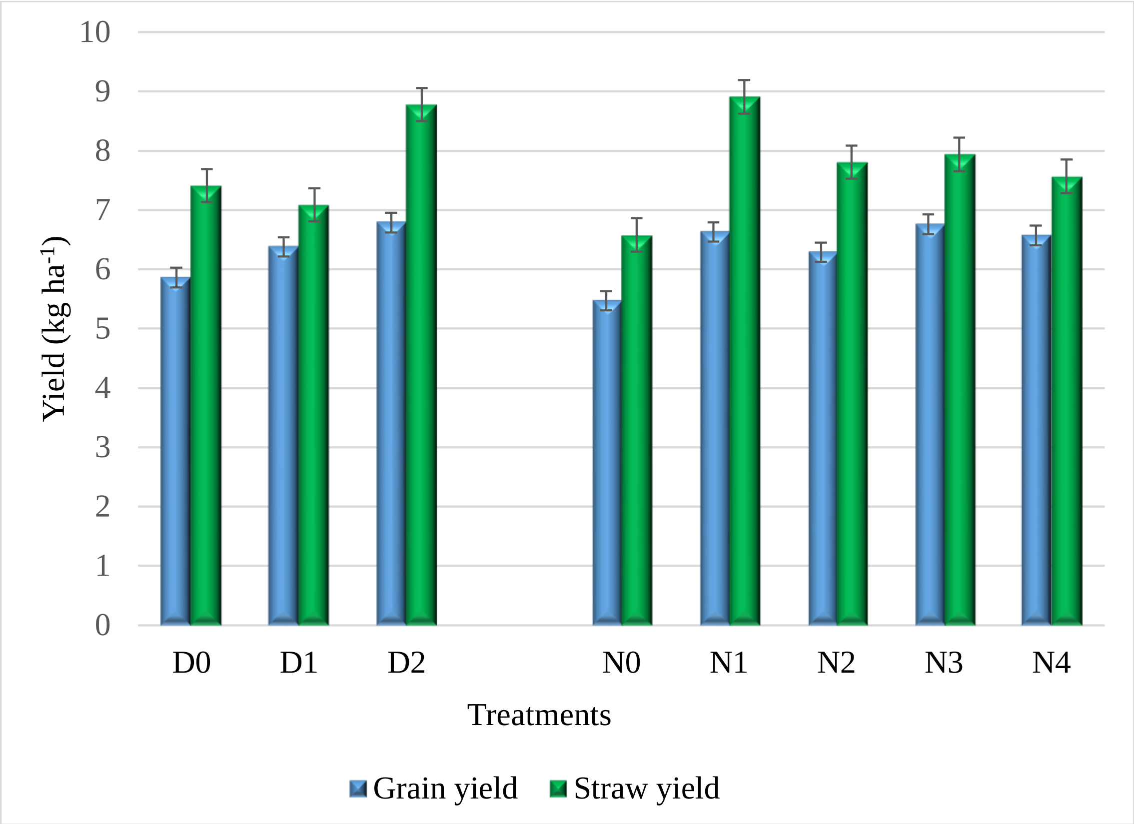

Fig 6. Effect of soil amelioration practices and foliar nutrition on yield

5.4 SOIL NUTRIENT CONTENT

5.4.1 Effect of soil amelioration on nutrient content of soil

5.4.1.1 Soil pH and EC

Soil pH and EC were significantly influenced by soil amelioration practices. Initially soil was extremely acidic in nature which was in conformity with the result of Chattopadhyay and Sidharthan (1985) and Beena and Thampatti (2013). Profound effect was seen on soil pH by the application of dolomite. The highest pH was obtained on application of granulated dolomite as basal and 30 DAS (D_2) and the lowest pH was obtained in treatment with no dolomite in both PI and harvest stages. This was in line with the findings of Rastija *et al*. (2014). Calcium present in dolomite increased the soil pH by reducing the soil acidity. Soil pH increased from initial value during the crop period and decreased at the time of harvest. The decrease in soil pH at the time of harvest might be due to the drying of soil, which resulted in the formation of sulphuric acid in acid sulphate soils, and increased the soil acidity. This was in agreement with the report of Chenery (1954).

Electrical conductivity decreased at PI stage and increased at harvest stage from the initial value and is presented in Table 8. The treatment with no dolomite application (D_0) recorded the highest EC at both PI and harvest stages and the lowest was obtained in treatment with granulated dolomite application. This may be due to the effect of dolomite in reducing the soluble salts by making them insoluble in the soil. Increase in EC at harvest stage may be because, as the soil dries at the time of harvest, the subsurface salinity comes on the soil surface by capillary action which in turn increases the EC of the soil. Similar trends of result were also obtained by Devi (2017).

5.4.1.2 Soil organic carbon status

Soil amelioration practices had a significant influence on OC content both at PI and harvesting stages as presented in Table 8. Soil OC increased from the initial value at PI stage and decreased at harvesting stage. The highest OC content was recorded with granulated dolomite as basally and 30 DAS (D_2), at both PI and harvesting stages and the lowest was obtained with treatment with no dolomite application (D_0).

The increase in OC might be due to the mineralisation process, by the application of dolomite the pH of the soil increases that enhances the process of mineralisation in soil and thus OC status also increased This is in agreement with result obtained by Wu *et al*. (2021) that the dolomite application increased soil organic carbon mineralization and also stimulate microbial growth and activity, which resulted from the increase in soil pH. Moreover, the effect was greater for the finer particle size, suggesting that the particle size of lime material has the role in regulating the soil organic matter mineralization in acidic soils.

5.4.1.3 Availability of macro nutrients

The available N was significantly influenced by soil amelioration practices at panicle initiation stage and did not have any influence at harvest stage. Application of granulated dolomite as basal and 30 DAS (D_2) recorded the highest N content of soil and the lowest was obtained in treatment without dolomite application (D_0). Initial status of available N was low which increased by the application of dolomite and decreased at the time of harvest. Higher available N content in the soil by dolomite application might be due increase in pH which in turn improving the microbial activity and N availability of the soil. Castro *et al*. (2016) also reported similar results. The decrease in available N at the time of harvest may be due to reduced pH which reduces the microbial activity. Similar findings were also reported by Koruth *et al*. (2013).

Available P content of the soil was significantly influenced by soil amelioration practices at PI stage and failed to express significant effect at harvesting stage as seen in Table 9. The highest soil available P was obtained with granulated dolomite basally and 30 DAS (D_2) which was on par with ordinary dolomite as basally and 30 DAS (D_1). Initial status of available P was low in the soil which increased at PI stage and then decreased at harvesting stage. Low availability of P at initial stage might be due to P fixation by Fe and Al oxides in highly acidic soil condition. This is in agreement with findings of Dixit (2006) and Audebert and Sahrawat (2000). Dolomite application increased the soil pH which also enhanced the P availability in the soil and at the time of harvest, decrease in pH due to diminishing effect of dolomite reduced the soil pH and dropped the availability of P. These findings are supported by the results obtained by Rahman *et al.* (2002) and Suriyagoda *et al*. (2017). Phosphorus availability can be increased through liming by changing organic P mineralization due to increased microbial activity and by enhancing the utilization of soil phosphate by plants through the amelioration of Fe toxicity (Haynes, 1981)

Soil amelioration practices had significant effect on soil available K at both panicle initiation and harvesting stages. Initial available K was medium which increased at PI stage and decreased at harvest stages. The increase of soil K at PI stage might be owing to the soil application of K. Granulated dolomite as basal and 30 DAS (D_2) recorded significantly higher status of available K which was on par with ordinary dolomite application (D_1) at both the stages and the lowest available K was recorded in treatment with no dolomite application (D_0). The reduction of available K might be due to antagonistic effect of Ca and Fe on soil K. Rasouli *et al*. (2013) stated that potassium availability of the soil can be enhanced by the application of Ca and Mg. Bishnoi *et al*. (1987) reported that the increase of available K content of acid soils by liming may be due to the release of K from non-exchangeable fraction to the available pool.

Significant influence of soil amelioration was observed in available Ca content as seen in Table 9. Application of granulated dolomite as basal + 30 DAS recorded the highest available Ca content in soil at both PI and harvesting stages, and at harvest it was on par with ordinary dolomite application. The lowest was obtained in treatment with no dolomite application at both stages. The initial status of available Ca content was high in the soil due to the deposit of $CaCO_3$ shells and the value increased at PI stage and decreased at harvesting stages. The increase in Ca content at cropping period from initial value may be due to the increase in pH and addition of Ca ions by the application of dolomite.

Available Mg content was significantly influenced by soil amelioration practices as seen in Table 10. The highest soil Mg content was obtained in treatment with application of granulated dolomite as basal and 30 DAS (D_2) at both PI and harvesting stage but was on par with ordinary dolomite application at harvest. The initial available Mg in soil was very low and it increased during cropping period due to the application of dolomite as it is a good source of Mg. This was in accordance with the result reported by Wood *et al*. (2005) that soil Mg is increased by the application of dolomite or dolomitic limestone by correcting the soil pH.

The soil was initially higher in available S which gradually decreased during cropping period. The treatment without dolomite application recorded significantly higher content of soil available S at both PI and harvesting stages which was on par with treatment with ordinary dolomite application as basally and 30 DAS. Granulated dolomite basally and 30 DAS registered significantly lower values at PI and harvest stages. Initial status of available S is high due to acid sulphate characteristics of *Kari* soils. It decreased during cropping period and at harvest. Decrease in available S at cropping period may be due to formation of Fe sulphides under flooded condition as well as due to the application of dolomite. Drying of soil at harvest may lead to oxidation of sulphides which in turn increased the available soil S status at harvest over PI stage. Astrom *et al*. (2007) opined that sulphur content of soil can be decreased by liming.

5.4.1.4 Availability of micronutrients

The initial status of available Fe was very high in the soil, which was also reported by Thampatti *et al*. (2005). The treatment without dolomite application was superior with respect to soil available Fe at both PI and harvesting stages compared to other treatments. Granulated dolomite as basal and 30 DAS registered the lowest value at both the stages. Significant reduction of Fe content was observed by the application of dolomite. This was in accordance with the findings of Benckinser *et al*. (1984). Application of dolomite gradually decreased the Fe content at both the stages and it increased at harvest from that at PI stage. The increased status may be due to the diminishing effect of dolomite and reduced pH.

Significantly higher soil available Mn was registered by the treatment with ordinary dolomite basally and 30 DAS (D_1) which was on par with granulated dolomite application at harvesting stage and no significant effect of soil amelioration practices was noticed at PI stage. Application of dolomite improved the Mn status of soil. Availability of Mn increased from the initial status to PI stage and decreased at harvest, high Ca and Fe contents present in the soil at the time of harvest may be the reason of reduced Mn content as these elements are antagonistic to Mn (Tisdale *et al*., 1993).

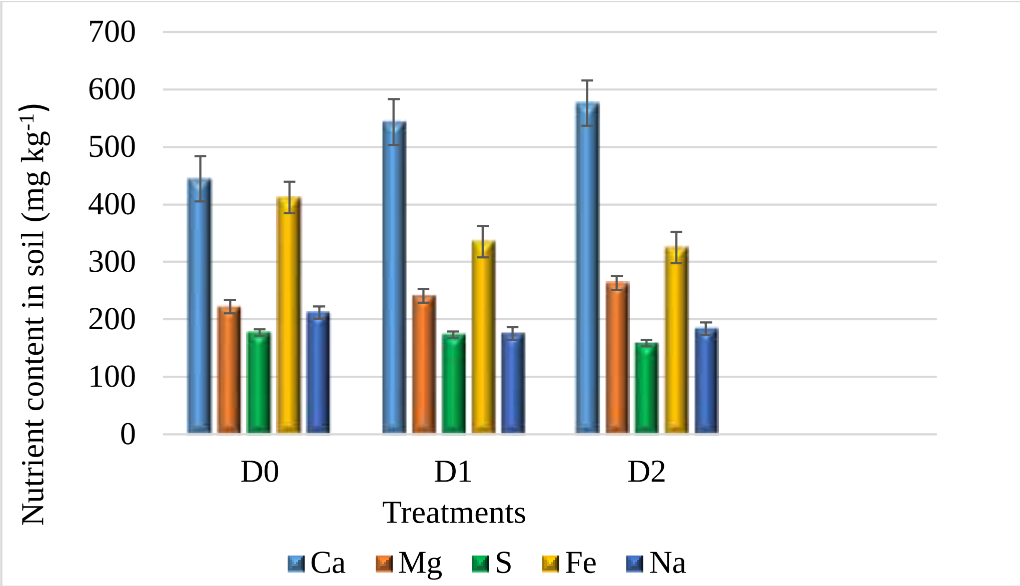

Fig 7. Effect of soil amelioration practices on available Ca, Mg, S, Fe and Na at PI stage

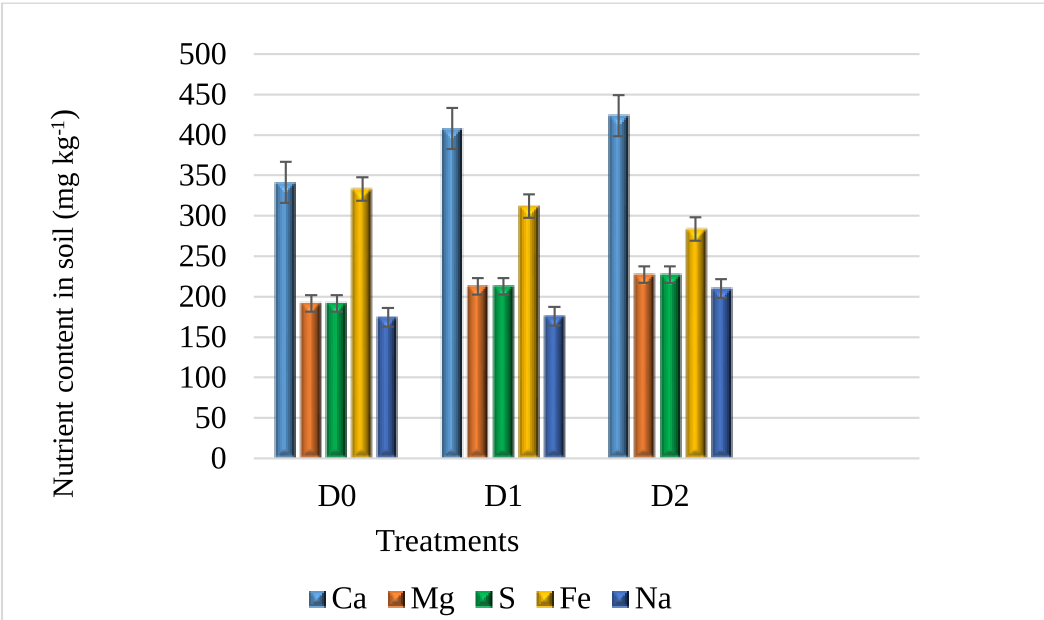

Fig 8. Effect of soil amelioration practices on available Ca, Mg, S, Fe and Na at harvesting stage

Effect of soil amelioration practices was found to be non-significant on available Zn and Cu content in the soil at both PI and harvesting stages. Available Zn and Cu content in the soil decreased from the initial values at both PI and harvest stages.

Available B content in the soil was significantly influenced by soil amelioration practices as presented in Table 12. Granulated dolomite as basal+30 DAS (D_2) recorded the highest soil available B at PI stage and at harvest and it was on par with ordinary dolomite application. The lowest available B was obtained for treatment with no dolomite application (D_0). Initial available B was very low in the soil, which was also reported by Sasidharan and Ambika Devi (2013), later it increased during cropping period by the application of dolomite as B availability can be increased by reducing acidity.

5.4.1.5 Exchangeable Na status

Initially, exchangeable Na was high in the soil, due to increased salinity by sea water intrusion which gradually decreased at PI and harvesting stages. Soil amelioration practices had a significant effect on exchangeable Na content of the soil. The sodium content in the soil decreased from the initial value at all the stages. At both PI and harvesting stage treatment without dolomite application obtained the highest value of exchangeable Na and the lowest was obtained by the application of granulated dolomite as basal + 30 DAS (D_2).

5.5 PLANT NUTRIENT CONTENT

5.5.1 Effect of soil amelioration and foliar nutrition on nutrient content of grain and straw

Plant parts were analysed to obtain the nutrient content of grain and straw after harvest and to reckon the nutrient uptake by the crop

5.5.1.1 Nitrogen, Phosphorus and Potassium

Nitrogen content in grain responded significantly to soil amelioration practices whereas N content in straw does not have any significant effect. Higher N content in grain was recorded in granulated dolomite application which was on par with $D_{1.}$ Foliar nutrition of 1% potassium nitrate + 0.5% micronutrient solution (N_3) recorded the highest N content in grain and foliar nutrition of 1% potassium nitrate (N_1) and N_3 obtained significantly higher N content in straw. Significantly lower N content was obtained in treatment with no foliar nutrition for both grain and straw. Among the treatment combinations, D_2N_3 recorded higher N content in grain and (D_1N_3) obtained the highest N content in straw. The increased N content in grain and straw may be the positive effect of foliar application of KNO_3 and also due to increased uptake of nutrients due to soil amelioration practices which increased the availability of nutrients. Varghese and Money (1964) also found increase in N content in plant by the application of Mg contained amendments.

Phosphorus content of grain and straw was significantly influenced by soil amelioration practices, foliar nutrition and their interaction (Table 13). Among soil amelioration practices, the highest P content in grain was observed with D_2 which was on par with D_1 and in straw, the highest P content was observed with $D_{0.}$ In grain, foliar nutrition of 1% KNO_3+ 0.5% micronutrient solution (N_3) recorded the highest P content which was on par with N_0 and was significantly superior to other treatments. The highest P content in straw was observed with foliar nutrition of potassium nitrate (1%) alone (N_1). Among treatment combinations, D_1N_1 recorded higher P content which was on par with D_2N_3 and in straw higher P content was obtained in D_0N_1. The increased availability of nutrients by soil amelioration practices enhanced the uptake of nutrients and thus increased the P content in grain. Dolomite application increased the pH, and available nutrients thus P and K contents were also enhanced. This is in line with the findings of Suriyagoda *et al*. (2017).

Potassium content in grain and straw was significantly influenced by individual treatments and their interactions (Table 13). In both grain and straw the highest K content was recorded in D_2 and lowest was in D_0. Foliar application of KNO_3 (1%) alone recorded the highest K content in both grain and straw. Significant interaction effects between soil amelioration practices and foliar nutrition on potassium content was observed. Significantly higher K content in grain was recorded by application of granulated dolomite along with FS of 1 % KNO_3 (D_2N_1) and in straw, treatment with application of ordinary dolomite along with FS of 1 % K_2SiO_3 (D_1N_2) obtained the highest K content and was on par with D_2N_1, D_2N_2, D_2N_3 and D_2N_4. Foliar spray of potassium fertilizers increased the concentration of K in both grain and straw, and also application of dolomite enhanced the uptake of K which in turn increased the K content in both grain and straw. Koruth *et al*. (2013) reported an increase in potassium content in plant by the application of magnesium sources in the soil. Ali *et al*. (2005) observed that K concentration in grain and straw were enhanced by the application of different K sources.

5.5.1.2 Calcium, Magnesium, Sulphur

Soil amelioration practices, foliar nutrition and their interaction significantly influenced the calcium content in grain and straw (Table 14). The highest Ca content in both grain and straw was obtained by application of granulated dolomite (D_2) and the lowest was in control. Foliar nutrition of 1% KNO_3 + 0.5% micronutrient solution (N_3) registered higher Ca content in both grain and straw which was on par with FS of 1% KNO_3 alone (N_1) and was significantly superior to other treatments. Application of granulated dolomite along with FS of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) obtained highest Ca content in grain which was on par with D_2N_2 and D_1N_1. In straw, granulated dolomite along with FS of (1%) K_2SiO_3 (D_2N_2) recorded higher Ca content which was on par with D_2N_3 and $D_1N_{1.}$ High initial status of Ca have reflected in the respective nutrient contents in grain and straw. Application of dolomite significantly increased the Ca and Mg contents in leaves as dolomite is a good source of these nutrients (Soratto and Crusciol, 2008).

Magnesium content in both grain and straw was significantly enhanced by granulated dolomite compared to ordinary dolomite application and treatment without dolomite application. Higher Mg content in grain was recorded in treatment with FS of 1 % KNO_3 (N_1) which was on par with application of 1% K_2SiO_3 + 0.5% micronutrient solution (N_4). In straw also N_1 obtained highest Mg content which was on par with N_0 and N_4 .Application of granulated dolomite along with FS of 1% K_2SiO_3 (D_2N_2) significantly enhanced the Mg content of grain and in straw it was increased by the application of granulated dolomite along with FS of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) followed by D_2N_2 ,$D_2N_{0,}$ D_1N_4 and $D_1N_{1.}$The lowest Mg content in treatment with no dolomite application might be due to low available Mg content in the soil and increased Mg content in dolomite applied treatment might be due to increased supply of Mg due to dolomite application.

Soil amelioration practices failed to express significant effect on S content in grain. In straw, treatment with no dolomite application (D_0) recorded the highest S content compared to other treatments. Foliar nutrition of 1 % KNO_3 (N_1) obtained higher sulphur content in grain and in case of straw FS of 1% KNO_3+ 0.5% micronutrient solution (N_3) recorded the highest S content followed by all other treatments except N_2. Among the interaction effects, treatment without dolomite application along with FS of 1% KNO_3 recorded the highest S content in both grain and straw and in straw it was on par with D_2N_4, D_2N_3 and D_1N_1.

5.5.1.3 Iron, Manganese, Zinc

The treatment without dolomite application obtained the highest Fe content in both grain and straw and in grain it was on par with D_1. Foliar spray of 1% KNO_3 registered the highest Fe content in both grain and straw. Among interaction effects, application of granulated dolomite along with FS of 1% KNO_3 + 0.5% micronutrient solution (N_3) recorded the highest Fe content in both grain and straw and in grain it was on par with D_1N_1 and D_0N_4. The highest Fe content in control plot is due to the high available Fe content during the initial status of the soil and was the lowest in treatment with dolomite application. This result was previously supported by Benckiser *et al.* (1984), because the uptake of Fe^{2+} decreased with increased K, Ca and Mg nutrition in soil.

The higher Mn content in grain was obtained by application of ordinary dolomite and was on par with D_2, and in straw application of granulated dolomite obtained the highest Mn content. FS of 1% KNO_3 + 0.5% micronutrient solution (N_3) recorded the highest Mn content in both grain and straw compared to other treatments. Application of granulated along with FS of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) obtained the highest Mn content in grain which was on par with D_2N_4 and D_1N_3. In straw FS of 1% K_2SiO_3 + 0.5% micronutrient solution (D_2N_4) recorded the highest Mn content which was on par with D_2N_3. Application of micronutrient solution enhanced the Mn content in both grain and straw.

Among soil amelioration practices treatment with no dolomite obtained the highest Zn content in grain and in straw granulated dolomite application recorded the highest zinc content FS of 1% K_2SiO_3 + 0.5% micronutrient solution (N_4) obtained the highest zinc in both grain and straw. Treatment without dolomite application along with FS of 1% K_2SiO_3 + 0.5% micronutrient solution (D_0N_4) showed the highest Zn content in grain and granulated dolomite along with of 1% K_2SiO_3 + 0.5% micronutrient solution (D_2N_4) showed the highest Zn content in straw which was significantly superior to all other treatments. Application of micronutrient solution might be the reason behind increased Zn content in both grain and straw. This is in agreement with the result obtained by Jin *et al*. (2008) where combined foliar application of Fe, Zn and B significantly increased nutrient concentration of these in rice grain.

5.5.1.4 Copper, Boron, Sodium

No significant effect on Cu content in the grain and straw due to soil amelioration, foliar nutrition and by their interaction was noticed except in grain Cu content by the influence of soil amelioration. The highest Cu content in grain was obtained with no dolomite application.

No significant effects were found on B content in grain due to interaction of soil amelioration practices and foliar nutrition, but the amelioration practices and foliar nutrition influenced the B content in straw. Application of granulated dolomite obtained the highest B content and in case of foliar nutrition, the highest was recorded by N_3 followed by N_4. Jin *et al*. (2008) also reported similar results.

Sodium content in grain was the highest in application of granulated dolomite and in straw, application of ordinary dolomite obtained the highest Na content. With regard to foliar nutrition, in grain, FS of 1% K_2SiO_3 was significantly superior to other treatments and in straw N_4 obtained highest Na content which was on par with N_1. Among interactions, granulated dolomite along with FS of 1% K_2SiO_3 (D_2N_2) obtained highest Na content in grain and in straw granulated dolomite along with FS of 1% K_2SiO_3 + 0.5% micronutrient solution (D_2N_4) recorded the highest Na content.

5.5.2 Effect of soil amelioration and foliar nutrition on uptake of nutrients

5.5.2.1 Uptake of primary nutrients

Application of granulated dolomite increased the uptake of N by grain and straw significantly (Table 17). In grain it was on par with ordinary dolomite application FS of 1% KNO_3 + 0.5% micronutrient solution (N_3) recorded the highest N uptake by grain and in straw, FS of 1% KNO_3 alone recorded higher uptake of N which was on par with N_3. Among the interaction, application of granulated dolomite along with 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) recorded higher N uptake by grain. Kundu *et al*. (2020) reported that foliar spray of potassium salts enhanced the uptake of N, P, K and S by rice. In straw higher N uptake was obtained by application of granulated dolomite along with FS of 1% $KNO_{3.}$ Son *et al*. (2012) also reported higher uptake of N and K in rice along with higher grain yield by one to three foliar application of potassium nitrate.

The mean data on P uptake showed that higher P uptake by grain and straw was obtained with granulated dolomite (D_2) which was on par with D_1 in grain and D_0 in straw. Application of 1% $KNO_{3\,+}$ micronutrient solution 0.5% (N_3) recorded P uptake by grain which was on par with N_1 and N_4. In straw, FS of 1% KNO_3 recorded the highest P uptake compared to all other treatments. This is in agreement with findings of Kundu *et al*. (2020).

Uptake of K by straw was the highest in application of granulated dolomite. Soil amelioration practices failed to produce significant effect on uptake of potassium in grain. K_2SiO_3 (N_2) obtained higher K uptake by grain which was on par with all other treatments except N_0. Application of 1% KNO_3 alone (N_1) recorded the highest uptake of K by straw followed by N_2 and N_3. Among interaction effects, higher uptake of K by grain was observed in treatment with granulated dolomite application along with 1% KNO_3 followed by D_1N_1 and $D_0N_{1.}$

5.5.2.2 Uptake of secondary nutrients

Calcium uptake by grain and straw was significantly higher in granulated dolomite application. Higher Ca uptake by grain was obtained with 1% KNO_3 + 0.5% micronutrient solution (N_3) which was on par with N_1 and uptake of Ca by straw was higher by the application of 1% KNO_3 (N_1) and was on par with N_3. In case of interaction, application of granulated dolomite along with 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) recorded higher Ca uptake by grain and straw.

Magnesium uptake by grain and straw was found to be significantly superior in the application of granulated dolomite. FS of 1% KNO_3 alone (N_1) recorded higher Mg uptake by grain and straw and in grain it was on par with N_4 and in straw N_1 was superior in Mg uptake. Among interaction effects, granulated dolomite along with 1% K_2SiO_3 + 0.5% micronutrient solution (D_2N_4) recorded the highest Mg uptake by grain which was on par with D_1N_4. Application of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) obtained higher Mg uptake by straw which was on par with D_2N_2 and D_2N_1.

Ordinary dolomite application recorded higher uptake of S by grain which was on par with D_2. Higher S uptake by straw was recorded by application of granulated (D_2) and was on par with D_0.Foliar nutrition with 1% KNO_3 (N_1) recorded the highest S uptake by grain and higher uptake of sulphur by straw was obtained by FS of 1% KNO_3 + 0.5% micronutrient solution (N_3) which was on par with N_1 and N_4. Application of ordinary dolomite along with 1% KNO_3 + 0.5% micronutrient solution (D_1N_3) registered S uptake by grain and in straw, higher uptake was recorded by application of granulated dolomite along with 1% KNO_3 + 0.5% micronutrient solution (D_2N_3).This was in line with the findings of Kundu *et al*., 2020.

5.6 PEST AND DISEASE INCIDENCE

Sheath rot caused by the fungus *Sarocladium oryzae* and Brown spot by *Helminthosporium oryzae* were the major diseases observed in the plants during the cropping period which was controlled by spraying Nativo [Tebuconazole 50% + Trifloxystrobin 25% [75 (WG)]. The major pests noticed in the experimental field were white stem borer (*Scirpophaga innotata*), and rice bug (*Leptocorisa acuta*) which was brought under control by the application of Fertera (chlorantraniliprole 0.4% GR) in the soil and Malathion 50 EC respectively. FS of (1%) K_2SiO_3 was found to reduce the disease and pest incidence compared to other treatments and in control disease severity was high. This was in agreement with the result obtained by Buck *et al*. (2008) that the application of K_2SiO_3 as foliar spray have reduced the incidence of rice blast. Potassium is effective in lowering down the infestation of insect-pests of rice crops (Chatterjee and Mondal, 2020).

5.7 ECONOMICS OF CULTIVATION

The highest gross income was obtained by the treatment D_2N_1 (Rs 213900 ha^{-1}). The maximum net return (Rs 123788 ha^{-1}) and maximum BCR (2.48) were obtained by the treatment D_1N_3. Higher grain yield obtained with these treatments has reflected in their economics. Application of granulated dolomite obtained higher yield compared to ordinary dolomite application, but as the cost of granulated dolomite is four times more than ordinary dolomite the highest BCR was obtained in treatment with application of ordinary dolomite along with foliar spray of potassium nitrate, hence they can be recommended for economic rice cultivation in *Kari* soil. Granulated dolomite can be recommended for cultivation after conducting trials with reduced rate of application compared to ordinary dolomite for making it more cost effective.

Summary

6. SUMMARY

The investigation entitled "Enhancing grain yield and quality through soil amelioration and foliar nutrition in rice (*Oryza sativa* L.) in *Vaikom Kari* soils" was carried out in *Vaikom Kari* soils of Kuttanad during *puncha* season from October 2020 to February 2021 for managing soil acidity, and to supplement nutrition at panicle initiation stage through foliar application of K and micronutrients and the results of the experiment are summarized below.

The experiment was laid out in Randomized Block Design (RBD). The effect of soil amelioration on soil parameters and growth characters was assessed in simple RBD with three treatments and fifteen replications. The treatments were, no dolomite application (T_1), application of ordinary dolomite basally and at 30 DAS at the rate of 500 kg ha^{-1}(T_2) and application of granulated dolomite basally and at 30 DAS at the rate of 500 kg ha^{-1} (T_3). The effect of soil amelioration and foliar nutrition on yield and yield attributes, plant nutrient content and uptake were analysed in factorial RBD with two factors and three replications. Factor A consisted of three levels of dolomite application, D_0, D_1 and D_2, similar to treatments mentioned above (T_1, T_2, and T_3), and factor B consisted of five levels of foliar nutrition at PI stage *viz.* without foliar application (N_0), FS of 1% KNO_3 (N_1), FS of 1% K_2SiO_3 (N_2), FS of 1% KNO_3 + 0.5% micronutrient solution (N_3) and FS of 1% K_2SiO_3 + 0.5% micronutrient solution (N_4). The treatment combinations were no dolomite application + without foliar application (D_0N_0), no dolomite application + FS of 1% KNO_3 (D_0N_1), no dolomite application + FS of 1% K_2SiO_3 (D_0N_2), no dolomite application + 1% KNO_3 + 0.5% micronutrient solution (D_0N_3), no dolomite application +1% K_2SiO_3 + 0.5% micronutrient solution (D_0N_4), ordinary dolomite application + without foliar application (D_1N_0),ordinary dolomite application + FS of 1% KNO_3 (D_1N_1), ordinary dolomite application + FS of 1% K_2SiO_3 (D_1N_2), ordinary dolomite application +1% KNO_3 + 0.5% micronutrient solution (D_1N_3), ordinary dolomite application +1% K_2SiO_3 + 0.5% micronutrient solution(D_1N_4), granulated dolomite + without foliar application (D_2N_0) granulated dolomite+1% KNO_3 (D_2N_1), granulated dolomite+1% K_2SiO_3 (D_2N_2), granulated dolomite+1% KNO_3 + 0.5% micronutrient solution(D_2N_3), granulated dolomite+1%

K_2SiO_3 + 0.5% micronutrient solution (D_2N_4).The medium duration rice variety Uma (Mo 16) was used for the study.

Studies regarding growth characters revealed that application of granulated dolomite as basal and 30 DAS (D_2) enhanced the plant height at PI and harvesting stages along with higher LAI at MT and PI stages, and the same treatment recorded the highest number of tillers at both MT and PI stages on par with ordinary dolomite application. Application of granulated dolomite as basal+ 30 DAS recorded significantly higher dry matter production. Foliar spray of 1% KNO_3 gave higher dry matter production which was on par with all other treatments except treatment without foliar application.

The results of the experiment revealed that soil amelioration practices had significant effect on yield and yield attributes. The highest grain yield, straw yield, productive tillers, total grains per panicle, thousand grain weight and percentage of filled grains were obtained in treatment with application of granulated dolomite basally and 30 DAS in which grain yield was on par with D_1. In case of foliar nutrition, application of 1% KNO_3 + 0.5% micronutrient solution at PI stage (N_3) resulted in higher grain yield which was on par with all other treatments except the treatment without foliar nutrition. Higher straw yield and thousand grain weight were obtained with application of 1% KNO_3 (N_1) at PI stage which was on par with N_3. The higher percentage of filled grains was recorded in (N_1) which was on par with all other treatments except in treatment without foliar application. The interaction of soil amelioration and foliar nutrition did not show any influence on yield and yield attributes.

Soil analysis was carried out at PI and harvest stages, and soil amelioration practices had significant influence on pH, EC, OC and all available macro and micronutrient contents in the soil except Zn and Cu. Available N and P contents in the soil at harvest stage were also not influenced by the treatments. Addition of granulated dolomite (D_2) significantly enhanced available Ca and Mg contents and reduced S and Fe contents in the soil. Among various treatments, granulated dolomite application (D_2) recorded the highest soil pH, OC, available K, available Ca, available Mg and available B at both PI and harvesting stages and the highest N content at PI stage and the lowest S and Na contents at harvesting stages were also observed with the same treatment.

Treatment without dolomite application recorded the lowest pH, highest EC, available S, Na, and available Fe at both PI and harvesting stages.

Plant nutrient contents and uptake were significantly influenced by soil amelioration practices, foliar nutrition and by their interaction effects. The highest N, P, K, Ca and Mg content in grain was increased with application of granulated dolomite as basal+30 DAS. Same trend was observed with the highest content of K, Ca and Mg in straw. The highest P and S content in straw was obtained with treatment with no dolomite application. Soil amelioration practices failed to express significant effect on N content in straw. In case of foliar nutrition, FS of 1% KNO_3 + 0.5 % micronutrient solution recorded the highest N content in grain and the same treatment recorded higher P content in grain followed by N_0, Ca content in grain followed by N_1 and the highest Ca and S content in straw followed by N_1. In grain, FS of 1% KNO_3 recorded the highest content of K, Mg and S in which Mg content was on par with N_4 .Similar trend of result was observed in N, P, K and Mg content in straw in which N was on par with N_3 and Mg on par with N_0 and N_4. Among interaction, D_2N_3 obtained the highest N and Ca content in grain and Mg content in straw. In grain, the highest P content was obtained by D_1N_1 followed by D_2N_3,K content in D_2N_1, Ca content in D_2N_3 followed by D_2N_2 and D_1N_1,Mg content in D_2N_2 and S content in D_0N_1. In straw, the highest N content was obtained by D_1N_3, the highest K content in D_1N_2 followed by D_2N_2, D_2N_0, D_1N_4 and D_1N_1, highest Ca content in D_2N_2 followed by D_2N_3 and D_1N_1, the highest Mg content in D_2N_3 followed by D_2N_2, D_2N_0, D_1N_4 and D_1N_1, the highest P and S content on D_0N_1,and in S content it was on par with D_2N_4, D_2N_3 and D_1N_1.

Soil ameliorants significantly decreased the uptake of iron, hence Fe content in both grain and straw was the highest in D_0 and was on par with D_1. In case of grain, Mn content was enhanced by D_1 followed by D_2 and highest Zn and Cu content was obtained by D_0. D_2 obtained higher content of Mn and Zn in straw. Foliar spray of 1% KNO_3 recorded highest Fe content in both grain and straw. N_3 enhanced Mn and Zn content in both grain and straw and B content in straw. N_2 obtained the highest Na content in grain and N_4 recorded the highest Na content in straw. With regard to interaction effects, FS of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) recorded the highest Fe content in both grain and straw and in straw it was on par with D_1N_1 and

D_0N_4. The treatment (D_2N_3) obtained the highest Mn content in grain which was on par with D_2N_4 and D_1N_3 and in straw FS of 1% K_2SiO_3 + 0.5% micronutrient solution (D_2N_4) recorded the highest Mn content followed by D_2N_3. Treatment with no dolomite application along with FS of 1% K_2SiO_3 + 0.5% micronutrient solution (D_0N_4) showed the highest Zn content in grain and (D_2N_4) showed the highest Zn content in straw. The treatment (D_2N_2) obtained the highest Na content in grain and in straw (D_2N_4) recorded highest Na content.

Nitrogen, phosphorus, calcium and magnesium uptake in both grain and straw were enhanced by granulated dolomite application in which N and P uptake by grain was on par with D_1 and P uptake was on par with D_0. Foliar spray of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) increased the uptake of N, P and Ca in grain and S uptake in straw in which P uptake was on par with N_1 and N_4. Foliar spray of 1% KNO_3 alone recorded higher uptake of N, P, K and Ca in grain, Mg uptake in both grain and straw and S uptake in straw. Among interaction, D_2N_3 recorded higher N uptake by grain and D_2N_1 increased the uptake of N in straw. Higher uptake of K by grain was observed in D_2N_1 followed by D_1N_1 and D_0N_1. (D_2N_3) recorded higher Ca uptake by grain and straw. D_2N_4 recorded highest Mg uptake by grain which was on par with D_1N_4. Application of granulated dolomite along with 1% KNO_3 + 0.5% micronutrient solution (D_2N_3) obtained higher Mg uptake by straw which was on par with D_2N_2 and D_2N_1. The treatment D_1N_3 registered higher S uptake by grain and in straw, higher uptake was recorded by D_2N_3.

The highest gross income was obtained by the application of granulated dolomite along with FS of 1% KNO_3 (D_2N_1). However, maximum net return and maximum BCR were obtained by ordinary dolomite application along with FS of 1% KNO_3 + 0.5% micronutrient solution (D_2N_3).

Future line of work

1. More foliar nutrition studies with different doses of KNO_3 should be experimented at PI and post PI stages like flag leaf stage as the effect of nutrient deficiency is more pronounced at these stages.

2. Grain discoloration which reduces grain quality is hindering the process of paddy procurement in Vaikom Kari soil. This is a complex problem of nutrient deficiency as well as fungal infection of grains. Hence research on compatible mixing of fungicides with foliar nutrients may be taken up.

3. The granulated dolomite is more effective but their cost is comparatively high. Hence investigation on effect of lower doses of granulated dolomite on ameliorating acidity may also be carried out.

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Appendices

APPENDIX I

Weather data during the cropping period of Experiment (08 October 2020 to 08 February 2021)

Standard week	Maximum temperature (^{o}C)	Minimum temperature (^{o}C)	Relative humidity (%)
41 (Oct 08 - Oct 14)	32.26	21.93	81.64
42 (Oct 15 - Oct 21)	31.31	21.51	81.14
43 (Oct 22 - Oct 28)	33.16	22.09	80.21
44 (Oct 29 - Nov 04)	33.27	21.83	80.86
45 (Nov 05 - Nov 11)	33.29	21.30	81.00
46 (Nov 12 - Nov 18)	33.99	21.40	80.21
47 (Nov 19 - Nov 25)	33.58	21.03	79.50
48 (Nov 26 - Dec 02)	29.35	20.51	79.38
49 (Dec 03 - Dec 09)	30.40	21.01	80.93
50 (Dec 10 - Dec 16)	33.63	20.03	78.64
51 (Dec 17 - Dec 23)	32.94	19.23	78.86
52 (Dec 24 - Dec31)	32.79	20.74	79.31
1 (Jan 01 - Jan 07)	31.60	19.10	79.93
2 (Jan 08 - Jan 14)	31.96	18.50	80.21
3 (Jan 15 - Jan 21)	32.70	20.20	80.86
4 (Jan 22 - Jan 28)	34.40	21.80	81.64
5 (Jan 29 - Feb 04)	34.20	22.10	80.71
6 (Feb 05 - Feb 11)	34.30	21.10	82.86

APPENDIX II

Rating of nutrient availability in the soil

Nutrient	Deficiency	Sufficiency	Toxicity
Available N (kg ha^{-1})	<280	280-560	-
Available P (kg ha^{-1})	<10	10-25	-
Available K (kg ha^{-1})	<110	110-270	-
Available Ca (mg kg^{-1})	<300	>300	-
Available Mg (mg kg^{-1})	<120	>120	-
Available S (mg kg^{-1})	<5	5-10	-
Available Fe (mg kg^{-1})	<5	>5	>300
Available Mn (mg kg^{-1})	<1	>1	-
Available Zn (mg kg^{-1})	<1	>1	-
Available Cu (mg kg^{-1})	<1	>1	-
Available B (mg kg^{-1})	<0.5	>0.5	-
Available Na (mg kg^{-1})	<80	80-120	>160
Exchangeable Al (mg kg^{-1})	-	-	>120

Source: Venugopal *et al.* (2013)

ENHANCING GRAIN YIELD AND QUALITY THROUGH SOIL AMELIORATION AND FOLIAR NUTRITION IN RICE (*Oryza sativa* L.) IN VAIKOM KARI SOILS

by

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ABSTRACT OF THE THESIS

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Abstract

ABSTRACT

A field experiment entitled "Enhancing grain yield and quality through soil amelioration and foliar nutrition in rice (*Oryza sativa* L.) in Vaikom *Kari* soils" was conducted in a farmer's field at Vechoor, during *puncha* season of 2020. The objectives were to augment the yield and quality of rice in Vaikom *Kari* soils through soil amelioration practices for managing soil acidity, and to supplement nutrition at panicle initiation stage through foliar application of K and micronutrients.

The field experiment was laid out in Randomized Block Design. The effect of soil amelioration on soil parameters and growth characters was assessed in simple RBD with three treatments and fifteen replications. The treatments were: no dolomite (T_1), application of ordinary dolomite basally and at 30 DAS (T_2) and application of granulated dolomite basally and at 30 DAS (T_3). The effect of soil amelioration and foliar nutrition on yield and yield attributes, and plant nutrient content and uptake were analysed in factorial RBD with two factors. Factor A consisted of three levels of dolomite application, D_0, D_1 and D_2, similar to treatments mentioned above (T_1, T_2, and T_3), and factor B consisted of five levels of foliar nutrition at PI stage: without foliar application (N_0), foliar spray of 1% KNO_3 (N_1), foliar spray of 1% K_2SiO_3 (N_2), foliar spray of 1% KNO_3 + 0.5% micronutrient solution (N_3) and foliar spray of 1% K_2SiO_3 + 0.5% micronutrient solution (N_4). The medium duration rice variety Uma (Mo 16) was used for the study.

Analysis of experimental results indicated that treatments had significant effect on growth characters, yield and yield attributes, soil nutrient content, and plant nutrient content and uptake in grain and straw as compared to control. Application of granulated dolomite (D_2) produced taller plants with higher LAI at PI and harvest stages, and the highest number of tillers at both maximum tillering and PI stages. The same treatment recorded the highest grain yield (6.79 t ha^{-1}), straw yield (8.78 t ha^{-1}), total dry matter production (15.05 kg ha^{-1}), productive tillers (564.38 m^{-2}), total grains per panicle (85.93), thousand grain weight (28.35 g), and percentage of filled grains (89.32%). Application of 1% KNO_3 + 0.5% micronutrient solution at PI stage (N_3) resulted in the highest grain yield (6.76 t ha^{-1}) which was on par with all other treatments except the treatment without foliar nutrition, and the highest straw yield (8.91 t ha^{-1}) and thousand grain weight (28.56 g) were

obtained with application of 1% KNO_3 alone at PI stage (N_1). The interaction of soil amelioration and foliar nutrition did not show any influence on yield and yield attributes.

Soil analysis was carried out at PI and harvest, and soil amelioration practices had significant effect on pH, EC, OC and all available macro and micronutrient contents in the soil except Zn and Cu. Available N and P contents in the soil at harvest stage were also not influenced by the treatments. Addition of granulated dolomite (D_2) significantly increased available Ca and Mg contents and reduced S and Fe contents in the soil. Among various treatments D_2 recorded the highest soil pH, OC, available K, available Ca, available Mg and available B at both PI and harvest stages and the highest N content at PI stage and the lowest S and Na contents at harvest stages were observed in the same treatment. Treatment without dolomite application recorded the highest EC, available S, Na, and available Fe at both PI and harvest stages.

Plant nutrient contents and uptake were significantly influenced by soil amelioration practices, foliar nutrition and by their interaction effects. Higher uptake of nutrients such as N, P, K, Ca, Mg and S was observed on dolomite application along with foliar nutrition. Plant nutrient content and uptake of nutrients varied among different treatments.

The results obtained from the experiment revealed the significant influence of soil amelioration practices, foliar nutrition and their interaction effect on growth and yield attributes, soil pH, EC, OC, available nutrients and plant nutrient uptake in rice as compared to control. Application of granulated dolomite basally and at 30 DAS was effective in reducing soil acidity, thereby increasing the available nutrient content in soil, which resulted in increased grain yield and quality. Foliar nutrition of 1% KNO_3 or combined spray of 1% KNO_3 with 0.5% micronutrients at PI stage were found to be more effective in enhancing grain yield and quality in rice in Vaikom *Kari* soils.

സംക്ഷിപ്തം

"വൈക്കം കരി മണ്ണിലെ നെല്ലിൻ്റെ (*ഒറൈസ സറ്റൈവ* L.) ധാന്യവിളവും ഗുണനിലവാരവും അമ്ലത്വ ലഘൂകരണത്തിലൂടെയും പർണപോഷണത്തിലൂടെയും വർധിപ്പിക്കൽ" എന്ന തലക്കെട്ടിൽ ഒരു ഗവേഷണം 2019-2021 കാലയളവിൽ നടത്തുകയുണ്ടായി. ഇതിൻ്റെ ഭാഗമായി കോട്ടയം ജില്ലയിൽ വെച്ചൂർ പഞ്ചായത്തിലെ നെൽ കർഷകന്റെ നിലത്തിൽ ഇടത്തരം നെല്ലിനമായ ഉമ പുഞ്ചകൃഷി ചെയ്യുകയുണ്ടായി. മണ്ണിന്റെ അമ്ലത്വം നിയന്ത്രിക്കുന്നതിനുള്ള മണ്ണ് മെച്ചപ്പെടുത്തൽ രീതികളിലൂടേയും, കതിര് നാമ്പിടൽ ഘട്ടത്തിൽ പൊട്ടാസ്യം, സൂക്ഷ്മമൂലകങ്ങൾ എന്നിവ പർണപോഷണത്തിലൂടെ നല്കിയും വൈക്കം കരി മണ്ണിൽ നെല്ലിൻ്റെ വിളവും ഗുണനിലവാരവും വർദ്ധിപ്പിക്കുക എന്നതായിരുന്നു പഠനത്തിന്റെ പ്രധാന ലക്ഷ്യം.

റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈനിലാണ് ഫീൽഡ് പരീക്ഷണം നടത്തിയത്. മണ്ണിന്റെ രാസഘടകങ്ങളിലും, നെല്ലിൻ്റെ വളർച്ചാ പ്രതീകങ്ങളിലും സിമ്പിൾ റാൻഡമൈസഡ് ഡിസൈനിൽ 3 ട്രീട്മെൻറ്റ്കളും 15 ആവർത്തനങ്ങളോടു കൂടിയാണ് പരീക്ഷണം നടത്തിയത്. ഡോളോമൈറ്റ് ഇല്ലാതെ (T_1) സാധാരണ ഡോളോമൈറ്റ് അടിസ്ഥാനമായും 30 ദിവസത്തിന് ശേഷവും (T_2) ഗ്രാനുലേറ്റഡ് ഡോളോമൈറ്റ് അടിസ്ഥാനമായും 30 ദിവസത്തിന് ശേഷവും (T_3) പ്രയോഗിക്കുക എന്നിവയായിരുന്നു പഠനത്തിനായി ഉപയോഗിച്ച പരിചരണ മുറകൾ. നെല്ലിൻ്റെ വിളവ്, വിളവ് സംബന്ധിച്ച ഘടകങ്ങൾ എന്നിവയിൽ മണ്ണ് മെച്ചപ്പെടുത്തലിന്റെയും പർണപോഷണത്തന്റെയും സ്വാധീനം, സസ്യങ്ങളുടെ പോഷക ഉള്ളടക്കം അവയുടെ ആഗീരണം എന്നിവ രണ്ട് പ്രതീകങ്ങളുള്ള ഫാക്ടോറിയൽ റാൻഡമൈസഡ് ഡിസൈനിൽ വിശകലനം ചെയ്തു. പ്രതീകം എയിൽ മുകളിൽ സൂചിപ്പിച്ച ട്രീട്മെൻറ്റ് സമാനമായി (T_1, T_2, T_3), മൂന്ന് തലത്തിലുള്ള ഡോളോമൈറ്റ് പ്രയോഗം, D_0, D_1, D_2 എന്നിവ അടങ്ങിയിരിക്കുന്നു, കൂടാതെ പ്രതീകം ബിയിൽ കതിര് നാമ്പിടൽ ഘട്ടത്തിൽ അഞ്ച് തലത്തിലുള്ള പർണപോഷണവും ഉൾക്കൊള്ളുന്നു: പർണപോഷണം പ്രയോഗിക്കാതെ (N_0) , 1% പൊട്ടാസ്യം നൈട്രേറ്റ് (N_1), 1% പൊട്ടാസ്യം സിലിക്കേറ്റ് (N_2), 1% പൊട്ടാസ്യം നൈട്രേറ്റ് + 0.5% സൂക്ഷ്മമൂലകലായനി (N_3), 1% പൊട്ടാസ്യം സിലിക്കേറ്റ് + 0.5% സൂക്ഷ്മമൂലകലായനി (N_4) . നെല്ലിൻ്റെ വളർച്ചാ സ്വഭാവം, വിളവ്, വിളവ് സംബന്ധിച്ച ഘടകങ്ങൾ, മണ്ണിലെ മൂലകങ്ങളുടെ അളവ്, സസ്യങ്ങളുടെ മൂലകങ്ങളുടെ അളവ്, എന്നിവയിൽ വിവിധ ട്രീട്മെന്റുകൾ നിയന്ത്രണവുമായി താരതമ്യപ്പെടുത്തുമ്പോൾ കാര്യമായ സ്വാധീനം ചെലുത്തുന്നുവെന്ന് പരീക്ഷണ

ഫലങ്ങളുടെ വിശകലനം സൂചിപ്പിച്ചു. ഗ്രാനുലേറ്റഡ് ഡോളോമൈറ്റ് (D_2) പ്രയോഗം കതിര് നാമ്പിടൽ, വിളവെടുപ്പ് ഘട്ടങ്ങളിൽ ഉയർന്ന ലീഫ് ഏരിയ ഇൻഡക്സോടെയുള്ള ഉയരമുള്ള ചെടികളും, കൂടാതെ ടില്ലറിങ്, കതിര് നാമ്പിടൽ ഘട്ടങ്ങളിൽ ഏറ്റവും കൂടുതൽ ടില്ലറുകളും ഉൽപ്പാദിപ്പിച്ചു .ഇതേ ട്രീട്മെൻ്റിൽ തന്നെ ഏറ്റവും ഉയർന്ന ധാന്യവിളവ് വൈക്കോൽ വിളവ്, മൊത്തം ഉണങ്ങിയ പദാർത്ഥങ്ങളുടെ ഉത്പാദനം ഉൽപ്പാദനക്ഷമമായ ടില്ലറുകൾ, കതിരിലെ മൊത്തം ധാന്യങ്ങൾ ,ആയിരം ധാന്യ തൂക്കവും, നിറഞ്ഞ ധാന്യങ്ങളുടെ ശതമാനം എന്നിവയും രേഖപ്പെടുത്തി. കതിര് നാമ്പിടൽ ഘട്ടത്തിൽ 1% പൊട്ടാസ്യം നൈട്രേറ്റ് + 0.5% സൂക്ഷ്മമൂലകലായനി (N_3) പ്രയോഗിച്ചതിന്റെ ഫലമായി ഏറ്റവും ഉയർന്ന ധാന്യ വിളവ് ലഭിച്ചു, ഇത് പർണപോഷണം കൂടാതെയുള്ള ട്രീട്മെൻ്റ് ഒഴികെ മറ്റെല്ലാ ട്രീട്മെൻ്റുകൾക്കും തുല്യമായിരുന്നു, കൂടാതെ ഏറ്റവും ഉയർന്ന വൈക്കോൽ വിളവും ,ആയിരം ധാന്യ തൂക്കവും കതിര് നാമ്പിടൽ ഘട്ടത്തിൽ 1% പൊട്ടാസ്യം നൈട്രേറ്റ് മാത്രം (N_1) പ്രയോഗിച്ചപ്പോൾ ലഭ്യമായി. മണ്ണ് മെച്ചപ്പെടുത്തലിന്റെയും പർണപോഷണത്തിന്റെയും പരസ്പര സ്വാധീനം വിളവ്, വിളവ് ഗുണങ്ങൾ എന്നിവയിൽ ഒരു സ്വാധീനവും കാണിച്ചില്ല.

കതിര് നാമ്പിടൽ, വിളവെടുപ്പ് ഘട്ടങ്ങളിൽ മണ്ണ് വിശകലനം നടത്തിയപ്പോൾ, മണ്ണ് മെച്ചപ്പെടുത്തൽ രീതികൾ പി എച്ച്, വൈദ്യുത ചാലകത, ജൈവാംശം എന്നിവയിലും സിങ്ക് ,കോപ്പർ എന്നിവ ഒഴികെയുള്ള മണ്ണിൽ ലഭ്യമായ മറ്റു എല്ലാ മൂലകങ്ങളിലും കാര്യമായ സ്വാധീനം ചെലുത്തിയതായി കാണിച്ചു. വിളവെടുപ്പ് ഘട്ടത്തിൽ മണ്ണിൽ ലഭ്യമായ നൈട്രജൻ, ഫോസ്ഫറസ് എന്നിവയുടെ അളവ് ട്രീറ്റ്മെൻറ്കളാൽ സ്വാധീനിക്കപ്പെട്ടില്ല. ഗ്രാനുലേറ്റഡ് ഡോളോമൈറ്റ് (D_2) ചേർക്കുന്നത് മണ്ണിൽ ലഭ്യമായ കാൽസ്യം, മഗ്നീഷ്യം എന്നിവ ഗണ്യമായി വർദ്ധിപ്പിക്കുകയും മണ്ണിലെ സൾഫർ, ഇരുമ്പ് എന്നിവ കുറയ്ക്കുകയും ചെയ്തു. വിവിധ ട്രീട്മെൻ്റുകളിൽ കതിര് നാമ്പിടൽ,വിളവെടുപ്പ് ഘട്ടങ്ങളിൽ D_2 വിൽ ഉയർന്ന പി എച്ച്, ഓർഗാനിക് കാർബൺ , ലഭ്യമായ പൊട്ടാസ്യം , കാൽസ്യം , മഗ്നീഷ്യം, ബോറോൺ എന്നിവയും കതിര് നാമ്പിടൽ ഘട്ടത്തിൽ ഉയർന്ന നൈട്രജനും രേഖപ്പെടുത്തി. ഡോളമൈറ്റ് പ്രയോഗമില്ലാതെയുള്ള ട്രീട്മെൻ്റുകൾ കതിര് നാമ്പിടൽ വിളവെടുപ്പ് ഘട്ടങ്ങളിൽ ഏറ്റവും ഉയർന്ന വൈദ്യുത ചാലകത, ലഭ്യമായ സൾഫർ, ഇരുമ്പ്, സോഡിയം, എന്നിവയും രേഖപ്പെടുത്തി.

മണ്ണ് മെച്ചപ്പെടുത്തൽ രീതികളും പർണപോഷണവും അവയുടെ പാരസ്പര്യ ഫലങ്ങളും നെല്ലിന്റെ മൂലകങ്ങളുടെ അളവിനെയും അവയുടെ ആഗീരണത്തേയും ഗണ്യമായി സ്വാധീനിച്ചു. ഡോളമൈറ്റ് പ്രയോഗത്തോടൊപ്പം പർണപോഷണം നൽകുന്നത് നൈട്രജൻ ,ഫോസ്ഫറസ്, പൊട്ടാസ്യം , കാൽസ്യം,

മഗ്നീഷ്യം, സൾഫർ എന്നീ മൂലകങ്ങൾ കൂടുതലായി സ്വീകരിക്കുന്നു എന്നും നിരീക്ഷിക്കപ്പെട്ടു.

പഠന ഫലങ്ങൾ സംഗ്രഹിച്ചാൽ,, മണ്ണ് മെച്ചപ്പെടുത്തൽ രീതികളും പർണപോഷണവും അവയുടെ പരസ്പര സ്വാധീനവും നെല്ലിൻ്റെ വളർച്ചയിലും വിളവിലും, ഗുണനിലവാരത്തിലും, മണ്ണിൻ്റെ പി എച്ച്, വൈദ്യുത ചാലകത, ജൈവാംശം, മണ്ണിൽ ലഭ്യമായ മൂലകങ്ങൾ, നെല്ലിൽ അടങ്ങിട്ടുള്ള മൂലകങ്ങളും അവയുടെ ആഗീരണം എന്നിവയിലും നിയന്ത്രണവുമായി താരതമ്യപ്പെടുത്തുമ്പോൾ ഗണ്യമായ സ്വാധീനം വെളിപ്പെടുത്തി. ഗ്രാനുലേറ്റഡ് ഡോളോമൈറ്റ് അടിസ്ഥാനപരമായും 30 ദിവസത്തിന് ശേഷവും പ്രയോഗിക്കുന്നത് മണ്ണിന്റെ അസിഡിറ്റി കുറയ്ക്കുന്നതിന് ഫലപ്രദമാണെന്ന് കണ്ടെത്തുകയും അതുവഴി മണ്ണിൽ ലഭ്യമായ മൂലകങ്ങളുടെ അളവ് വർദ്ധിപ്പിക്കുകയും ഇത് ധാന്യവിളവും ഗുണനിലവാരവും വർദ്ധിപ്പിക്കുകയും ചെയ്തതായി കണ്ടെത്തുകയുണ്ടായി. 1% പൊട്ടാസ്യം നൈട്രേറ്റ്ൻ്റെ പർണപോഷണം അല്ലെങ്കിൽ 1% പൊട്ടാസ്യം നൈട്രേറ്റ്+ 0.5% സൂക്ഷ്മമൂലകലായനി സംയുക്തമായി തളിക്കുന്നത് വൈക്കം കരി മണ്ണിൽ ധാന്യവിളവും നെല്ലിന്റെ ഗുണനിലവാരവും വർദ്ധിപ്പിക്കുന്നതിന് കൂടുതൽ ഫലപ്രദമാണെന്ന് കണ്ടെത്തി.