‘IMPROVING NITROGEN AND PHOSPHOROUS USE EFFICIENCY IN RICE – WHEAT CROPPING SYSTEM THROUGH APPLICATION OF MODIFIED FERTILIZERS’

A Thesis

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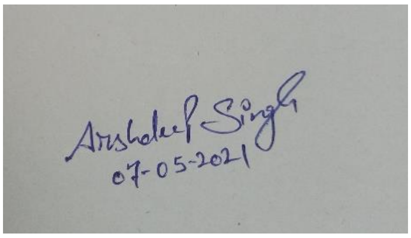
DECLARATION

I do here by declare that this thesis entitled **"Improving Nitrogen and Phosphorous Use Efficiency in rice – wheat cropping system through application of modified fertilizer"** is a bonafide record of the research work carried out by me and no part of the thesis has been submitted earlier to any University or Institute for the award of any degree or diploma.



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<u>CERTIFICATE- I</u>

This is to certify that this thesis entitled "**IMPROVING NITROGEN AND PHOSPHOROUS USE EFFICIENCY IN RICE – WHEAT CROPPING SYSTEM THROUGH APPLICATION OF MODIFIED FERTILIZERS"** being submitted by Arshdeep Singh for the award of Degree of Doctor of Philosophy (Agronomy) to the Lovely Professional University is a record of bonafide research work carried out by her under our supervision and guidance. The thesis has reached the standard fulfilling the requirements of the regulation relating to the degree.

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This is to certify that the thesis entitled entitled "**IMPROVING NITROGEN AND PHOSPHOROUS USE EFFICIENCY IN RICE – WHEAT CROPPING SYSTEM THROUGH APPLICATION OF MODIFIED FERTILIZERS"** submitted by **Arshdeep Singh** to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Agronomy) has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Abstract

The rice-wheat cropping system, which is considered as the backbone of food self-sufficiency, is facing a sustainability problem due to practices of modern production system with indiscriminate use of chemical fertilizers and pesticides. The decline in the rice- wheat crop responses to applied fertilizer nutrients, could be ascribed to emerging nutrient deficiencies on account of modern era of agriculture and inadequate or imbalanced application of fertilizers. It has become increasingly recognized around the world that N, P and K fertilizers alone are not always sufficient to provide balanced nutrition for optimal rice yields and quality, therefore, application of secondary and micronutrient elements has to be made. The highest fertilizer consuming states have the greatest imbalanced use of nutrients. Usage of imbalanced fertilizers badly influences production potential and soil health. The main reason of the variation in fertilizer consumption ratios is due to the nature of soils and cropping pattern. Chemical fertilizer has played a major role in the global food production over the past 60 years. It supplies about 50 % of total N required by crops. However, its use efficiency in crop production is low (10-50 %) mainly due to loss of N through nitrate (NO_3) leaching, volatilization of ammonia (NH_3) and nitrous oxide (N_2O) emission resulting in pollution of groundwater and atmosphere Moreover, the production cost of nitrogen fertilizer is very high. These scenarios lead to the use technologies such as nitrogen inhibitors and slow nitrogen releasing fertilizers given as fertilizer additives to increase nutrient uptake, fertilizer use efficiencies and yields of crops. Slow-release fertilizers, nitrification and urease inhibitors are the three possible types of products that control nitrogen loses and consequently improve nitrogen use efficiency. The field experiment study entitled "Improving nitrogen and phosphorous use efficiency in rice-wheat cropping system by use of modified fertilizers" was conducted during 2018-19 and 2019-20. The field experiments were conducted at Research Farm of Lovely Professional University, Phagwara and Punjab. The experiment was laid out in a Randomized complete block design with three replications and nine treatments namely i.e., T0 Control (RDF), T1 Neem Coated Urea, T2 Anhydrous ammonia + PK recommended, T3 Neem coated urea + PK + S + Zn –EDTA, T4 Anhydrous ammonia + PK + S + Zn- EDTA, T5 Neem coated urea + PK + $ZnSO_4$, T6 Anhydrous ammonia + PK + $ZnSO_4$, T7 RDF + $ZnSO_4$, T8 RDF + S + Zn-EDTA. The results obtained in this study showed that the T3 - Neem coated urea + PK + S + Zn –EDTA performed significantly better than the other treatments for almost all the crop growth and agronomic yield attributing characters (plant height, number of tillers, fresh weight, dry weight, leaf area, CGR, RGR, NAR, effective tillers, panicle/spikelet length, grain per panicle/spikelet,

test weight, grain, and straw yields. The organic carbon, available nitrogen, phosphorus, potassium, sulphur, and zinc in soil at harvest of crop were recorded significantly maximum with the application of Neem coated urea + PK + S + Zn –EDTA over control. It was found that balanced application of NCU+PK +S+ Zn resulted in higher nutrient use efficiency of N, P and K. The total uptake of nitrogen, phosphorus and potassium by rice-wheat was significantly higher in recommended dose of nitrogen through neem coated urea. The soil pH and electrical conductivity (EC) was significantly influenced by slow-release nitrogen fertilizer. The urease, dehydrogenase, acid phosphatase, alkaline phosphatase, nitrate reductase and aryl sulfatase enzyme activities were increased at heading stage and decreased at later stages. The highest enzymatic activities were recorded at surface soil (0-15 cm) as compared to sub-surface soil (15-30cm). The maximum enzymatic activities recorded with the application of neem coated urea + PK + S + Zn –EDT. Minimum enzymatic activities were recorded under treatment T2- Anhydrous ammonia + PK recommended and their combinations with zinc and sulphur. It can be concluded that the nutrient management through chemical fertilizers along with customised slow-release fertilizer were the viable tools of improving FUE and synchronized crop demand. Therefore, balanced fertilization using chemical fertilizers of macro and micro-nutrients not only has the potential to improve crop yields and farmer profits but also has positive implications on possible environmental footprint of fertilizer.
Key words: *NCU, slow-release fertilizer, modified fertilizers, Zn-EDTA, balanced fertilization, leaching, soil enzymes, nutrient use efficiency,*

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Abbreviations/ Acronyms

Ag.	Agriculture
&	And
AAS	Atomic absorption spectrophotometer
BD	Bulk density
C	Carbon
CV	Coefficient of Variance
DHA	Dehydrogenase activity
dSm^{-1}	Deci Siemens per meter
^{o}C	Degree centigrade
Dist.	District
E	East
EC	Electrical conductivity
Fig.	Figure
FAO	Food and Agricultural Organization
AA	Anhydrous ammonia
g	Gram
>	Greater than
ha	Hectare
ICAR	Indian Council of Agricultural Research
IISS	Indian Institute of Soil Science
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
M	Molar
µg g-^{1} TPF g^{-1} d^{-1}	microgram TPF/gm soil/day
Max.	Maximum
µg g-^{1} h^{-1}	Micro gram/gram soil/hour
Mg C g^{-1}	Micro gram carbon per gram
m	Meter
mg kg^{-1}	mega gram per kilogram
min	Minimum

mm	Milli meter
'	Minutes
viz	Namely
N	Nitrogen
N	North
N	Normality
No.	Number
OC	Organic carbon
OM	Organic matter
ppm	Parts per million
%	Per cent
K	Potassium
P	Phosphorus
RDF	Recommended Dose of Fertilizer
NCU	Neem coated urea
SOC	Soil organic carbon
SIC	Soil inorganic carbon
S	Sulphur
pH	Soil reaction
Temp.	Temperature
TPF	Triphenyl Formazon
t ha-1	Tonnes per hectare
USDA	United States Department of Agriculture
Vol.%	Volume percentage
vs	Verses
$ZnSo_4$	Zinc sulphate
EDTA	Ethylene diamine tetra acetic acid
et al.	And co-workers
DMRT	Duncan’s multiple range test
LSD	Least significant difference
CGR	Crop growth rate
RGR	Relative growth rate

NAR	Net assimilation rate
SPAD	Soil plant and development
LA	Leaf area
NUE	Nutrient use efficiency
PUE	Phosphorous use efficiency
KUE	Potassium use efficiency
SUE	Sulphur use efficiency

CHAPTER 1: INTRODUCTION

Rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) both are the cereal crops that belong to the garmineae family and are the rich source of carbohydrate along with other nutrients (Gangwar and Singh, 2011). The rice-wheat rotation based cropping system is one of the dominant cropping systems in the world especially in Indo-Gangetic plain region of Asian countries covering around 13.5 million hectares of cultivated land. As far as India is concerned, 75% of national food grain production is produced by Punjab, Haryana, Bihar, UP and MP through this cropping system. Both crops are the major staple food crops not only for India but also for around the world hence they are also known as "global grain" (Ladha *et al.*, 2003). Even though, the basic requirement for cultivations of both the crops are totally different because rice crops needs stagnant water while wheat crop needs well pulverized soil. The trend of last ten years of rice and wheat production in India was recorded as,

Rice			
Year	Area (m ha)	Production (m ton)	Yield (kg ha^{-1})
2013-2014	44.14	106.65	2416
2014-2015	44.11	105.48	2391
2015-2016	43.39	104.32	2404
2016-2017	43.19	110.15	2550
2017-2018	43.79	112.91	2578
Wheat			
2013-2014	30.47	95.85	3145
2014-2015	31.47	86.53	2750
2015-2016	30.42	92.29	3034
2016-2017	30.79	98.51	3200
2017-2018	29.58	99.70	3371

Table:1 Area, production and yield of rice and wheat from 2013-2018(Source; Directorate of economics and statistics and DAC &FW)

The global population is increasing at exponential rate and will reach around seven billion up to 2050 and to fulfill or to meet the demand of food, the production of grains should also be increased at the same proportion. The developmental conditions of soil and environment are different for rice- wheat cropping system. In rice-wheat cropping system there is conversion of soil from anaerobic to aerobic condition (Mahajan, 2006). Rice is cultivated in puddled soils and stagnant water conditions whereas wheat required pulverized and friable seed bed with proper moisture. Puddling / wet tillage in rice is responsible for hard pan formation in sub soil and due to this the infiltration rate decreased (Greenland and De data, 1985 and Mahajan *et al*., 2007).This system suitable for rice but not for wheat (Sharma *et al*., 2003). In post rice soils wheat yield decreased due to poor infiltration, lack of aeration and rough seed bed (Regmi *et al*., 2002). Stagnating water in rice field change the chemical properties of soil like pH, EC, CEC and affect the availability of nutrients (Ladha *et al*., 2003). Most of the changes are modified with proper drainage which promotes the implication of proper nutrient management strategies in rice- what cropping system.

Currently, India is the second largest consumer of nitrogen in the world because urea is one the cheapest source of nitrogen and very suitable for most of the growing crops hence the consumption of urea gradually increased from 0.6 metric ton to 16.95 metric tons between 1965-66 to 2014-15 (FAO, 2016). A huge amount of nitrogen and phosphorus is required by the rice-wheat cropping system throughout the season / year to fulfill the demand of major nutrients. Both the nutrients are major or essential plant nutrients that plays a very vital role to strengthen plant growth and development during its growing period (Fageria *et al.*, 2008). Nitrogen is the key element and major component of amino acid, nucleic acid, nucleotides, chlorophyll content, enzymes and hormones though it contributes a lot to promote many physiological, biochemical and yield contributing characters in plant like root establishment, tillering, leaf area, chlorophyll, nitrogen and protein content, test weight ,number of grains and grain yield etc. (Kumar *et al*.,2015) Phosphorus is the second most important essential nutrient after nitrogen that plays a vital role directly or indirectly in many metabolic processes like photosynthesis, energy storage and transfer, cell division etc. in plants. Hence, it improves and establish root system in the soil including other plant parts like shoot, leaf, and grain. Application of nitrogen and phosphorus increased yield of crop by 40% over last 50 years but overdose application of both the fertilizers may not help in further enhancement of crop production. Overdose of these fertilizers has created some global issues in which environmental pollution is one of them. Excess use of nitrogen base fertilizer has decreased the nitrogen as well as phosphorus use efficiency while through surface runoff, leaching, voltalization, and denitrification process causes water and environmental pollution because it release in the form of NO_2^-, NO_3^-, N_2 and NH_3 in the atmosphere. Out of all the form of nitrogen emitted in the atmosphere, N_2O is a one of the powerful ozone depleting compound in the atmosphere and contributes 75 % of greenhouse gas alone (Swarup *et al.,* 2010). To nourish the agriculture crops, huge amount of energy is derived from fossil fuels. During the derivation of energy from fossil fuels, incredible amount of CO_2 is released in the atmosphere while the utilization of fossil fuels could be decreased, if less nitrogen fertilizers are produced, consumed and transported. Nowadays, most of the issues are just because of certain reasons such as overuse of fertilizers and continuous rice-wheat cropping system. Even though the application of optimum dose of N, P and K along with micronutrient Zn, B, Fe and S is regular in rice-wheat cropping (Singh *et al.,* 2013). Anaerobic condition of rice crop and aerobic condition of wheat is one of the causes for the deficiency of macro and micro element under rice-wheat cropping system. Among the growing medium of crop either field or pot, the ability of soil to supply available nutrients to the crop may also vary in the same cropping system (Dobermann *et al.,* 2004). Nowadays, many strategies have been developed to increase the NUE such as proper time, rate of application, deep placement and modified form of fertilizer application. The nutrient use efficiency can also increase by applying in split dose along with the supply of micro-nutrient as per the requirement like Zn, S and B (Khalil, *et al.,* 2014). Ultimately there are two forms of nitrogen available in the soil i.e. ammonium and nitrate form in which ammonium form of nitrogen is lost mostly as NH_3 (ammonia gas) while the nitrate form of nitrogen through leaching below the root zone. For increasing the NUE and reducing the denitrification process in the agricultural field, there are many denitrification inhibitors available in the market that help in reducing bacterial oxidation of ammonium-N by suppressing the activity of nitrosomonas bacteria. But due to high cost of theses inhibitors, Indian farmers are unable to afford this facility yet (Vasantha and Madiwalar 2010).

The oil extract from the neem seeds (*Azadirachta indica*) and their cake both can be used to coat the urea for increasing the nutrient use efficiency in rice wheat cropping system because in early 1970s, the property and quality of neem in respect to improving the nutrient use efficiency were reported by various researchers. The excellent results in term of increasing crop yield was recorded while neem coated urea either produced by manually on small scale or in factories by mixing @ 0.1 to 0.2 tonnes neem cake per tonnes of urea were used (Bains *et al.,* 1971 and Schmutter, 1990). The neem coated urea not only improves the yield of rice-wheat crop but also help to improve the agronomic efficiency (AE) and apparent recovery efficiency

(ARE). The AE efficiency shows the direct production effect of an applied fertilizer (yield increase per unit of nutrient applied) and correlate with economic return. However, ARE is the difference in nutrient uptake by above ground part between fertilized and unfertilized crop. Nowadays the life span of fertilizer can be increase by coating and pelleting of fertilizers with inert material (Biswas *et al*., 2013). Another solution for improvement of nutrient use efficiency of nitrogen is the use of liquid nitrogen fertilizers especially anhydrous ammonia because it enhances the nitrogen use efficiency as well as inhibits the unproductive losses of nitrogen. The application of these form of fertilizer in the soil strongly fixed into the soil colloid hence reduced the losses through infiltration vise versa (Abalos *et al.,* 2013). Injecting the liquid nitrogen fertilizer in the form of anhydrous ammonia below the soil surface enhances the retention capacity in the soil and consumption by the plants. Anhydrous ammonia in the form of injection confirmed higher content of nitrogen, modified microbial activity and nutrient pool in the top layers of the soil .

Application of balance proportion of Phosphorus and Zinc help to achieved good yield because the interaction of these fertilizers show synergistic effect. The application of Zinc fertilizer also increases the uptake of phosphorus in rice-wheat cropping system, but more or less amount of Zinc than optimum dose can adversely affect the uptake of phosphorus in wheat crop. Zinc use efficiency probably more in rice crop as compared to wheat crop because it might be due to more availability of Zinc in the soil due to well aerated condition which retard the formation of insoluble form of Zinc compound (Alam and Islam 2016; Gill *et al.,* 2014: Oseni, 2009). Zinc as a micronutrient plays a very vital role not only for the growth and development but also for enhancing the yield drastically in various crops in combination with N, P and K fertilizers. It is involved directly or indirectly in various hormonal, enzymatic and metabolic processes to facilitate the reactions for contributing towards gain of dry matter and grain yield. The deficiency of zinc in the plant system during the growth period may cause the yield losses because zinc is also responsible for the synthesis of protein via tryptophan. However, the response of crop growth, development and yield gain differs according to the source of zinc fertilizers (Qui and Liu, 2010; Shehu and Jamala, 2010 and Fageria *et al.*, 2011). Zn-EDTA is the source of Zn which is a kind of chelated form of Zn fertilizers provides large amount of Zn to the plant without any complex reaction with soil component. The application Zn-EDTA and

$ZnSO_4.7H_2O$ shows different efficiency and stability during the course of interaction with soil component due to available pool of Zinc in soil (Ali *et al*., 2015).

The requirement of sulphur by cereal crops are less as compared to root crops, leguminous crops and oil crops. The source and placement of sulphur fertilizer is an important factor that need to be taken care of during the development of fertilizer management strategies due to presence of oxidized and reduced layers in the soil. In case of rice, 50 % amount of Sulphur absorb when it is applied to the surface of soil while 30 % with deep placement because it absorbs by plant through the root system from the soil. The Sulphur elemental form is not directly absorbed by plant because it needs to convert into sulphate though it depends upon the population and activity of microorganism, soil temperature and moisture status. The nitrogen use efficiency may increase with the application of sulphur because the nitrogen and sulphur both are deeply associated in various processes like synthesis of amino acid (cysteine and methionine), chlorophyll biosynthesis, sulpholipids synthesis, defense system against nutrient stress and attack of pest on crop. The method of application and source of fertilizers vary from crop to crop because the residual effect of Sulphur is shown in succeeding crop accordingly. The application of recommended dose of N and S lead to improve nutrient uptake efficiency and help to reduce soil pH (Zhao *et al*., 2013; Raj Kumar *et al*., 2014; Thind *et al*., , 2010; Parama sivan *et al.*, 2011 and Siam *et al*.,2012).

To increase the nutrient use efficiency especially nitrogen and phosphorous in rice-wheat cropping system, it is a demand of current scenario to find out some modified form of fertilizer along with the combination of micronutrients. The loss of fertilizers especially urea through leaching is another aspect that adversely affect the nutrient use efficiency. To check these kinds of nutrient losses, it is a need to conduct the trial in field as well in pot to estimate the losses as well as to find out the possible ways to overcome the problem. On the basis of above-mentioned issues, the following objectives were taken into consideration.

1- To increase nitrogen and phosphorus use efficiency of crop by use of modified fertilizers
2- To study the role of sulphur in increasing nutrient use efficiency with crop productivity
3- To study the nutrient uptake and crop productivity
4- To study the effect of modified fertilizers on enzymatic activities

The function of nitrogen and phosphorous in enhancing crop production has been well established. In soils, nitrogen is present in 3 forms – organic, ammonical and nitrate. Nitrogen is taken up by plant in ammonical form. Most of the crops take nitrogen in nitrate form except rice. But, crop response to applied nitrogen mainly based upon the rate of conversion of applied nitrogen to available form and used by crop.

Urea is the most famous fertilizer of nitrogenous fertilizers in India. The nitrate use efficiency is commonly less for cultivated crops and cereals. The huge amount of nitrogen is lost through denitrification, runoff, volatilization, immobilization, and leaching. There are so many management practices which can increase efficiency of nitrogen fertilizer, out of all this use of increase efficiency of nitrogenous fertilizers is one important practice. Many types of coated fertilizers of urea are made and coming into market. The variation in the release of nitrogen from these coated fertilizers is main point of consideration to improve the nitrogen use efficiency.

The research on the how nitrogen released from coated fertilizers helps in understanding the nitrogen availability over certain time. The nutrient use efficiency can be enhanced if the nitrogen demand of crop coincides with the release nitrogen form coated fertilizers. The merits of coated fertilizers are reduction in leaching and volatilization, delay in nitrification and nitrogen supply for long time. The crop uptake most of nitrogen during maximum growth period. So, the time and rate of release of nutrients from slow release nitrogenous fertilizers are point of interest in management decision. The environmental factors-temperature and moisture play vital role in the rate of nitrogen release and nitrate accumulation. The suitability of slow release fertilizer under particular soil condition is important in enhancing fertilizer nitrogen and phosphorous use efficiency.

Keeping these points in view, the studies pertaining to improving nitrogen and phosphorous use efficiency in rice – wheat cropping system through application of modified fertilizers are reviewed and presented under following subheadings-

2.1 Rice – Wheat cropping system

2.2 Concept of fertilizers

2.3 Concept and need of nutrient use efficiency

2.4 Effect of modified fertilizers on enzymatic activities in soil

2.5 Effect of modified fertilizers on crop nutrient uptake

2.6 Effect of modified fertilizers on yield attributing characters of rice – wheat

2.7 Effect of modified fertilizers on yield

2.8 Effect of modified fertilizers on soil chemical properties and nutrient availability

2.9 Effect of modified fertilizers nutrient use efficiency, phosphorous use efficiency and sulphur use efficiency

2.1 Rice – Wheat cropping system: - The rice – wheat crop rotation is the main cropping system followed in South – Asian countries, which covers about 135 million hectares in India-Gangetic plain region (Mahajan, 2006). Out of 135 million heactare, 10 million hectares occupied by India, 2.2 million hectares by Pakistan, 0.8 million hectares in Nepal (Anonymous, 2005). This cropping system is the most prevalent cropping system in Indian states like Punjab, Haryana, Bihar, Uttar Pradesh, and Madhya Pradesh. These states contributed 75% in total food grain production. The rice – wheat cropping system is the main cropping system of India's food self-sufficiency (Acharya *et al.*, 2003). Behzad Murtaza *et al.*, 2017 has examined that, there is global scarcity of water resources, soil pollution and increasing of salinity. According to worldwide data there is more than 8×10^8 ha of land is affected by salt accumulation (Rozema and Flower, 2008). The main reason of salt affected soil is heavy Na content, high pH ratio, more solubilized sodium in water. Whenever nitrogen application is done in the crop then there is more chance of pH disturbance. The magnesium and calcium ions will be disturb by adding excess amount of phosphorous and soil salt will be increase. High amount of fertilizers may cause heavy losses due to the ion toxicity, imbalance in crop growth hormones (Munns *et al.*, 2006). Due to the imbalance of elements most of the nitrogen content will be loss by leaching as nitrate with high pH levels, loss of nitrogen in form of nitrate to nitrite form (Marschner, 2011). By all these factors nitrogen use efficiency (NUE) and physicochemical properties will be limited (Gratten and Grieve, 1999). Nitrogen cycle in relation of soil-plant is affected by climatic conditions, soil factors, and plants factors. It is very dynamic and complex situation for the availability of nutrients (Fageria and Baligar 2005). Non coated urea will release to nitrogen quickly and will loss by volatilization and denitrification. So, that for improvement of nitrogen use efficiency, coated urea will be used for avoiding or reduce the nitrogen loss. There is less contact of urea granules with the soil by its coated element and also reduce to environmental pollution (Ladha *et al.*, 2016; Ortega *et al.* 2016).

2.1.1 Characteristics of Rice – Wheat cropping system: - In Indian subcontinent rice – wheat cropping system is quite new and initiated only in 1960s with introduction of dwarf wheat from CIMMYT, Mexico. Dwarf wheat required less temperature for germination as compared to traditional tall wheat (Chenkual *et al.*, 1990) whereas rice is cultivated in different conditions like wet tropical, humid to subtropical and temperate (Fujisaka *et al.*, 1994). The environmental and soil conditions for the development of rice – wheat both are different. Rice cultivates under water stagnation while wheat in well pulverized soil with proper moisture and air. Therefore, the most important feature of rice – wheat cropping system is the yearly conversion of soil from is the yearly conversion of soil from aerobic to anaerobic and then again aerobic condition (Mahajan, 2008).

Rice is traditionally cultivated on well puddled soils. Puddling is also known as wet tillage which is responsible for change in physical properties of soil. Due to puddling sometimes hardpan formation in subsoil which decreased the percolation (Greenland and De Datta, 1985 and Mahajan *et al.*,2007). This type of change is suitable for rice but not for upland wheat (Sharma *et al.*, 2003). So, yield of wheat is less in post – rice soils due to rough seed bed; poor drainage lacks of aeration and nutrient stress (Regmi *et al.*, 2002). Rice crop required more water for its cultivation but puddling decreases permeability. Rice crop consumes 5000 liters of water in irrigated conditions for 1 kg of grain produced (IRRI, 1995). But wheat crop required 1000-2000 liters of water to produce 1kg of grain. Water stagnation in rice field responsible for change in chemical properties, which continues transformation and availability of nutrients (Ponna perma 1972 and 1985). The flooded rice field soil having exchangeable potassium and sodium as compared to wheat (Pathak *et al.,* 2003). The pressure of CO_2 in stagnant water buffers carbonate content and reduce pH. The changed pH changes the chemical equilibrium and availability of plant nutrients (Ladha *et al.*, 2003).

2.2 Concept of fertilizers: -

2.2.1 Nitrogen fertilizers: - From many years, the demand for supplying nitrogen in fertilizers was the second main concern because of the significant role of nitrogen in crop production (Dev., G 1997). Coal having 1% nitrogen half of nitrogen was evolved as ammonia in by product in gas producers (Mohanty ,1989). During later part of 19^{th} century, nitrogen became a growing source of nitrogen fertilizers. Most of it inform of ammonium sulphate, minor in form of gas liquor as dilute solution of ammonia .As population growing day by day to meet the demand of food more nitrogen required. In 1903, the arc process was introduced in Norway (Rattan *et al.*, 1997). To form nitric oxide nitrogen and oxygen combined at extremely high temperature (32.50^0C) in an electric arc. After that nitric formed which was converted to calcium nitrate by reacting with limestone (Lian *et al.,* 1989). Calcium cyanamide formed reacting with pure nitrogen extracted from air. But $CaCN_2$ and are process were costly. The first-time direct synthesis of ammonia from nitrogen and hydrogen carried out in Germany in 1913 (Von Uexkull *et al.*, 1992). The use of centrifugal compress started in 1960's. The final products made were low analysis fertilizers ammonium sulphate, calcium nitrate, sodium nitrate and calcium cyanamide (Rattan *et al.,* 1997). In 1940's ammonium nitrate, become an important fertilizer and as leading fertilizers 1960's. But urea production (46% N) grown rapidly and now its use is number one worldwide. On the other hand, in some country's anhydrous ammonia (82% N) direct application to soil growing quickly (Go swami, N.N 1997). Nitrogen is one of the most yield-limiting nutrients for crop production in the world. It is also the nutrient element applied in the largest quantity for most annual crops (Thompson *et al.,* 2007). Nitrogen also increases shoot dry matter, which is positively associated with grain yield in cereals and legumes (Fageria 2008). Grain harvest index (grain yield/straw dry weight plus grain yield) and N harvest index (N uptake in the grain/N uptake in grain plus straw) are also reported to be improved by addition of N to crop plants. Nitrogen always helps to increase vegetative parts of the plants (leaves, chlorophyll content) and phosphorous always helps in proper photosynthesis, respiration, and storage of energy, cell division and enlargement of the plants (Fageria 2008). Nitrogen (N) is the most limiting factor in crop production. Hence, application of N fertilizer results in higher biomass yields and protein content in plant tissue (Blumenthal *et al.*, 2008). Surface broadcasting of PUE is practiced by farmers to meet up the N demand for rice crop. Broadcasting of urea to agricultural soils can result in considerable losses by NH_3 (Ammonia) volatilization (Rochette *et al.*, 2009). Ammonia (NH_3) volatilization is a bad pathway for fertilizer N loss from soil and is also a major source of air and environmental pollution (Wang *et al.*, 2004). Numerous experiments have shown that the efficiency at which N is utilized by wetland rice is only about 30% of the applied fertilizer N and in many cases even less (Prashad and de Datta, 1979). Phosphorus fertilization often does not substantially increase soil test levels because P can quickly convert from plant available to unavailable. However, the nature and magnitude of N and loss largely depend upon the sources of N and P fertilizer and methods of fertilizer application. This loss of N and P may be reduced by the deep placement neem coated urea and phosphorous coated fertilizers. So, that the loss of fertilizers will be reduced and their availability in soil will be increase. The mineral fertilizers, apart from their immense benefit, when applied in excess cause eutrophication of freshwater estuaries and coastal water ecosystems (Raven and Taylor 2003), and the increased emission of greenhouse gases, such as nitrous oxide N_2O (Matson *et al.* 1998).

2.2.2 Phosphate fertilizers: - Ground bone was firstly used phosphate fertilizer in Europe during beginning of 19th century (Colwell *et al.*, 1973). In 1840, phosphate rock treated with sulphuric acid to form effective phosphatic fertilizer. The first commercial superphosphate was prepared by laws in England in 1842. The first triple superphosphate was prepared in 1870's in Germany (Bowden *et al.,* 1974). But triple superphosphate was not considered effective fertilizer. In 1960's ammonium phosphate had been an effective fertilizer. Ammonium phosphate recently the most leading form of Phosphatic fertilizers in world .Phosphorus (P) is an essential macronutrient often limiting the plant growth due to its low solubility and fixation in the soil. Nitrogen and Phosphorous are fundamental to crop development because they form the basic component of many organic molecules, nucleic acids and proteins (Debouba *et al.*, 2013).Improving soil fertility by releasing bound phosphorus by microbial inoculants is an important aspect for increasing crop yield.

2.2.3 Potash fertilizers: - Previously, potash sources were wood ashes; sugar beet waste and salt petar low grade manure salts, kainite were first products. High grade potassium chloride (60% K_2O) is main product. Potassium sulphate and potassium nitrate are principle non chloride potash fertilizers (Rae *et al.,* 1977). MA Mazid Miah *et al.*, 2008 has examined that potassium is always important nutrient in the form of large amount for proper development of plants. It also increases the CO_2 uptake by plant roots and making drought resistance. It is also examined that potassium is required for proper photosynthesis in plants. All the opening and closing of stomata for gas exchange by respiration process. The yield was recorded more in rice-wheat cropping system by all factors like opening and closing of stomata, proper photosynthesis, enzyme activation, more uptakes of CO_2, and proper respiration with adenosine triphosphate (ATP). Where potassium fertilizer continuously applied in recommended dose by 10 t ha^{-1} but completely in the absence of potassium rice and wheat yield badly degraded or decreased by 1 t ha^{-1} in 1985 and after that 6.2 t ha^{-1} in 2000. Earlier the rice yield was not sharply decreased with less amount of potassium but with more gap (no application of potassium) rice yield quickly decreased. This is examined by Ma Mazid Miah *et al.*, 2008 that the 50 kg/ha 'K' showed significant role by economic ratio and produced good yield in wet and dry season. In another case 'K' showed again best result in wheat with more production. In the control plot 'K' increased wheat grain by 53% but in rice there is 16% grain increased in clay soil but in sandy loam soil it is 30%. 'K' will never present in soil for long time so, soil can-not serve 'K' to crop adequately for an indefinite period . Crop residue will add potassium in soil organically, but rock potassium is the only one who will fulfill the requirement and enhance to wheat and rice yield adequately.

2.2.4 Role of fertilizers: - Soils need maintenance of fertility. Soil is a natural body of fine rocks, minerals, and organic matter (Tomar *et al.,* 1984). Sand, Silt, Clay, and Organic matter provide tilth, aeration to soil and increase infiltration rate. But they slightly maintain continuity in healthy plant growth. So, to accelerate the rate of growth, there is a need of fertilizer.

2.2.4.1Chemical fertilizers in Rice – Wheat cropping system: - The fertilizers are and will remain the vital component of intensive cropping system, as they are responsible for 50% increase in food production (Ladha *et al.,* 2003). About 3/4th of fertilizers consumed in rice and wheat. The application of recommended dose of nitrogen in rice – wheat cropping system to both crops without any residual effect (Pathak *et al.*, 2003). The availability of Phosphorous in soil under submergence in rice is more as compared to wheat. In phosphorous deficient soils, the application of phosphorous is very compulsory in both the crops. Rice crops were sensitive towards potassium than wheat, so add potassium to soils based on soil test recommendation (Ram, 2002). The sulphur free fertilizers like Urea, DAP, MOP use increased which led to need of sulphur application (Yadav and Kumar, 2000a). The more nutrient responsive varieties of rice and wheat in intensive croppingresponsibe for micronutrient deficiencies(Chaudhary *et al.*, 2002), commonly Zn. So, this micronutrient deficiency is a main yield limiting barrier. So, as per the crop needs the deficient micronutrient should be supplied through the belonging carriers in soil. In case of rice – wheat cropping system zinc can be supply to soil through soil application or foliar application to both crops (Acharya *et al.,* 2001).

2.2.4.2 Functions of N, P, K, S and Zn

1. Nitrogen: - Nitrogen promotes the vegetative growth of plant. An important element in the formation of chlorophyll helps in the synthesis of amino acids which changes to protein. Helps in uptake of other nutrients N is a main ingredient of nucleic acid and enzymes (Prasad, R 2005).

2. Phosphorous: - Initiates root formation in plants and elongate their root hairs which absorb nutrients from soil. It maintains strength of plant. It hastens the maturity, helps in blooming of flowers and seed development. Act as energy transformer and convert sugar to hormones, protein, and energy to newly emerged leaves. Helps in formation of nucleic acids. Phosphorous important for photosynthesis and cell division (Anonymous, 1993).

3. Potassium: - Potassium helps in development of stems and leaves. Enhance disease resistance and hardiness in plants. Provide strength to cell wall, helps in translocation of nutrient, potassium act as a catalyst in Fe uptake, important for formation and translocation of protein, starch, and sugar (Anonymous, 2000).

4. Sulphur: - Main component of 3 amino acids and important for the formation of protein. It helps in maintaining green colour. Helps in reclamation of alkaline soils. Helps to make compacted soils loose and increase infiltration rate (Chaudhary *et al.*, 2002). Commonly two forms of sulphur available to plants and soils – Sulphate sulphur $SO^{2-}{}_4$ and elemental sulphur

(S). Sulphate sulphur present in gypsum. Elemental sulphur converts into sulphate from into soil. This reaction is slow based upon particle size and soil conditions. If once it is transformed to sulphate form, it is available to plants, its lowers pH of soil (Ladha *et al.*, 2003).

5. Zinc: - Zinc is the vital component of many plant enzymes. It is a part of auxin and central the function of indole acetic acid also affects intake and efficient use of water by plants (Yadav and Kumar, 2000b). Debnath S *et al.*, 2015 has examined that in Indo-Gangetic plains region rice-wheat cropping system is most important system. They have observed that Zn application always leave positive impact on the growth and development of rice-wheat cropping system; in experiment it was observed that there is significant effect of zinc fertilizer on crops for nutrient uptake, proper use efficiency, increasing in yield and good output in the form of grains by using agronomic parameters. They have also examined that the combination of P X Zn not significantly increased in Basmati rice but for wheat crop this combination gave best result (5.43t ha^{-1}). The most common micro-nutrient deficient in soil like Zinc, Boron, and Iron even farmers are applying regular 'NPK' in rice-wheat field. Mostly the soil effect is responsible for the P X Zn combination because during rice the soil's condition is anaerobic (Singh and Singh ,2000). The availability of soil nutrients always varied there is recommended dose or not, there is very large variation according to season (Dobermann *et al.*, 2004). Mostly the phosphatic fertilizers are essential to obtain the good results but only up to 20% of the applied 'P' fertilizer is used by the crops and mostly 'P' is lost from soil by erosion through water bodies (Swarup 2010). 'P' and 'Zn' combination interaction is showing positive impact on rice- wheat cropping system due to this cropping system (Rice- Wheat). Indian soils are mostly deficient in 'P' and 'Zn' fertilizers or micronutrients (Jain & Dahama, 2007). With the high 'P' fertilizer dose the uptake of 'Zn' is low and may low 'Zn' concentration in plant tissues. So, that more amount of 'Zn' is required to maintain the crop growth rate (Aref, 2012). By this more accumulation of 'P' in plant leaves may cause toxic effect when the Zn fertilizer or level is low in leaves (Loneragan *et al.*, 1982). 'P' and 'Zn' combination is hardly required in cropping system to fulfillment of Zn requirement in human body by crop production (Akhtar *et al.*, 2010). It has observed by (Correa *et al.*, 2002) that the 'P' and 'Zn' interaction left the best result on plant growth, flag leaf, grains and in straw. They both are not leaving any bad impact on each other when both are used as recommended dose. There is significantly 'Zn' increased in grain and in basmati straw as compared to control plot. Impact of 'P' and 'Zn' on wheat and rice shoot is positively significant and accumulation in shoots as compared to control plot. It was highly observed that 'Zn' content more present in basmati rice shoot as compared to wheat shoot. So, this is proper evidence that there is slow translocation of Zn from roots to tip of crops and it is considered as mobile nutrient.

2.2.5 Soil related constraints in Rice – Wheat cropping system: - The imbalanced use of fertilizers of N, P, and K not declined production but also depleted soil fertility. The soil becomes sick in terms of organic matter and micronutrients. The physical, chemical, and biological properties of soil deteriorated i.e. soils are low in available plant nutrients: -

Deficiency of N: - Most of Indian soils are low in available N, P and little bit K. Nitrogen is the barrier in the wheat rice production various experiments conducted at various research stations in agriculture universities resulted that wheat and rice crop responds to 120 kg nitrogen ha^{-1}, although lower and high doses responses to 120 kg ha^{-1} found. CAN and urea were equally effective in wheat; the same yield was obtained with CAN and urea in Delhi, Haryana, and Punjab soil conditions (Gupta *et al.,* 1984).

Deficiency of Phosphorous: - Along with N, P addition also found suitable to get good yield of rice – wheat crop. It has been calculated that 20-25% phosphorous utilized by crop, which recommended that preceding crops grown should be taken care. Good yield is not obtained under added nitrogen in rice – wheat cropping system unless phosphorous is added (Meelu *et al*., 1991).

Deficiency of Potassium: - Deficiency towards the added potassium has been noticed in North-Indian soils due to the illite nature of clay minerals in Himachal Pradesh (Gupta *et al.,* 1986, 1990) and Punjab (Sehgal 1972). The long-term studies on fertilizer in rice wheat, maize – wheat cropping system have shown positive response to added potassium. This study resulted that with continuous cropping without potassium application the soils rapidly deficient in available potassium.

Deficiency of Potassium and Phosphorous by continuous use of Nitrogen: -

The long-term fertilizer addition has shown that repeated use of only nitrogen can never perform well without phosphorous and potassium fertilizers. The long-term nitrogen fertilizer application in rice – wheat cropping system is a short-lived process and responsible for depletion of phosphorous and potassium. The progressive depletion of potassium and phosphorous resulted heavy removal and soils become deficient with phosphorous and potassium, with continuously using nitrogen only (Anonymous, 2000).

Deficiency of Sulphur: - In light textured soils currently deficiency of sulphur reported in wheat crop. The response of wheat to sulphur in various soils has been noticed with an increment in wheat yield as compared to control (Meelu *et al.*, 1990).

Deficiency of Micro nutrients: - Zinc deficiency has been noticed in all rice growing soils of India (Prasad, 2005), rather than N, P, K and S, the deficiency of Zn and other micronutrients Mn, Fe, has been noticed (Anonymous, 2000). Therefore, the NPK application in rice – wheat for maximum yield is no longer available, and consideration for secondary and micro-nutrients should be take care (Mahajan, 2006).

2.3 Concept and Need of Nutrient Use Efficiency: -

2.3.1 Need of Nutrient Use Efficiency in plants and soil: -

The serious challenge of feeling the world's population of around 7 billion with healthy food is faced by agriculture (FAO, 2013). The population will reach to 9 billion by 2050. So, this much increase in the growth of population will increase pressure on the world's resources (Land, air and water) to meet the demand of food production. Increasing the land area under crop cultivation and enhancing food production only help in enhancing food production. Approximately, 1.54 billion ha of worlds land area under crop cultivation .Inappropriate management and more cultivation led to soil degrading due to which reasonable production of annual and perennial crop not achieved. Most of the soils are lacking in most of essential nutrients and some of them contain toxic elements (Baligar *et al.*, 2001). Accumulation of salts responsible for the degradation of soil and poor fertility. Addition of fertilizers/ soil amendments can improve the degraded soil and provide essential nutrients to get more production.

Recently, 105 million tons of nitrogen, 20 million ton of Phosphorous and 23 million ton of potassium used by world for the production of food (FAO, 2018). The applied fertilizer recovery efficiency is exceptionally low i.e. 50% for nitrogen, 10% phosphorous, 40% for potassium (Fageria *et al.,* 2002). Leaching, runoff, volatilization fixation in soil and inefficient use of nutrient are the reasons of low fertilizer efficiency.

In today's agriculture use of the essential plant nutrients very much required to enhance productivity and maintain the sustainability of cropping system. Use of nutrients by plants directly affected by climatic, soil, plant factors. Most of the nutrients part is lost in the soil plant system. The low nutrient use efficiency not only increases cost but lead to environmental pollution also (Faeria *et al.,* 2008). The nutrient use efficiency depends on uptake efficiency, incorporation efficiency and utilization efficiency. Nutrient use efficiency can be defined as the yield produces per unit nutrient applied (Mengel and Kirk by, 2001). Clark 1990 defined NUE in crop species, in this manner that those crops are efficient to nutrient use which produce more yield and has less deficiency symptoms.

2.3.2 Nutrient use efficiency terms

Nutrient use efficiency: - It may be defined as the highest economic yield produced per unit of applied nutrient (Graham, 1984). Blair (1993) defined nutrient use efficiency as the potential of a plant to take nutrients form growth medium and utilize that nutrient in its metabolic activities.

Nutrient Efficiency Ratio (NER): - Nutrient Efficiency Ratio was proposed by Gerloff and Gabelman (1983) to find out the nutrient utilizers. It can be defined as yield obtained in Kg as per unit of nutrient in plant tissue in Kg. The units of NER are (kg /kg).

Agronomic efficiency (AE): - It is defined as the economic yield obtained from unfertilized plot subtracted from yield obtained from fertilized plot and divided by quantity of applied nutrient in kg. Units of AE (kg/ kg).

Physiological efficiency (PE): - It may be defined as the biological yield getting from unfertilized plot subtracted from biological yield getting from fertilized plots and divided by nutrient up take in fertilized- nutrient uptake in unfertilized plot in Kg. Units are (Kg /Kg).

Agro physiological efficiency (APE): - It is defined as the grain yield per unit of nutrient uptake.

$$\text{APE (kg/ kg)} = \frac{\text{Grain yield in fertilized plot in kg} - \text{Grain yield in unfertilized plot in kg}}{\text{Nutrient uptake by fertilized plot} - \text{Nutrient uptake in unfertilized plot in kg}}$$

Apparent Recovery efficiency (ARE): - It is the quantity of nutrient uptake per unit of nutrient applied.

$$\text{ARE (\%)} = \frac{\text{Nutrient uptake in fertilized plot} - \text{Nutrient uptake in unfertilized plot}}{\text{Quantity of nutrient applied}} \times 100$$

Utilization efficiency: - It is multiplication of physiological efficiency and apparent recovery efficiency. Units are kg/ kg.

2.3.3 Factors affecting Nutrient Use Efficiency: - The efficiency of nutrients transport and utilization by crop grown on soil medium is regulated by (i) the ability of soil to provide nutrients (ii) the potential of plants to absorb and make use of the nutrients. The nutrient use efficiency divided into uptake efficiency and utilization efficiency.

1. Plant factors: - The genetic variability in species of plants is mainly responsible for the variation in nutrient use efficiency. The variation in nutrient use efficiency differs the rate of absorption, translocation, and dry matter production. The other plant factors which affects the nutrient use efficiency are roots and root hair morphology, secretion of H^+, OH^-, HCO_3^- by roots, organic acids exudation by roots, secretion of enzymes and microbial association (Baligar *et al.,* 2001), (Agrama 2006).

2. Soil factors: - The soil productivity of many soils in world reduced due to poor soil physical properties (bulk density, hardpan, soil structure and texture, crust formation, water holding capacity, exchange of gases and temperature) and chemical properties (pH, EC, toxicity of nutrients soil organic matter). These problems of soil influenced the transformation (mineralization,immobilization), fixation of nutrients and leaching of applied nutrients. The mineral deficiencies of nutrients and toxicities due to ore pH influence the growth and morphology of roots. This change in root growth and morphology influence the ability of roots to absorb the nutrients from soil (Fageria 2013).

3. Fertilizer factors: - Berber (1976) gave the term fertilizer use efficiency. Fertilizer Use Efficiency is defined as the quantity of increase in production as per unit of applied nutrient. There should be improvement in recovery efficiency of applied fertilizers by adopting suitable fertilizer source, right time of application, by use of controlled and slow release fertilizers. So, use of fertilizers should be efficient so that leaching, volatilization, immobilization and fixation of fertilizers in soil (more pH, low soil organic matter) conditions, plants show deficiency symptoms, which affect crop growth, development and nutrient use efficiency (Fageria, 2009) .

4. Agronomic factors: - Physical, chemical, and biological properties of soil are influenced by the various tillage operations. Rooting pattern, water holding capacity, moisture retention capacity, and hardpan formation, microbial population all are affected by tillage and change the nutrient and affect nutrient availability.

5. Abiotic stresses: - The plants are subjected to many abiotic (Soil acidity, deficiencies of nutrients, toxicities, drought, flood, more temperature) and biotic stresses (pest, disease, weeds). These stresses have vast effect on the plant's growth and development which resulted low absorption and less utilization of nutrients led to low nutrient use efficiency (Lyad, 1981).

6. Biotic stresses: - The disease and insect infestation lower growth, yield and nutrient use efficiency. The disease and insect infestation affected leaves stem and roots, due to which photosynthetic activity reduced and absorption of nutrients decrease (Baligar *et al.*, 2001).

2.3.4 Need of Balanced Fertilization: - Balanced fertilization concept is very simple and developed 150 years ago. The concept is that crop demands optimum supply of all out of 17 essential nutrients, one is deficient in supply growth of plant is affected (Kumar and Shivraj, 2007). So, for this balanced fertilization is required to enhance the fertilizer use efficiency and production of crop. It is based on the concept of application of fertilizers in accurate quantity (right amount, right rate, and at right time) through appropriate method (Goswamy, 1997). Balanced fertilization in rice – wheat cropping system is very essential (Prasad, 2000). The rice – wheat cropping system is highly exhausted resulted in highest nutrients removal from soil not only macro nutrients but also micro-nutrients and secondary nutrients (Rattan and Singh, 1997).

The deficiency of nutrients replenished by fertilizers, but the residual effect of fertilizers not take into consideration . Application of nutrients not only fulfilled uptake requirement, of crop but also make allowance for losses to maintain soil fertility. So, for this the effective use of fertilizer or rice – wheat cropping system is very much important.

2.3.4.1 Selection of the Right kind of fertilizers: - The efficiency of nitrogenous fertilizers is very less, mostly in rice crop; slightly increase 40%, Soil nitrogen is lost in atmosphere by denitrification, leaching, volatilization (Gupta and Kanwar, 1984). Nitrate form of nitrogen is easily lost by leaching. NO_3^- - N and NH^+_4 - N is less effective due to this their use is avoided. But application of NH_4 containing fertilizers i.e. $(NH_4)_2SO_4$ and NH_4Cl proved beneficial for rice crop (Jalali *et al.,* 2001). Urea is considered as an efficient NH_4 source in most of soils. It may be due to the application of urea its N which is in amide form converted into NH^+_4 and NO^-_3 form and become available to plants.

Now a days urea became the major fertilizer of nitrogen and its importance increased day by day. There is continuously efforts have made to improve its efficiency. As a result, several modified fertilizers of urea compounds have been formed. Neem coated urea, sulphur coated urea and urea super granules (Gupta and Sharma, 2004) are examples of modified urea compounds. The effect of modified fertilizers like neem coated urea, chelates, anhydrous ammonia, secondary nutrient along with Zn micronutrient was reviewed under further points like on enzyme activities, nutrient uptake, soil nutrient status and crop productivity.

2.4 Effect of modified fertilizers on yield attributing characters of rice – wheat

Chlorophyll content: - Orhue *et al.,* (2005) observed that the growth of maize plant and chlorophyll content was increased with fertilizer application over control. Bahr *et al.,* (2006) reported that with the increasing rate of slow release fertilizers, from 60 – 100 kg ha^{-1}, the chlorophyll content also increased. Amujoyagbe *et al.,* (2007) observed the effect of organic and inorganic fertilizers on production and chlorophyll content. The study resulted that greatest leaf area and chlorophyll content recorded with inorganic fertilizers over control. Felix *et al.,* (2014) reported that nitrogen application through slow release fertilizers positively correlated with leaf area and chlorophyll content of maize. Zhang *et al.,* (2014) noticed that intercropping and enhancing nitrogen application increased the chlorophyll content of maize. Dong *et al.,* (2016) reported that at tasselling and grain filling stage in maize plant – the chlorophyll content significantly increased with application of coated fertilizers. Abd El- Megeed and T.M (2017) revealed that with the application of nitrogen @ 165 kg ha^{-1} through anhydrous ammonia recorded more chlorophyll content, leaf area index, dry matter, plant height and number of tiller/plant. Chaturvedi (2005) reported that the ammonium fertilizers enhance the availability of nitrogen which accelerates the absorption of nitrogen which increases chlorophyll formation. Osman *et al.,* (2013) and Ismai l *et al.,* (2013) emphasized that application of anhydrous ammonia as nitrogen fertilizer act as an important constituent of enzymes and chlorophyll which are positively correlated with the vegetative and reproductive growth of the rice plant. Debiprasad *et al.,* (2016) reported that when anhydrous ammonia injected into soil before flooding affect the leaf area index. Highest leaf area index was recorded when full dose of anhydrous application injected into dry soil @ 165 kg nitrogen ha^{-1}. Alim (2012) indicated that anhydrous ammonia showed superiority over other treatments in dry matter yield. This superiority might be due to the enhancement in nitrogen availability which increases leaf area and photo assimilates. Osman *et al.,* (2013) stated the height of plant significantly varied by nitrogen fertilizer application. The full dose of anhydrous ammonia application increased the plant height over all other treatments. This result also supported by Ismail *et al.,* (2013) who observed significantly effect of nitrogen on plant height. Payee *et al.,* (2011) reported that application of full dose of anhydrous ammonia resulted greatest number of effective tillers m^{-2} followed by urea application in rice crop. Matsuo *et al.,* (1995) stated that it is compulsory to give more nitrogen fertilizers to help rice plant to absorb more phosphorous for enhancing tillering. Alim (2012) observed the variation in number of tillers by different sources of nitrogen fertilizers in rice crop. It might be due to availability of nitrogen and other nutrients. The adequate amount of nitrogen support cellular activities which increased number of tillers/hills. Chaturvedi. 2005 highest number of panicles was recorded by anhydrous ammonia application over other treatments. It might be due to the role of nitrogen in physiological process. Bagayoko *et al.,* (2012) reported highest panicle weight with anhydrous ammonia application followed by urea application. Sahar and Burbey (2003) observed a significant variation in panicle length (cm) of rice plant by different nitrogen fertilizers. Debi Prasad *et al.,* (2010) reported that full dose of anhydrous ammonia in dry soil in rice responsible for highest number of filled grains/panicles followed by urea + anhydrous ammonia application. Boli *et al.,* (1995) found that increase in 1000 grain weight by nitrogen fertilizer application. Mehla and Panwar (2001) demonstrated that increase in 1000 grain weight by application of full dose of anhydrous ammonia might be due to more photosynthetic rate. Khandey *et al.,* (2017) conducted an experiment to study the response of applied neem coated urea on yield contributing characters of rice. The result of the study showed that 125% neem coated urea performs better as compared to other treatments in case of crop growth parameters. The highest tillers 320, paniclesm-^{2} – 345, panicle length 23.3 cm, filled grains per panicle – 140, test weight 27.6 gm. were recorded with 15% NPK by neem coated urea. Raj *et al.*, (2014) reported that increasing levels of nitrogen fertilizer significantly enhance the number of tillers and length. The highest number of tillers 343 and panicle length 24.3 cm were recorded when neem coated urea applied at high rate within 3 splits (basal, at tillering and at panicle initiation). Kumar *et al.*, (2007) stated that with nitrogen application tiller formation increased it might be due to enhancement in the availability of nitrogen which increase tiller numbers. Kumar *et al.,* (2015) found that neem coated urea increased growth and production of plant, plant height, number of tillers, panicle length and no. of panicles/plant along with phosphorous and potassium. Pushpanathan *et al.*, (2005) stated the yield components improved by coated fertilizers. Suganya *et al.,* (2007) stated that the number of filled grains per panicle (147) and 1000 grains weight (28.6gm) were recorded highest with neem coated urea over other treatments. Similar findings were observed by Pushpanathan *et al.,* (2005) and Kumar *et al.,* (2011).Mangat and Narung (2004) reported that highest doses of nitrogen fertilizer by neem coated urea influence vegetative growth of plant in case of plant height and number of tillers. The reason behind this the increased nitrogen uses efficiency and availability of nitrogen continuously to plant which boost the vegetative growth of plant. Dash *et al.,* (2015) demonstrated that grain filling percentage and chaff formation affected by secondary and micro-nutrients. The study result that chaff content increased by 23.1% with sulphur and zinc. Hasan (2007) revealed that number of tillers increased per hill with increased level of nitrogen as urea super granules. Ha sanuzzaman *et al.,* (2009) found that coated fertilizers @ 75 kg N ha^{-1} gave highest 1000 grain weight and straw yield. Azam *et al.,* (2012) reported that varieties method of fertilizer application and selection of fertilizer influenced the yield attributing characters of rice. All these had significant effect on plant height, number of tillers per hill, dry weight, leaf area index, number of panicles/plants. Das *et al.,* (2012) result that amount of urea coated fertilizer significantly affect the yield attributing characters. Maximum productive tillers (14) grains per panicle (109), obtained with modified fertilizer USG (urea super granules).Xiang *et al.,* (2015) revealed that urea, coated urea and urea super granules increased the plant height, no. of tillers. Bandaogo *et al.,* (2015) found that application of prilled urea and USG increased the plant height, effective tillers and nutrient uptake.

2.5 **Effect of modified fertilizers on yield:** Blaylock *et al.,* (2005) observed that slow release (neem coated urea) nitrogen fertilizer produced high yield as compared to normal urea. A field experiment was carried out by S. Singh in 2005 to study the effect of prilled urea with eco-friendly neem (*Azadirachta indica* A. Juss.) formulations in improving the efficiency of nitrogen use in hybrid rice. The Pusa Neem Golden Urea proved to be significantly superior to other sources with regards to panicle length, grain yield, N uptake, agronomic nitrogen use efficiency and apparent N recovery (%), indicated that coating urea with neem formulations not only increased the grain yield, NUE and apparent N recovery, but also helped to reduce the environmental hazards associated with the use of large amounts of urea. Baho *et al.,* (2006) conducted an experiment to study the effect of slow release fertilizers on yield of maize in reclaimed sandy soil. The study result that cob length, no. of grains/row; seed index and straw yield were significantly increased by slow release fertilizer treated plots. Alekha *et al.,* (2009) observed the effect of controlled mineralizing acetaldehyde condensation urea fertilizer effect on *Brassica napus*. They study resulted that, it reduces the leaching of nitrate and emission of nitrous oxide. Kabat and Panda (2009) studied that the placement of controlled release N+ prilled urea in 3:1 proportion in furrows recorded 25% more grain yield and nitrogen use efficiency as compared to broadcasting of prilled urea. Various indices are commonly used in agronomic research to assess the efficiency of applied N (Novoa and Loomis, 1981; Cassman *et al.,* 2002), mainly for purposes that emphasize crop response to N. In field studies, these indices are either calculated based on differences in crop yield and total N uptake with aboveground biomass between fertilized plots and an unfertilized control ('difference method'), or by using N-labeled fertilizers to estimate crop and soil recovery of applied N.. Junejo *et al.,* (2010) conducted a pot experiment to analyses the effect of coated urea on crop yield and nutrient uptake. The study resulted that coated urea increased the yield by 40% as compared to non-coated urea. Bernard *et al.,* (2012) stated that the different forms of urea affect maize yield and nitrogen use efficiency. The yield increased with increased dose of urea and polymer coated urea in all seasons. Zhao *et al.*, (2013) indicated the role of controlled release fertilizers on nitrogen use efficiency in spring maize. They observed that the application of fertilizers enhanced grain yield as compared to other treatments. The coated fertilizers increased grain yield as compared to synthetic fertilizers. Hala *et al.,* (2014) observed the development of urea with neem coating to increase efficiency of fertilizer. The coated fertilizers increased the plant height more as compared to normal urea. Joshi *et al.*, (2014) supported neem coated urea @100 kg ha^{-1} in 3 splits to get more production. Neem coated urea increase grain yield by 6.2% more as compared to normal urea. Khan *et al.,* (2014) conducted an experiment to study the effect of agrotain coated urea in arid calcareous soil on nitrogen use efficiency and yield of maize. The study resulted that maximum grain yield was obtained in 115 kg N ha^{-1} fertilized plot inform of coated agrotain urea. Rasid *et al.*, (2014) analyzed the effectiveness of coated urea on palm growth. They observed that sulphur coated urea increases girth size, leaf dry matter and leaf nitrogen content as compared to normal urea. They recommended that sulphur coated urea is an alternative to urea. Tanwar (2014) demonstrated the effect of various organic manures and fertilizers on production and nutrient uptake of maize. They observed that 100% recommended dose of nitrogen through neem coated urea recorded high yield of maize grain and straw. Shah and Waqar (2015) conducted an experiment to study the nitrogen use efficiency of urease coated urea on calcareous alkaline soils for maize. The study revealed that grains, stover yield of maize improved with nitrogen coated fertilizers and inhibitors. Wakvi *et al.,* (2016) demonstrated the comparison of coated urea and normal urea to enhance nitrogen use efficiency and production under maize – wheat cropping system. There was 7.9 – 10.3% increase in production in wheat and 9.1 – 21% increase in maize with coated urea over normal urea. Rajendra Kumar *et al.*, (2012) conducted experiment to study the impact of nitrogen, phosphorous, potash and sulphur on productivity of rice – wheat system. They reported that grain and straw yield improved due to sulphur application @60 kg ha^{-1} along with NPK fertilizer. Ullah *et al.,* (2018) reported that growth and yield of cereals improved with zinc application. Same result also supported by Rehman *et al.*, 2016. Sahrawat *et al.*, (2010) stated that application of S, B, and Zn along with recommended NPK increased yield and nutrient response i.e. uptake and availability. Shaheen *et al.*, (2010) resulted that 40 kg N + 30 kg P_2O_5 + 2 kg Zn + 1 kg B enhance yield of wheat –

maize cropping system as compared to control. Rao *et al.,* (2010) indicated that NP + S, B, Zn significantly improve the yield and uptake of N, P, K, S and Zn in grain in maize biomass as compared to control. Ilhan and Erdal (2010) conducted an experiment to evaluate the effect of different levels of phosphorous and zinc on maize – wheat cropping system. They resulted that excess application of fertilizers nor only reduce zinc concentration but also lead to fixation of other micro-nutrients. Yarnia and Khorshidi (2009) resulted high yield with application of $ZnSO_4$ along with NPK. The net assimilation rate and crop growth rate also increased with $ZnSO_4$ application. Rahmatullah *et al.,* (2009) reported that there was positive interaction of zinc with phosphorous which increased the yield of wheat – maize. Thomas *et al.,* (2007) indicated that significant increase in yield found when S, Zn applied with NPK. Hossieni *et al.,* (2007) observed the interaction of zinc with NPK in rice – wheat cropping system. They found synergistic effect of nitrogen and phosphorous with zinc which increase crop yield. Arauju (2004) resulted that nitrogen fertilizer application enhance crop yield by 25% compare with other treatments. Tara and Stephen (2003) demonstrated the effect of dicyanamide along with zinc in rice – wheat cropping system. They study resulted that grain and straw yield both are increased by use of nitrification inhibitors with zinc. Sharer *et al.,* (2003) revealed that application of nitrogen @ 180 Kg ha^{-1} through neem coated urea produced high grain yield as compared to control. It might be due to more 1000 grain weight, no. of grains/spike. Selvi and Sathi (2002) studied the different doses of N, P, NPK, NP, N and NPK + FYM + Zn on finger millet. The results show that 100% NPK + FYM + Zn increase the yield of finger millet. Song and Yong (2002) conducted an experiment to study the effect of Zn, B materials on rice and maize. The mixed fertilizers increased the grain yield of rice and maize. Ocampo (2002) studied that addition of P, K and Zinc along with nitrogen increased grain yield and dry matter production. Singh (2001) emphasized that combined application of 6 kg Zn and 45 kg S ha^{-1} show synergistic effect on yield of safflower. Arya and Singh (2001) conducted a field experiment to find the response of different rates of phosphorous and zinc on rice. The result showed that grain and straw yield was highest with 39.6 kg ha^{-1} phosphorous and 30 kg Zn ha^{-1}. Fecenko and Lozek (1996) conducted an experiment to check the effect of zinc and nitrogen on yield. They revealed that sole application of nitrogen enhanced grain yield by 24% as compare to control whereas N + Zn application increased 42.2%.Prasad *et al.,* (2002) conducted a trial to evaluate the optimal efficiency of zinc fertilizer application in rice – wheat cropping system. The results revealed that yield of rice recorded more as compare to wheat. The recommendation of study was use of 25 kg $ZnSO_4$ ha^{-1} after two crop intervals. Abd El – Megeed and T.M (2017) conducted a field experiments to study the effect of urea and anhydrous ammonia fertilizer on yield and yield contributing characters of rice plants. The experimental study resulted that supply of 165 kg N ha^{-1} through anhydrous ammonia increased panicle length (cm), panicle weight (g), filed grains/panicles a result of this grains yield also recorded highest. Highest yield was recorded when full dose of anhydrous ammonia applied before flooding in rice field. Chaturvedi (2005) reported that there was increase in growth and yield of rice by ammonium fertilizers. Chaturvedi (2005), Debiprasad *et al.,* (2010) and Osman *et al.,* (2013) revealed that grain and straw yield of rice was improved by nitrogen fertilizer application. Khandey *et al.,* (2017) recorded highest grain yield (42.5q $ha^{-1)}$ and straw yield (67 q ha^{-1}) with 125% nitrogen and recommended phosphorous and potassium. Nitrogen sources is neem coated urea. Shivay *et al.,* (2000) and Suganya *et al.,* (2007) emphasized more grain and straw yield with neem coated urea application. Mangat and Narang (2004) observed more grain and straw yield in rice and wheat with 100% neem coated urea. Which was decreased with 80% neem coated urea. Sarangi *et al.,* (2016) reported high grain and straw yield with neem coated urea as compared to prilled urea. Bhatt Rajan (2012) reported that 80% neem coated urea or 100% ordinary urea are equally effective in yield for rice – wheat cropping system in Punjab region. Devasenapathy *et al.,* (2009) revealed that 80% nitrogen through neem coated urea produced 14.8% high grain yield as compared to 100% nitrogen through ordinary urea in case rice crop. This might be due to nitrification inhibitor properties of neem oil coated urea. Dash *et al.,* (2015) carried out an experiment to evaluate the effects of integrated macro, secondary and micro-nutrients on yield, nutrient uptake and accumulation of rice. The study revealed that the greatest grain yield of 76.7 q ha^{-1} obtained with (N, P, K, S, B and Zn). There was reduction in yield by 19.4 – 27% in absence of S, B, and Zn.

2.6 Effect of modified fertilizers on soil chemical properties and nutrient availability

2.6.1 pH and EC: - Bolan *et al.,* (1991) found that with the application of ammonium sulphate and urea, pH of soil decreased. It led to acidification effect of ammonium ions at the time of transformation in soil. These results also supported by Kemmit *et al.,* (2006). Dixit and Gupta

(2000) reported that, there was a minimum variation in pH of soil (7.7 – 7.8) by various NPK combinations with FYM. Eghball (2002) revealed that 0 – 15cm surface soil pH enhanced with application of nitrogen-based manure but reduced with NH_4^+ - N fertilizer. Sofi *et al.,* (2004) observed that nitrogen, potassium nutrition improve soil available N, P and K, but pH, EC and organic carbon remain unchanged .Aggarwal *et al.,* (2015) stated that urease enzyme plays important role in the hydrolysis of urea fertilizers which changes into NH_3 and CO_2 and pH increased. Khandey *et al.,* (2017) observed that highest pH – 7.2 and electrical conductivity 0.25 dSm^{-1}, recovered with 125% neem coated urea (3 splits) and lowest with control after harvest. Murthy *et al.,* (2014) reported lowest electrical conductivity and pH with control (N_0 P_0 K_0).Dash *et al.,* (2015) reported that greatest pH was recorded in integrated nutrient management with N + P + K + S + Zn. It might be due to the maintenance of soil fertility. Kumar *et al.,* (2014) reported that soil pH, EC, available, N, P, and K showed significant and positive correlation with NPK fertilizers.

2.6.2 Organic carbon: -Poll *et al.,* (2003) concluded that addition of FYM along with NPK increase the organic matter and microbial biomass in soil. Microbial biomass carbon directly correlated with enzymes. Selvi *et al.,* (2004) investigated that increase in biomass carbon content in soil with 100% NPK + FYM followed by 150% NPK application. Deshmukh *et al.,* (2005) indicated the increment in organic carbon from 0.56 to 0.69% due to application of 75% NPK + FYM @ 2.5 t ha^{-1}. Khandey *et al.,* (2017) reported that high soil organic carbon (0.58%) recorded with (N_{125}, P_{60}, K_{40}) kg ha^{-1} over other treatments. Murthy *et al.,* (2015) reported that organic carbon content increased from (0.51% to 0.83%) by macro and secondary nutrients.

2.6.3 Soil Available Nitrogen: - Muthuvel *et al.,* (1990) stated that the soil physical properties, organic matter and available nitrogen increased by application of neem coated urea with FYM. Tiwari *et al.,* (2002) reported that organic and inorganic fertilizer increased available nitrogen content up to 290 kg ha^{-1}.Dahiya *et al.,* (2004) found that urea formaldehyde, sulphur coated urea and polymer coated urea release nutrients slowly and retain the nutrients for long time in soil. N, P, K nutrients commonly matches with the physiological needs of the plant. They supported coated fertilizers as an alternative to sustainability. These results also supported Ingale *et al.,* (2010). Sharma and Singh (2010) identified that ammonium available for long duration which matched with requirement of nitrogen by brassica plants because of slow release nutrients from coated fertilizers. Shilpashree *et al.,* (2012) conducted an experiment to evaluate the effect of INM on soil available nitrogen at different growth stages of maize. They identified that the nitrogen availability in soil increased at different growth stages of maize with integrated nutrient management as compared to control. Chandel *et al.,* (2014) checked the response of different nutrient management practices in wheat – maize cropping system. They observed that available N, P, K and S in soil increased after harvest of crop as compare to initial samples with NPK + 10 tonnes FYM ha^{-1}.Sanjay Kumar *et al.,* (2015) illustrated that compost + neem cake urea + PK fertilizer recorded highest available nitrogen (192.5 kg ha^{-1}), available phosphorous (374.6 kg ha^{-1}) and potassium (180.2 kg ha^{-1}) in soil over the other treatments. Kashiri *et al.,* (2013) recorded that neem oil coated urea maintain more availability of nitrogen for prolonged time - period. This result also supported by Khandey *et al.,* (2017). Meena AK (2018) reported that greatest available soil nitrogen (220 kg ha^{-1}) was observed with 125% neem coated urea along with P_{60}, K_{40}, and Zn20 kg ha^{-1} in transplanted rice. Suresh and Swarna (2008) resulted that neem coated urea + $ZnSO_4$ increased the availability of nitrogen. It might be due to inhibition of nitrification and increased availability due to slow release of nitrogen into soil and decrease the losses of applied nitrogen. Rajeswar *et al.,* (2009) recorded that soil available nitrogen range from 130 to 185 kg ha^{-1} with different sources of nitrogen fertilizer. Gogoi *et al.,* (2010) observed that with integrated nitrogen management the available nitrogen content is 268 kg ha^{-1}. Vaisnow (2010) found that with modified fertilizers the available nitrogen range from 100.2 to 451.58 kg ha^{-1}. Kumar *et al.,* (2014) reported positive correlation between macro and micro nutrients and soil properties. The study resulted that NPK along with S, Zn increased the nitrogen content in soil. Ramana *et al.,* (2015) reported that N, P, K, S were available in medium range with application of micronutrients with macro nutrients.

2.6.4 Soil Available Phosphorous: - Gaur *et al.,* (1984) observed that with enhancement in NPK + FYM doses, the uptake of phosphorous improved may be due to solubllization of phosphorous by phosphorous solubilizing bacteria of organic FYM. Mathur (1997) found that those pots which receive NPK fertilizer + FYM sowed more phosphorous availability over other treatments. Birajdar *et al.,* (2000) conducted an experiment to check the effect of FYM and flash on nutrient availability of sweet potato. They stated that the recommended NPK along with 15 t FYM increased the availability of phosphorous followed by recommended by NPK with flash.

Tiwari *et al.,* (2002) observed that an increment in available phosphorous content of soil with neem coated urea with FYM. They recommended that integrated application of FYM with fertilizers increase the availability of phosphorous of soil. Tolanur and Badanur (2003) reported that application of nitrogen through neem coated urea along with FYM increased the availability of phosphorous in soil. It might be due to solubllization of phosphorous in soil by release of organic acids. Krishna maruthy *et al.,* (2010) observed that available phosphorous was significantly higher in 125% neem coated urea application which was followed by 100% neem coated urea at 60 DAT. Whereas the minimum available phosphorous recorded with control (N_0 P_{60} K_{40}).Murthy *et al.,* (2014) observed that the states of available phosphorous were not affected by high dose of N, P, and K. This result was in conformity with the findings of Kumar *et al.,* (2015).Dash *et al.,* (2015) reported that micro and secondary nutrients increased the uptake of N, P, K and availability in soil. Ramana *et al.,* (2015) recorded that phosphorous use efficiency, nutrient use efficiency increased with application of sulphur which also enhances phosphorous availability in soil.

2.6.5 Available Potassium: - Santhy *et al.,* (1998) reported that available potassium content of rice increased over initial value of potassium by application of 100% NPK. Suresh and Hasan (2002) observed that significant changes in soil available potassium recorded at vegetative stage with 100% NPK. **.**Ingal *et al.,* (2010) reported that slow release fertilizers were slowly released nutrients and increase the availability of N, P and K in soil for long time. Khandey *et al.,* (2017) found that the highest available nitrogen 106 kg ha^{-1}, P_2O_5 8.8 kg ha^{-1} and 190 kg ha^{-1} with 125% neem coated urea followed by 100% neem coated urea. This result was in conformity with the findings of Murthy *et al.,* (2014) and Kumar *et al.,* (2015).Nirawar *et al.,* (2009) reported that available potassium content ranged from 353 to 630 kg ha^{-1}. Bali *et al.,* (2010) reported that available potassium in Punjab soils recorded 280.57 kg ha^{-1}. Vaisnow (2010) found that available potassium ranged from 23.5 to 566 kg ha^{-1} by different treatments. Shukla (2011) investigated that available potassium content ranged from medium to high in Inceptisols.

2.6.6. Soil Available micronutrients and Secondary nutrients: - Swarup and Yaduvanshi (2000) reported that with the application of FYM with NPK increased the available DTPA – Zn and Mn over control. Prakash *et al.,* (2002) stated that micronutrient Fe, Cu and Zn availability increased with NPK + FYM application. Kadam *et al.,* (2010) found that by the application of organic nitrogen sources in soil the availability of soil nutrients nitrogen, P_2O_5 and K_2O increased in all applied treatments over control. The DTPA extractable zinc amount was increased by application of organic nitrogen sources. Singh *et al.,* (2000) observed that sulphate and sulphur content in soils varied from 9.1 to 54.3 mg kg^{-1}.Kumar *et al.,* (2002) reported that extractable sulphur content ranged from 2.3 to 6.7 mg kg^{-1} in soil. Mali and Syed (2002) found that sulphur deficiency in Maharashtra soils. Bhatnagar *et al.,* (2003) reported that sulphate sulphur in soils from 11.25 – 13.25 ppm in surface soil. Kundu *et al.,* (2005) found that medium sulphate content in soil with average value 12.61ppm.Jat and Yadav (2006) reported that available sulphur content in soil ranged from 4.1 to 39.95 mg ka^{-1}.Singh and Bansal (2007) found that available sulphur status in soil ranged from 3.75 to 4.35 mg kg^{-1} soil. Ghosh *et al.*, (2012) recorded lowest available sulphur content in Bribhum district. Singh and Mishra (2012) investigated that available sulphur, potassium, phosphorous and nitrogen. Isitekhal *et al.,* (2013) emphasized that inorganic sulphur availability positively correlated with available phosphorous.

2.7 Effect of modified fertilizers on crop nutrient uptake: -

2.7.1Nitrogen uptake: - Miller and Mackenzie (1978) demonstrated the effect of different nitrogen sources on yield and nitrogen uptake of maize. The study results that greatest yield and nitrogen uptake was recorded with ammonium nitrate, followed by sulphur coated urea. Bahr *et al.,* (2006) evaluated the effect of slow release fertilizers on yield of maize in sandy loamy soil. They observed that, those plots which received slow release nitrogen have more nitrogen uptake at silking stage as compared to control due to more nitrogen use efficiency.Kabat and Panda (2009) found that basal application of controlled release fertilizers with prilled urea increased the nitrogen uptake in rice due to the less leaching.Wen *et al.,* (2001) observed that coated urea gave more grain yield and enhance nitrogen uptake in maize as compared to commercial fertilizers because coaeted fertilizers improved the nitrogen use efficiency by reducing voltalization loss of ammonia as compared to normal and ordinary urea.Zhao *et al.*, (2013) reported that controlled release fertilizer application, increase nitrogen uptake during growth phase rapidly and slowly at flowering stage. The nitrogen uptake increased with controlled release fertilizers application during the growth of crop due to more NUE that might be due to nitrification inhibitor property of NCU. Tanwar *et al.,* (2014) reported that nitrogen uptake by maize significantly increased by application of neem oil coated urea, highest uptake (174 kg ha^{-}

^{1}) recorded by 100% recommended dose of nitrogen through neem coated urea. Khan *et al.,* (2015) demonstrated the effect of urease urea and sulphur on biomass, yield, and nitrogen uptake of rice. They observed that sulphur and coated urea significantly increase nitrogen uptake in plants over normal urea and other treatments . The balanced fertilization of macro and micro nutrients increase nutrient use efficiency.Rao *et al.,* (2010) stated that when NPK + SB Zn applied to maize crop, then nutrient uptake improves in grain and Stover also. Thomas *et al.,* (2007) resulted that S, B, Zn significantly increased the N, P, K, S, B, Zn uptake in crop. Keckman (2007) conducted a field experiment to check the nutrient uptake an in harvested wheat crop. They recorded highest nutrient uptake with NPK + SB Zn treated plots. Khandey *et al.,* (2017) observed the highest nitrogen uptake (103 kg ha^{-1}) with 125% neem coated urea which was followed by 100% neem coated urea (84.3 kg ha^{-1}). Raj *et al.,* (2014) observed the high nitrogen availability in soil with neem cake blended urea as compared to prilled urea. Upadhyay and Tripathi (2000) reported that neem cake blended urea resulted highest uptake of nitrogen as compared to prilled urea. Thichd *et al.,* (2010) found better performance of neem coated urea over normal urea in case of nitrogen uptake and nutrient use efficiency. Dash *et al.,* (2015) reported that highest uptake of nitrogen in grain (2.06%) and straw (0.70%) was recorded with integrated application of NPK + S + B + Zn. In the absence of K, N uptake decreased by 41.71% might be due to solubility of phosphorous in soil at neutral pH. Jan *et al.,* (2008) reported that accumulation of nitrogen greatly reduced without sulphur application although plots received full dose of nitrogen. Chakravorti SP (1999) stated that in absence of zinc, the nitrogen accumulation decreased by 32%. Hakoomat ali *et al.,* 2014 reported that nitrogen and zinc both are the important element to increase the yield of Basmati rice. These nutrients interacted and affected the availability of the other alkaline soil, to examine the effect of elements on quality and yield of Basmati rice an experiment was conducted in Pakistan. By this combination Kernel or grain length, panicle length, water absorption and kernel protein ratio were improved. There was a significant positive correlation between the total dry matter and total grain yield. The harvest index was positively increased by application of 160 kg/ha and showed the best result by reduce the agronomic efficiency. The soil pH also showed the good output with use on N and Zn fertilizer combination improvement in soil properties due to balanced fertilization. Zn deficiency in the staple food caused health problem in many under developing countries (Impa *et al.,* 2013). Zn always plays important role after the nitrogen element. According to cropping system Zn always used by the green crops and this is only reason that why Indian soil have deficiency of Zn element. There is little bit contribution of Zn element in soil by doing rice cultivation (Quijano-Guerta C *et al.,* 2002). The Nitrogen use efficiency almost new concept, earlier definition of NUE states that it is totally inversed of concentration of nitrogen in the plant tissue (Chapin, 1980). However, after that so many definitions were described by different researchers (Barraclough *et al.,* 2010). By the definition of Moll et al., 1982, Nitrogen use efficiency is a source of two different independent computing (i) Uptake efficiency of nitrogen (NUpK) (ii) Application of nitrogen efficiency (NUtE). Increasing nitrogen use efficiency and response of nitrogen in wheat crop will help to farmer by reducing cost of nitrogen fertilizer because nitrogen is primary and major input for crops and always required in more amount. But with leaching and volatilization most of the nitrogen will be lost from the soil and leaving negative impact on environment. To examine the effect of nitrogen use efficiency the split experimental design was used for conducting this experiment. Different four varieties were used with different four nitrogen doses, were 0, 33.6, 89.7 and 145.7 kg N/ha. The result showed significant difference according to yield response by the used varieties at same location and in same type of soil conditions. These four varieties showed the result according to genetically variation. It means soil is not just important for uptake, genetic variation is also important for proper utilization of nitrogen fertilizer.

2.7.2 Phosphorous uptake: - Vimla and Subramanian (1994) evaluated the effect of nitrification inhibitors on the availability of nutrients, yield and uptake in rice. Higher uptake of nitrogen, phosphorous and potassium by rice plant recorded in inhibitors applied plots. Selaraju and Iruthayaraju (1995) observed that as the levels of nitrogen increased from 75 to 150 kg ha^{-1}, the N, P and K uptake also increased. Kurum thottical and Jose (2007) compared the performance of various nitrogen fertilizers formulation on productivity and uptake of nutrients of rice. The uptake of phosphorous increased in all fertilized plots over control. Tanwar *et al.,* 2014 observed that uptake of phosphorous greatly affected by coated urea. Largest uptake recorded (5.6 kg^{-1}) by neem oil coated urea over control. Koramaina and Nazirkar (2016) observed the effect of inhibitors and nitrogen levels on soil nitrogen availability and uptake of maize. The uptake of phosphorous (90.82 kg ha^{-1}) was significantly high with neem coated urea over other treatments. Rama and Gautam (2005) found that phosphorous and sulphur enhanced the uptake of phosphorous, Sulphur and Boron. Latha (2003) emphasized that the addition of zinc along with NPK increased the uptake of N and P due to synergistic effect. Singh and Vyas (2000) observed that with the increment in nitrogen dose, the phosphorous uptake efficiency improved in kharif season crops. Gao and Yang (1986) reported synergistic effect between phosphorous and zinc in maize, but high doses of phosphorous showed antagonistic effect in roots. The properties of P: Zn in plants increased with phosphorous rates.. Zinc application increased the uptake of phosphorous and translocation of zinc also. Khandey *et al.,* (2017) recorded highest uptake of phosphorous with 125% neem coated urea followed by 100% nitrogen. Similar findings recorded by Thind *et al.,* (2010) and Shivay *et al.,* (2000). Lowest phosphorous uptake recorded with control. Kumar Neena *et al.,* (2019) study indicated that 125% neem coated urea with recommended dose of phosphorous and potassium and zinc application with 3 splits at basal, active tillering and panicle initiation recorded more uptake of potassium and phosphorous in stem, leaves at harvest in rice as compared to 100% recommended dose of nitrogen through prilled urea. Guo C, *et al.,* (2016) revealed that neem coated urea @ 120 kg ha^{-1} with phosphorous, potassium and zinc recorded highest phosphorous uptake (28.9 kg ha^{-1}) as compared to prilled urea (26.6 kg ha^{-1}).Dash *et al.,* (2015) reported that phosphorous uptake in grain varied from 13.2 – 21.5 kg ha^{-1}. The highest phosphorous uptake was recorded with integrated application of N, P, K, S, B, and Zn. The study results that absence of N, NP, NPK, decreased phosphorous uptake by 13.9 – 20.4%. On the other hand, absence of Zn and S reduced the phosphorous uptake by 21.08 and 17.2%.

2.7.3 Potassium uptake: - Pajama *et al.,* (1999) stated that the 150 kg N ha^{-1} significantly increased uptake of N, P and K in grain as well as Stover. Kuru mthotticak and Jose (2007) reported that modified fertilizer enhanced the uptake over all other treatments in rice. Majumdar (2007) noticed the performance of combined nitrogen fertilizer and neem seed crush application in maize. The results showed that combination of urea with neem seed crush increase the nitrogen, phosphorous and potassium uptake of maize. Sawar gonkar *et al.,* (2009) noticed pronounced effect of nitrogen fertilizers doses and stated that 75 – 100% RDF increased the uptake of nitrogen, phosphorous and potassium. Tanwar *et al.,* (2014) observed highest potassium uptake by 100% recommended nitrogen through neem oil coated urea in rice. This commonly based on yield and concentration of nutrients in maize. Koramaina and Nazirkar

(2016) observed the influence of nitrogen levels and nitrification inhibitors on availability of soil nitrogen uptake in maize crop. The highest phosphorous uptake (178.72 kg ha^{-1}) was highest in 85% coated urea as compared to control (50.45 kg ha^{-1}). Khandey *et al.,* (2017) reported highest uptake of potassium (190 kg ha^{-1}) with 125% neem coated urea. The range of potassium uptake varies from 111.7 kg ha^{-1} to 189 kg ha^{-1}. The lowest uptake was recorded with control. Kumar *et al.,* (2009) recorded that highest potassium uptake (113.5 kg ha^{-1}) recorded with 120 kg neem coated urea ha^{-1} along with P_{60}, K_{40}, Zn_{10} kg ha^{-1} as compared to 100% phosphorous use with same recommended nutrient doses. The highest potassium uptake with more nitrogen doses might be due to synergetic effect of nitrogen and potassium with this availability of nitrogen increased which increased potassium uptake in grain and straw. This result in conformity with findings of Meena AK *et al.,* (2018) and Olsen (1986). Dash *et al.,* (2015) stated that the integrated application of N, P, K, S, B, and Zn increased the accumulation of nutrients and uptake of nutrients. The uptake of potassium influenced by nitrogen and phosphorous. The highest potassium uptake (110.02 kg ha^{-1}) recorded with combined application of N, P, K, S, Zn, B. the study showed that skipped N, P from fertilizer application K uptake decrease by 33% and 31.2%. On the other hand, absence of Zn and S reduced the uptake by 29 and 31.7%.

2.7.4 Micronutrient uptake and Secondary nutrients: - Singh *et al.,* (1998) stated the enhancement in Zn content with increment levels of nitrogen, might be due to the synergistic effect of nitrogen on zinc uptake. Salam and Subramanian (1988) find the interaction of nitrogen and zinc doses on the uptake of nutrients. The nitrogen and zinc concentration synergistically correlated means combination of nitrogen and zinc enhance concentration and uptake of both nutrients. Ghosh *et al.,* (2011) considered that integrated application of FYM + RDF of NPK enhance uptake of Zn, Cu, Mn in wheat as compare to control. Duan and Singh (2002) observed that nitrogen fertilizers significantly improved the Fe and Zinc uptake. Debi Prasad *et al.,* (2010) stated that application of synthetic nitrogenous fertilizers induced increment on sulphur and manganese content over control. Application of neem coated urea increase the sulphur and manganese content in plant. Keram *et al.,* (2013) reported that with the application of recommended dose of N, P, K and Zn @ 25 kg ha^{-1} on wheat crop, the yield , harvest index, nutrient uptake of N, P, and K also increased. Song and Yong (2002) analyzed the effect of Zn, B mixtures on rice and maize. The availability and uptake of DTPA extractable zinc increased with mixture of zinc and boron as compared to sole application. Jahi ruddin *et al.*, (2001) conducted an experiment to study the effect of Zinc, boron with basal application of N, P, K in rice – wheat cropping system. They found that concentration of Zn and B increased in plant tissues and in rhizosphere also. Mandal *et al.*, (2006) conducted an experiment to check the uptake and utilization of zinc was highest in flooded rice field. Dinesh and Babhulkar *et al.*, (2000) reported that zinc application decrease the concentration of sulphur in seeds and dry matter, but total uptake was increased. Thakur *et al.*, (2001) conducted an experiment to evaluate the effect of sulphur and zinc on soya bean – wheat. The results recommended that application of 50 kg S ha^{-1} was required for high nutrient availability and production. Sharma and Bapat (2000) conducted a field experiment with 3 levels of zinc and 4 levels of phosphorous on wheat. The results showed that as levels of zinc increased the concentration of phosphorous and zinc also increased in plant parts but concentration of Mn, Fe was not improved. Umar khan *et al.*, (2007) reported that increasing levels of zinc along with 120 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1} increased the yield of rice crop. The study recommended 10 kg Zn ha^{-1} for rice crop. Dash *et al.*, (2015) recorded that by missed the N, P, NP, NPK from fertilizer schedule reduced the uptake of sulphur by 54 – 58%. Sulphur uptake reduced by 56.32% in absence of zinc. It might be due to that zinc plays important role in sulphur absorption. Dash *et al.*, (2015) recommended that integrated macro, micro and secondary nutrients increased the zinc concentration (1.30 kg ha^{-1}). The zinc concentration increased P uptake due to synergistic affect.

2.8 Effect of modified fertilizers on soil enzymes

The transformation of nutrients which occurs in soil is done by the enzymes which convert the unavailable form of nutrient to available form. Enzymes also known as soil environment purity (Aon and Colaneri, 2011). The biological properties of soil changes quickly with change in soil conditions as compared to physical and chemical properties. The activities of soil enzymes act as indicators of soil fertility.The effect of modified fertilizers on enzymes activities is followed:

2.8.1 Soil Urease: - (mg NH^+_4 released g^{-1} soil hr^{-1})

One of the most active hydrolytic enzymes in the soil is urease. The urea applied to soil is hydrolyzed by urease enzymes and release ammonia which is used by crop. It plays an important role in nitrogen cycle. Soil urease act as an important index to check soil organic matter and applied nitrogen. These days soil urease is main point of attention because it gave quick response to environment change and management practices of agriculture (Dahiya *et al.*, 2004).

Singh and Mudgal (1983) demonstrated the impact of neem cake and neem oil coated urea on enzymatic activities. They found that neem coated urea did not affect the urease activity. Singh and Singh (1999) stated that the highest urease activity was found 7 days after incubation, which decreased after 15 days. This variation may be due to the changes in carbon fractions in soil. Xiaoguange *et al.,* (2004) attributed that the urease activity was lower at seedling stage and highest during jointing stage in all the treatments of slow release fertilizers as compared to control. The soil urease activity and soil NH^{+}_{4} - N are directly correlated. Sanz-cobena *et al.,* (2008) reported that the inhibitor compounds of urease. Effect the ammonia emission by reducing rate of hydrolysis of urea, which restrict the pool of NH^{+}_{4} lost through volatilization. Shen *et al.,* (2010) indicated that activities of phosphorous and urease lowers with the enhancement in nitrogen application rate in greenhouse polytonal of vegetables. The different changes in the extra cellular enzymatic activities by various nitrogen fertilizers. Urease and nitrate reductase enzyme activities significantly increased by 62.7 and 32.7 % as compared to control. Reddy *et al.*, (2011) conducted an experiment to study the impact of vermicompost and nitrogen fertilizers and urease enzymes activities of onion – radish cropping system. They reported that the enzyme activity was more uptake active growth stages after that, it decreases. Zhang *et al.*, (2013) reported that the interaction of roots and nitrogen fertilizers increase activities of enzymes- urease, acid phosphatase and protease in soil. Sun *et al.,* (2005) observed urease activities, microbial rates. They revealed that high soil urease activity recorded in nitrogen fertilizer plot. Rai and Yadav, 2011 emphasized that application of 100% NPK by use of neem coated urea resulted highest urease activity in soil after rice and wheat (7.94 and 8.1 mg urea g^{-1} 24 h^{-1}) in 0-15 cm upper soil. Chhonkar and Tarafdar (1984) observed that enzyme activities in soil directly correlated with organic carbon and microbial population in soil. They observed that 100% NPK + Zn recorded highest urease activity which was at par with 150% NPK. Garg and Bahl (2008) reported that minimum urease activity recorded in control and with 100% nitrogen alone. Elayaraja and Singarvel, 2011 reported that 100% NPK with no zinc recorded 11.83% less urease activity as compared to 100% NPK + Zn. It might be due to the release of large proportion of nitrogen exudates in roots which accelerate enzyme urease activity. Ladha *et* *al.,* (2003) reported that integrated use of 100% NPK + FYM@ 10 t ha^{-1} increased the urease activity by 32.33% over control. Bhavani *et al.,* (2017) revealed that balanced fertilization 100% NPK + Zn + S recorded highest urease activity which was at par with 150% NPK and 100% NPK + FYM @ 15 t ha^{-1}. Ramalakshmi (2011) demonstrated that urease enzyme activity highest at blooming stage (60DAT) and decreased after 90 DAT. Highest urease activity 9.34 mg NH^{+}_{4} recorded with 100% NPK + Zn with was followed by 150% NPK and 100% NPK + FYM. Kanchikerinath and Singh (2001) observed that with balanced inorganic fertilization urease activity significantly increased. Vajantha *et al.,* (2010) found that highest activity of urease enzymes recorded at flowering stage and there after activities decreased. Same results supported by Nayak and Manjappa (2010) .

2.8.2 Soil dehydrogenase (mg TPF produced g^{-1} soil d^{-1}): - Dehydrogenase enzyme plays an important role in the beginning stage of the oxidation of soil organic matter by shifting of hydrogen and electrons from substrates to acceptors. The various intracellular enzymes contribute to the activities of total soil dehydrogenases. Goyal *et al.,* (1992) indicated that the activity of dehydrogenase enzymes increased in Typic Haplustept soil with the organic and amended with straw showed highest dehydrogenase activity (218 µg g^{-1} soil 24 h^{-1}) as compared to control. Along with this, they also found positive correlation of dehydrogenase and microbial biomass carbon. Pervcci (1992) stated that dehydrogenase enzyme act as an indicator of microbial activity to check the oxidative activity of soil micro flora. Sangram and Kamala Kumari (1995) resulted from the study of FYM long term effect and inorganic fertilizers on enzymatic activities of dehydrogenase in sandy – loamy soil. They observed that the dehydrogenase activity was maximum in FYM amended plots. The NPK fertilizers high doses increased the enzymatic activities and highest was recorded with combination of FYM. Tiwari and Mishra (1995) conducted an experiment to study the activity of dehydrogenase enzymes under forest and natural grasslands in winter season. They found highest enzymes activities in forest soils as compared to grassland.. Shen *et al.,* (2010) found that with increase of nitrogen application rate, the dehydrogenase activity decreased. Dinesh *et al.,* 2013 stated that those plots which received organic manures and bio fertilizers recorded more dehydrogenase activity followed by those plots which received NPK and FYM as compared to control. Sharma *et al.,* (2011) revealed that dehydrogenase activity was positively correlated with soil microbial biomass carbon. The highest dehydrogenase activity was recorded by application of 25 kg N ha^{-1} + 25 kg P_2O_5 + FYM as compared to control. Meena *et al.,* (2018) conducted an experiment to study the effect of manure and inorganic fertilizers on enzymatic activities in alluvium soils of Varanasi. The greatest dehydrogenase activity was recorded in 100% NPK treated plots. The activities of enzymes were directly correlated with organic carbon content. Goutami *et al.,* (2015) stated that the addition of organic carbon through FYM, led to increase the soil dehydrogenase activity, the dehydrogenase activity record highest at flowering and decreased at the time of harvest and maximum activity recorded with combined application of 150 kg N + FYM + bio fertilizers. Romero *et al.,* (2010) stated that balanced use of fertilizers (100% NPK + Zn) gave greatest dehydrogenase activities as compared to 150% NPK. Chu *et al.,* (2007) reported that greatest values of dehydrogenase recorded in soils of wheat as compared to soils of rice. Mandal *et al.,* (2007) confirmed that balanced fertilizer application of NPK responsible for the maintenance of active pools of carbon and nitrogen in soil surface layer. Bhavani *et al.,* 2017 and Gill *et al.,* 2016 supported that 100% NPK + Zn + S recorded highest values of DHA in wheat as compared to rice over all other treatments. Bhatt *et al.,* 2016 observed that with 100% sole nitrogen application, dehydrogenase enzyme activities decreased due to redox potential of soil. The redox potential of soil increased due to accumulation of nitrates and responsible for reduction in DHA activities. Sharma *et al.,* 2006 stated that (0-15) cm upper surface of soil has more DHA values in rice and wheat crop after harvest. Niewiadomska *et al.,* 2015 supported that 100% NPK + S is beneficial for the dehydrogenase enzyme activities in soil. They stated that sulphur being an essential component of amino acids and enzymes and maintain microbial metabolism. Tejada and Gonzalaez, 2009 found that highest dehydrogenase activity (4.85 mg TPF g^{-1} soil d^{-1}) with 100% NPK + Zn which was followed by 100% NPK + 10 t FYM and 150 % NPK. .Bharti *et al.,* 2011 reported that dehydrogenase activity improved with graded levels of NPK as compared to control.

2.8.3 Soil Nitrate Reductase: - Nitrate reductase is the substrate inducible enzyme and it is responsible for the availability of nitrate. Nitrate availability is positively correlated with nitrate reductase activity in soil (Hirel *et al.,* 2001). The main problem for nitrogen as similation is nitrate reduction (Patterson *et al.,* 2016). Nitrate reductase is present in cytosol and important metabolic enzymes in plants which reduced nitrate to nitrite (Mendel *et al.,* 2007).

2.8.4 Phosphatase enzyme (µg PNP released g-$^{-1}$ soil hr^{-1}): - Enzyme activities states an index of microbiological activities. Among other enzymes, phosphatase accelerated soil phosphorous decomposition and enhance soil phosphorous concentration. Phosphatase has the potential of catalyzing esters hydrolysis and hydrides of phosphoric acid. These enzymes are considered to play an important role in 'P' cycle in soil system. Acid phosphatase gives a potential index of the mineralization of soil organic phosphorous. Bentz *et al.,* (2000) reported that highest phosphatase activity 125.87 µg pnitrophenol g^{-1} soil hr^{-1} at 60 and 90 DAT with 150% NPK during kharif season. Acid phosphatase activity was recorded highest with 100% NPK + Zn followed by 100% NPK during 90 DAT. Kadog *et al.*, 2008 stated that 100% NPK + FYM @ 10 t ha^{-1} increased the acid phosphatase activity. Same results will supported by Sheng *et al.*, 2005, Bhattacharya *et al.*, 2005, and Reddy and Reddy (2012). Reddy and Reddy (2012) reported that highest alkaline phosphatase activity was recorded (133.56 µg PNP released g^{-1} soil hr^{-1} at 60 and 90 DAT with 100% NPK + Zn which was at par with 150% NPK. Yadav *et al.*, 2011 demonstrated that lowest alkaline phosphatase activity was recorded (91.85 µg PNP released g^{-1} soil hr^{-1}) with control followed by 100% N alone at 60 and 90 DAT in rice crop. Sheng *et al.,* (2005) reported that supplement of NPK through coated fertilizers increased the alkaline phosphatase activity. Kanchi kerianth and Singh (2001) observed that greatest activity of acid and alkaline phosphatase at 60 DAT and decreased at 90 DAT. Eivazi and Tatabati (1977) stated that alkaline phosphatase activities of enzymes were more as compared to acid phosphatase activities in soil. Bhatt *et al.,* (2016) found that acid and alkaline phosphatase activities increased by NPK fertilizers application. Mishra *et al.,* (2008) reported that balanced application of 100% NPK + Zn was recorded highest acid and alkaline phosphatase over control and other treatments. Garg and Behal (2008) found that acid and alkaline phosphatase activities reduced with soil depth after harvest of rice – wheat crop. They reported that enhancement in the alkaline phosphatase activity with integrated nutrient management while minimum activity of enzymes recorded with control. Vineet Kumar *et al.*, 2019 conducted a field experiment on crop productivity and soil biological properties influenced by mineral fertilizers under rice – wheat cropping system. The study result that enzymes dehydrogenase, acid and alkaline phosphatase and urease activities increased with 100% NPK + Zn. Yang *et al.,* (2004) observed that rice soil recorded highest acid phosphatase activities as compared to alkaline phosphatase on the other hand the reverse mechanism recorded in wheat. Parham *et* *al.,* (2002) reported that aerobic environment of wheat field accounted more microbial population as compared to anaerobic rice field. Mali *et al.,* 2002 has experimented on Phosphorous use efficiency use by the crops up to 30% only from applied recommended dose. While using this, the future contribution will improve use efficiency of fertilizers by improving crop recovery with crop yield and economic returns. Coating phosphorous fertilizer have less contact with the soil, so the absorption rate of the fertilizer by soil should be less and phosphorous remain present in available form in the soil for root development. One of the biggest benefits of coating fertilizer is that Phosphorous will present in the soil whenever crop demanded and will increase yield with good returns.

2.9 Effect of Modified fertilizers on nitrogen use efficiency, phosphorous use efficiency and sulphur use efficiency: - Mishra *et al.,* (1999) reported that the efficiency of neem coated urea was increased by 40% over prilled urea. The apparent nitrogen recovery also higher in neem coated urea treated plots. Morales *et al.,* (2000) found high nutrients use efficiency with coated fertilizer. Shoji *et al.,* (2001) observed that slow release fertilizers and nitrification inhibitors has the potential to increase nitrogen use efficiency and decrease nitrogen application rate. Jeena *et al.,* (2003) recorded highest nutrient use efficiency and phosphorous use efficiency with urea super granules and reduction in ammonia volatilization. Dhyani *et al.,* (2007) resulted that balanced fertilization in rice – wheat cropping system increased nitrogen and phosphorous use efficiency. Siddika (2007) reported high nutrient use efficiency with prilled urea as compared to USG. Kapoor *et al.,* (2008) found that neem coated urea enhances nutrient use efficiency and phosphorous use efficiency and agronomic use efficiency. Nodlsch *et al.,* (2009) recorded polymer coated urea enhance nutrient use efficiency, phosphorous use efficiency and sulphur use efficiency as compared to control. Kaur *et al.,* (2014) conducted an experiment to compare the efficiency of urea fertilization via USG and PU. They recorded high nutrient use efficiency with PU. Khalil *et al.,* (2011) found the direct and residual effect of sulphur on yield nutrient uptake and use efficiency in Mustard and succeeding rice crop. They found that sulphur application increased nutrient use efficiency and phosphorous use efficiency in rice. Hasan *et al.,* (2016) reported that neem coated urea + poultry manure increases the nutrient uptake, nutrient recovery. Huda *et al.,* (2016) compared the effect of urea briquettes and prilled urea in rice crop. The results showed that neem coated urea increased by 21% with phosphorous use efficiency as compared urea briquettes.

2.10 Nitrogen fractions (NH_4 - N and NO_3 – N)and pot studies regarding leaching: Singh and Singh (1989) observed that neem oil coated urea increased the NO^-_3 in soil during the growing season of wheat. The nitrogen recovery in wheat by neem coated urea is 30.8%.Josephy and Prasad, 1994 indicated that the nitrogen fertilizer application improves the ammonical nitrogen and nitrate – N in soil over control. Prasad and Singh (2005) reported that the coated urea fertilizers fixed an amount of nitrogen in soil for long time. Shola *et al.,* (2001) found that the dicyandiamide and polymer coated urea decrease N_2O emission in barley field by 81%.Majumdar (2005) observed that the nitrification inhibitors conserve the soil ammonium nitrogen followed by neem coated urea in rice crop. Amekha *et al.,* (2009) observed that amount of total nitrate leaching was minimum in neem coated urea treated plots followed by dicyandiamide. Suganya *et al.,* (2009) resulted that with the application of neem gold coated urea the minimum nitrate content was recorded. Sharma and Singh (2011) revealed that slow release fertilizers under laboratory incubation conditions release nitrogen in 50 days which was responsible for maximum retention of nutrients in soil and increase in growth of plant. Sanz – Cobena *et al.,* (2012) found that urea treatment with nitrification inhibitor (NBPT) decrease N_2O emission by 54%.Saha *et al.,* (2013) observed that the neem cake urea increases NO^-_3 – N content in soil by 25% as compared to 100% nitrogen through normal urea. Sridharan *et al.,* (2017) conducted an experiment on nitrification inhibitor and found that highest concentration of NH_4^+ - N (136 mg kg^{-1}) recorded in neem coated urea plots as compare to 109 mg kg^{-1} in normal coated. Reddy and Mishra (1983) observed that blending of ordinary urea with neem cake reduced ammonia volatilization by 31.3%.. Rajan (2012) showed that nutrient use efficiency was equally effective with ordinary urea both at 80% and 100% dose in field.

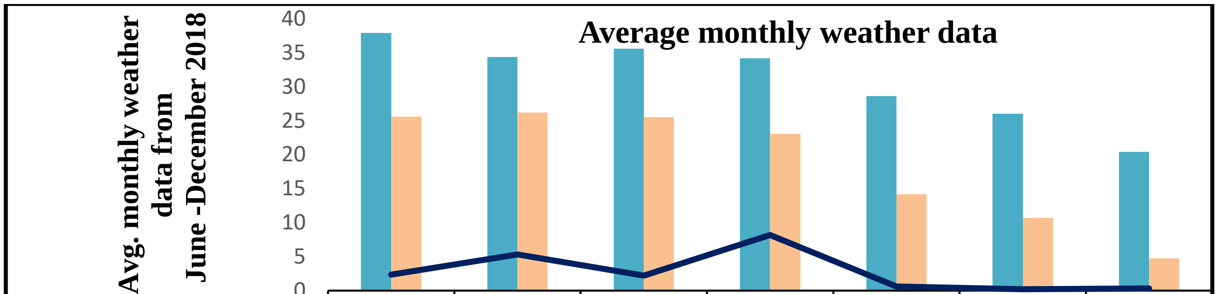
Chapter- 3

MATERIALS AND METHODOLOGY

The present study entitle 'Improving Nitrogen and Phosphorous Use Efficiency in rice – wheat cropping system through application of modified fertilizers' was carried out during 2018 – 2019 and 2019 – 2020. The description of experiment prevailing weather conditions, materials used, and methods used for soil and plant sampling analysis and statistical data during course of study are briefly discussed under following sub – headings: -

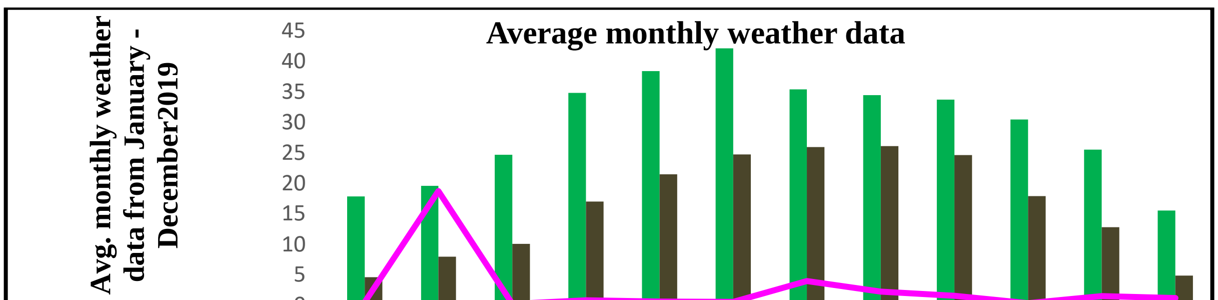
3.1 Location of experiment site: - The field experiment was carried out during kharif -Rabi season of 2018 – 2019 and 2019 – 2020 at Agronomic research fields of school of Agriculture of Lovely Professional University, Phagwara, Punjab to' Improve Nitrogen and Phosphorous Use Efficiency in rice – wheat cropping system through application of modified fertilizers'. The experimental farm is located at latitude 31.25^0 N and longitude 75^0 E along with altitude of above 232 m above mean sea level.

3.2 Climate and Weather conditions: - The general climate of the Punjab region is subtropical with cool winter, hot summer and region received annual 1150 mm rainfall. Out of the total rainfall received – 88% rainfall received during rainy season (July – September). The hottest months are May, June, and July where maximum temperature reaches as high as 48^{0}C and coldest months are December, January and temperatures drops to 5^{0}C. Minimum temperature sometimes touching to freezing point. The meteorological data recorded during study period from 2 years of experiment are presented in Fig 3.2 (a), (b) and (c).



	June	July	August	September	October	November	December
Avg. of Max. temp. ° C	37.9	34.38	35.6	34.16	28.6	26.03	20.4
Avg. of Min. temp. ° C	25.6	26.19	25.5	23.06	14.2	10.7	4.74
Avg. of Rainfall (mm)	2.33	5.3	2.2	8.18	0.61	0.21	0.33

Fig. 3.2 (a); Standard Meteorological monthly average weather data from June to December 2018 (Source: accurate weather.com)



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. of Max. temp. ° C	17.8	19.57	24.64	34.8	38.38	42.1	35.38	34.4	33.7	30.4	25.5	15.5
Avg. of Min. temp. ° C	4.6	7.96	10.06	17	21.45	24.7	25.9	26.09	24.6	17.9	12.8	4.83
Avg. of Rainfall (mm)	0.54	18.7	0.22	0.83	0.58	0.56	3.96	2.25	1.56	0.32	1.5	1.2

Fig. 3.2 (b); Standard Meteorological monthly average weather data from January to December 2019(accurate weather. com)

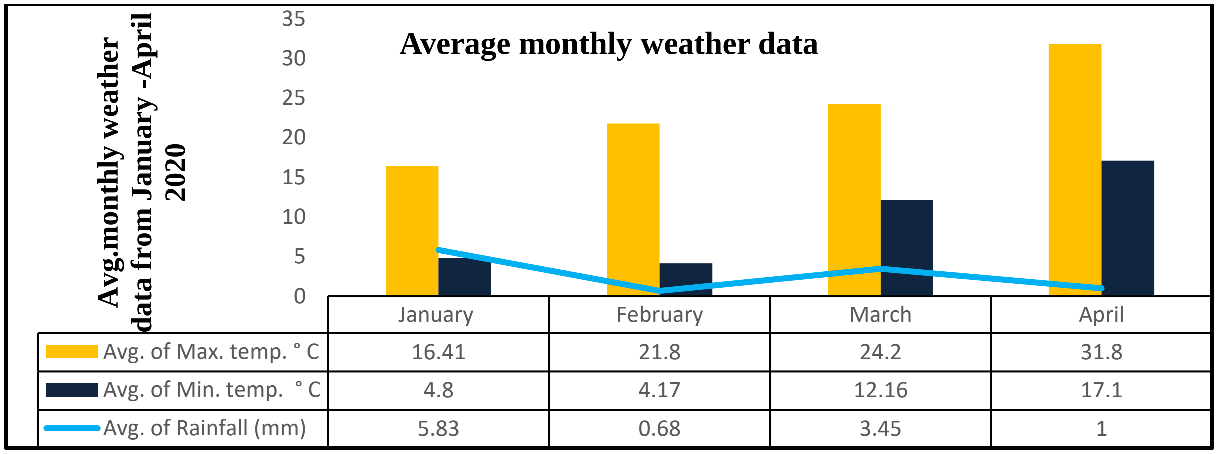


Fig. 3.2 (c); Standard Meteorological monthly average weather data from January to April 2020(accurate weather.com)

3.3 Soil Physico – Chemical Properties: - The soil of experimental site is represented as Typic haplustept and classification field as coarse sandy loamy soil. The soil is characterized as sandy loamy in texture. The sampling of soil was done at depth 0 – 15 cm from different locations before sowing of rice crop in the experimental field. The collected samples were mixed properly, and composite soil samples were air dried, powered and pass through 2 mm sieve for the analysis of physical, chemical, and biological properties. The analyzed data is presented in table. The experimental soil is sandy loam in texture, slightly acidic in nature, low in available nitrogen, organic carbon, and potassium and medium in available phosphorous. The zinc and sulphur content changed from exceptionally low to low. The important physico – chemical properties of soil before sowing were characterized in Table no. 3.3.1 and methods used for each explained under heading 3.10.3.

Table3.3.1: - Initial Physico – Chemical and Biological properties of soil: -

S. no	Properties	Values	Methods used
1.	Physical properties		Hydrometer method
	(a) Texture – Sand	77%	
	Silt	10.9%	
	Clay	12.1%	
	(b) Textural class	Sandy Loam	
2.	Chemical Properties		
	(a) pH (1:2.5)	6.85	Glass electrode
	(b) EC (dSm^{-1})	0.19	Conductivity meter
	(c) Organic Carbon (%)	0.40	Wet oxidation
	(d) Available Nitrogen ($Kg\ ha^{-1}$)	148	Alkaline permanganate
	(e) Available Phosphorous ($Kg\ ha^{-1}$)	16.0	Watnabe and Olsen(1965)
	(f) Available Potassium ($Kg\ ha^{-1}$)	171	flame photometer
	(g) Available Sulphur ($Kg\ ha^{-1}$)	42	Turbid metric method
	(h) Available Zinc ($mg\ Kg^{-1}$)	0.82	DTPA
3.	Biological Properties		
	(a) Urease mg urea/g soil 24h	0.98	Urea reduction technique
	(b) Dehydrogenase (µg TPF/24h/g soil)	24.1	2, 3, 5 triphenyl tetrazolium chloride reduction technique
	(c) Nitrate reductase (NR – mg/g soil/hr)	0.12	Sulfanilamide (diazotizing agent) and N-1-naptyhl ethylene diamine (coupling reagent)
	(d) Alkaline Phosphatase (mg NH_4^+/g soil/hr)	3.45	p-nitro phenyl phosphate tetra hydrate (pH6.5)
	(e) Acid Phosphatase (µg – PNP/hr/g soil)	4.8	p-nitro phenyl phosphate tetra hydrate (pH11)

	(f) Aryl Sulfatase (µg p-pnitrophenol sulphate/g soil/hr)	0.74	Colorimetrically

3.4 Cropping history of the experimental field: -

The cropping history of the experimental area from the last 3-4years examined carefully. Rice – Wheat cropping system has been adopted during kharif – Rabi season. Rice crop was sown during kharif and wheat crop was sown during rabi in 2018 – 2019 and 2019 – 2020. This study was conducted to aware about the nature of crop sown in a region where research experiment was carried out, which may be beneficial in the interpretation and discussion of result.

Table 3.4.1 Cropping history of experimental field

Year	**Kharif crop**	**Rabi crop**
2018 - 2019	Rice	Wheat
2019 – 2020	Rice	Wheat

3.5 Experimental details and layout plan: -

The experiment was conducted during Kharif and Rabi season of 2018 – 2019 and 2019 – 2020. The experiment comprised with 9 treatments and 3 replications. The total number of plots were 27. The treatments arranged in randomized complete block design (RCBD). The experiment structure and layout presented below:

Table 3.5.1 Experimental detail

S. no.	**Experimental detail**	**Design**
1.	Experimental design	Randomized Complete block design
2.	Treatments	9
3.	Replication	3
4.	Total number of plots	27

5.	Plot size	$5 \times 4 = 20m^2$
6.	Total experimental area	600 m^2
7.	Crop/variety	Rice – Pusa Basmati 1121
		Wheat – PBW 550
8.	Spacing	Rice – 20 cm × 15 cm
		Wheat – 22 cm × 7 cm (during thining and gap fillin after germination)

Table 3.5.2 Treatments detail

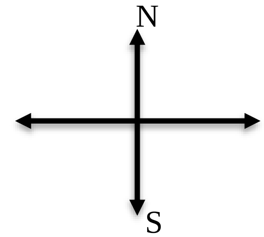
S. No.	Treatments
T0	Control (RDF)
T1	Neem Coated Urea+PK recommended
T2	Anhydrous ammonia + PK recommended
T3	Neem coated urea + PK + S + Zn -EDTA
T4	Anhydrous ammonia + PK + S + Zn- EDTA
T5	Neem coated urea + PK + $ZnSO_4$
T6	Anhydrous ammonia + PK + $ZnSO_4$
T7	RDF + $ZnSO_4$
T8	RDF + S + Zn-EDTA

Recommended dose of fertilizer for Basmati rice

RDF (N, P_2O_5, K_2O) = 42,30,30 Kg ha^{-1}, Zinc – 10 kg, Sulphur – 45 Kg ha^{-1} (Rice)

RDF (N,P_2O_5,K_2O) = 120,60,60 Kg ha^{-1}, Zinc – 10 kg, Sulphur – 40 Kg ha^{-1} (Wheat).

Layout



====================Main irrigation channel =======================

1 m Path	R1	1 m I.C	1 m Path	R2	1m I.C	1 m Path	R3	I m I.C
WALKING PATH	T0	IRRIGATION CHANNEL	WALKING PATH	T3	IRRIGATION CHANNEL	WALKING PATH	T6	IRRIGATION CHANNEL
	T3			T1			T4	
	T5			T7			T1	
	T8			T4			T3	
	T1			T6			T7	
	T6			T8			T5	
	T2			T5			T2	
	T4			T0			T8	
	T7			T2			T0	

3.6 Cultural Operations

Crops were grown by following the recommended package and practices of Punjab Agriculture University, Ludhiana. All the intercultural operations were performed for the normal growth of crops. The crop protection measures were applied on need basis. The details of cultural operation performed during two years of experiment were presented in table no. 3.6.

Details of field operations in experimental field

Table 3.6.1 Schedule of cultural operations carried out in Rice 2018 and 2019 in field and pot.

S.No.	Operations	Rice
1.	Nursery bed preparation	15 days before sowing
2.	Soaking of seeds	1 night before sowing
3.	Sowing of seeds	After soaking of seeds
4.	Main field preparation - First ploughing	20-25 days before transplanting
	- Final puddling	15 days before transplanting
5.	Transplanting	25 days old seedlings
6.	Basal fertilizer application	At time of transplanting
7.	First split of urea	At tillering stage
8.	Irrigation	5-7 days interval
9.	Weeding	20-25 DAT, 40-45 DAT
10.	Second split application of urea	At panicle initiation
11.	Harvesting	120DAT

Table 3.6.2 Schedule of operations performed in field of wheat crop during 2018-2019-2020

S.No.	Particular operations	Wheat 2018-19
1	Pre sowing irrigation	10 days before land preparation
2	Ploughing, harrowing	4-5 days before sowing
3.	Layout preparation,	2 days before sowing
4	Sowing of seeds	10 days after land preparation
5	Basal fertilizer application	During day of sowing
6	First irrigation	21 DAS
7	First top dressing	30 DAS
9.	Second Irrigation	20-25 days after first irrigation
10	Second split application of urea	Booting stage
12.	Weeding	20-25 DAS, 40-45 DAS
13	Harvesting	120 DAS
15.	Threshing	3-4 days after harvesting

3.7 Inputs for the experiment: -

3.7.1 Seeds and varietal description: - The certified seeds of rice and wheat seeds were got from the agriculture field of Lovely Professional University, Phagwara. For rice "Pusa Basmati 1121" is an early maturing variety used. It is a semi dwarf (110 -120 cm), having sturdy stem and photo insensitive. This variety was developed by IARI in 2003 and completes its life cycle in 145 days. For wheat "PBW 550" variety used as planting material. This variety was developed by Punjab Agriculture University, Ludhiana and released by Punjab state seed subcommittee in

August 2007. It is a double dwarf variety having average plant height 86 cm, grain is bold, amber, hard, and lustrous. It takes 146 days to mature.

3.7.2 Fertilizers: - The crop was maintained with the nutrient inputs as per treatments. Neem coated urea, SSP, MOP, Zinc sulphate, elemental sulphur, Zn-EDTA and Anhydrous ammonia used as source of N, P_2O_5, K_2O, Zn and S. Recommended dose of P_2O_5 and K_2O, S applied as basal dose. Whereas nitrogen applied in split forms. $ZnSO_4$ and Zn-EDTA applied to soil after 14 DAT in rice and as a basal dose in wheat. Anhydrous ammonia injected 15 – 20 cm deep in soil with the help of injection at different places before flooding in rice and after germination in wheat. The recommended dose of fertilizers for rice basmati is 47, 30, 30 kg ha^{-1} and for wheat is 120, 60, 60 kg ha^{-1}.

Table 3.7.2 Characteristics of fertilizers used in experiment

S.No.	Fertilizers	Nutrient content (%)
1.	Neem Coated Urea	46% Nitrogen
2.	Single Super Phosphate	16% P_2O_5, 12% S
3.	Di Ammonium Phosphate	18% N, 46% P_2O_5
4.	Muriate of Potash	60% K_2O
5.	Anhydrous ammonia	82% N
6.	$ZnSO_4.H_2O$	33% Zn, 15% S
7.	Zn-EDTA	12% Zn
8.	Elemental sulphur	80%

3.8.1 Crop establishment and planting density

Rice crop was established by transplanting method. The nursery beds for transplanted rice prepared 30 – 35 days before transplanting in main field. 25 – 30 days old seedlings are suitable for transplanting. The seedlings transplanted 20 cm × 10 cm spacing when 25 days old. Wheat variety PBW 550 was sown at 120 kg ha^{-1} at 22 cm spacing row to row and 5 – 7 cm plant to plant spacing by manual seed drill at 5 cm depth.

3.8.2 Field preparation for rice and wheat

For the transplanting of rice, puddling was done by tractor drawn rotavator. The bunds were made to control the water in plots and avoid mixing of one treatment with other. Proper care was taken to level the plots uniformly. The transplanting was done manually, and the seedlings sprouted after 25 days from nursery and transplanted 20 × 15 cm spacing. For, the wheat crop 1 deep ploughing, 2-3 harrowing and 1 levelling were done. The field prepared according to layout. Bunds were prepared around each plot.

3.8.3 Plant protection measures

The plant protection measures were taken as and when required. Weeds were controlled by hand weeding and application of suitable herbicides for rice and wheat like bispyribac sodium (10% SC (9.5% w/w) dose required/acre is 80-120 ml/acre and clodinafop dose required/acre is 75g/ha. The insecticides were applied based on the infestation of insects.

3.8.4 Harvesting and threshing

Harvesting and threshing of rice and wheat was done manually to reduce yield loss and experimental error by using sickle. Threshing was done by beating the bundles on drum. Plot wise yield calculated.

3.8.5 Soil sampling at harvest

The soil samples were collected from each plot from 0 -15 cm depth after the harvesting if crops for the analysis of physico-chemical properties.

3.9 Observations recorded in field experiment

The parameters recorded during field experiments at time mentioned below in table no. 3.9

(a) Soil Analysis

S.No.	Parameters	Sub parameters	Stage of observation
1.	Physical properties	Soil texture	Initial
		Texture class	Initial
2.	Chemical properties	pH	Initial and after harvest of crop
		EC (dSm^{-1})	Initial and after harvest of crop
		Organic Carbon (%)	Initial and after harvest of crop
		Available nitrogen (%)	Initial and after harvest of crop
		Available Potassium (%)	Initial and after harvest of crop
		Available Potassium (%)	Initial and after harvest of crop
		Available Sulphur (%)	Initial and after harvest of crop
		Available Zinc (mg kg^{-1})	Initial and after harvest
3.	Biological properties (Soil enzymes)	Urease	At initial and heading stage of rice and wheat crop from 0-15 cm and 15-30 cm.
		Dehydrogenase	At initial and heading stage of rice and wheat crop from 0-15 cm and 15-30 cm.
		Nitrate reductase	At initial and heading stage of rice and wheat crop from 0-15 cm and 15-30 cm.
		Acid Phosphatase	At initial and heading stage of rice and wheat crop from 0-15 cm and 15-30 cm.
		Alkaline phosphatase	At initial and heading stage of rice and wheat crop from 0-15 cm and 15-30 cm.
		Aryl Sulfatase	At initial and heading stage of rice and wheat crop from 0-15 cm and 15-30 cm.

(b) Plant parameters: -

S.No	Attributes	Growth attributes	Stage/time of observation	
	Crops		Rice	Wheat
1.	Plant growth attributes and Physiological studies	(a) Plant height (cm)	20, 40, 60, 80 DAT and at harvest	30, 60, 90 Das and at harvest
		(b) Tillers/hill/m^2	20, 40, 60, 80 DAT	30, 60 and 90 DAS
		(c) Flag leaf length (cm)	40 and 80 DAT	60 and 75 DAS
		(d) Fresh and dry weight of plant (g)	40 and 80 DAT	60 and 75 DAS
		(e) Chlorophyll (SPAD)	40 and 80 DAT	60 and 75 DAS
		(f) Leaf area (cm^2)	40 and 80 DAT	60 and 75 DAS
		(g) Crop growth rate (g day m^{-1})	40 and 80 DAT	60 and 75 DAS
		(h) Relative growth rate (g. g^{-1} day^{-1})	40 and 80 DAT	60 and 75 DAS
		(i) Net assimilation rate (g(Crop)m^{-1}(leaf) day^{-1}	40 and 80 DAT	60 and 75 DAS
2.	Yield attributes	(a) Panicles, spike's	No. of panicles/plant	No. of spike/plant
		(b) Length (cm)	Length of panicle	Length of spike
		(c) Filled grains	No. of filled grains/panicle	No. of filled grains/spike
		(d) Unfilled grains	No. of unfilled grains/panicle	No. of unfilled grains/spike
		(e) Test weight	1000 grain weight	1000 grain weight
		(f) Grain yield (Kg ha^{-1})	At harvest	At harvest
		(g) Straw yield (Kg ha^{-1})	At harvest	At harvest

		(h) Harvest index (%)	After harvest	After harvest
3.	Nutrient concentration and uptake	(a) Nitrogen uptake by grain and straw	After harvest	After harvest
		(b) Phosphorous uptake by grain and straw	After harvest	After harvest
		(c) Potassium uptake by grain and straw	After harvest	After harvest
		(d) Sulphur uptake by grain and straw	After harvest	After harvest
		(e) Agronomic nutrient use efficiency (Kg grain/kg nutrient applied	After harvest	After harvest

3.10 Methods Used for observation :

3.10.1 Plant growth and Physiological attributes

3.10.1.1 Plant height: - The height of the highest tiller was recorded from 5 tagged plants fromthe base to the tip of the highest plant part by measuring tape. Average of 5 plants were takento calculate mean plant height at 20,40,60,80 DAT and at harvest in rice and 30,60,90 DASand at harvest in wheat.

3.10.1.2 Number of tillers (m^{-2}): - Total shoot and the shoots containing panicles per square m were counted at different intervals in both crops and named as total tillers and productive tillers.

3.10.1.3 Fresh and dry weight of plant (g): - Plants from selected one meter square area was cut close to the ground from each plot to measure fresh and dry weight of plant at different intervals in both crops. The fresh weight was taken from fresh samples after that samples placed in oven at 65 degree Celsius till constant weight achieved. After drying the samples were weighed for measuring dry weight.

3.10.1.4 Leaf area index - The leaves were plucked and separated from the lamina. Leaf area was recorded at 40 DAT and 80 DAT in rice and 60 DAS, 75 DAS in wheat with the help of leaf area meter. The leaf area was also calculated with the help of formula given by Watson, (1947) .

$$\text{Leaf area} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Total land area (cm}^2\text{)}}$$

3.10.1.5 Leaf Chlorophyll index- Leaf chlorophyll index was measured by estimating greenness of leaf using a chlorophyll meter which also known as SPAD (Soil plant analysis development meter). SPAD value was measured from fully expanded leaves. Three times the greenness measured from a single leaf and taken average value (Arregui, 2006)

3.10.1.6 Crop growth rate (CGR g day^{-1} m^{-2}): - Crop growth rate estimated the increment in dry weight of plant material. Data was calculated by formulae of CGR is given by Watson (1952):

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where W_2 = Dry weight (g) of plant at time t_2, W_1 = Dry weight (g) of plant at time t_1

3.10.1.7 Relative growth rate (RGR g g^{-1} day^{-1}): - Relative growth rate expressed as increase in dry weight of plants at two different intervals. Data was calculated by following formulae given by Williams in 1946.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{T_2 - t_1}$$

3.10.1.8 Net Assimilation rate (NAR g (crop)m^{-2}(leaf) day^{-1}: -

The dry matter of the plants measured at different intervals which were used to count NAR.

$$NAR = \frac{(W_2 - W_1)(\log_e L_2 - \text{loge } L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

W_2, W_1 = Dry weight (g) of plants at time t_2, t_1 and L_2, L_1 = Leaf area index

3.10.2 Yield attributes

3.10.2.1 Panicles and Spikes plant^{-1}: -

The number of panicles/spikes/plant counted. Randomly 5 tagged plants selected and count the number of panicles and spikes from each plot.

3.10.2.2 Panicle length and spike length (cm)

From each plot randomly 5 plants selected and length of panicles/spikes was measured with scale from neck to tip of apical grain mean value of 5 plants taken as panicle and spikes length.

3.10.2.3 Number of filled/unfilled panicle and spike

The no. of filled and unfilled grains per panicle and spike counted from randomly selected 5 plants from each plot.

3.10.2.4 Test weight (g)

One thousand grains from the produce of the net plots were counted and their weight was measured in grams.

3.10.2.5 Grain yield and straw yield (Kg ha^{-1})

To measure the dry matter (Grain + Straw) the harvested product tied in bundles and dried for 3 days. After 3 days, threshing done and measured the weight of grains obtained from each treatment. The straw yield was calculated by subtracting gain yield from biological yield.

3.10.2.6 Harvest Index (%)

Harvest index concept was proposed by Donald in 1962. It is the ratio of economic yield to biological yield.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.10.3 Soil Sampling: - The soil samples were taken from surface and subsurface soil from each plot. The collected soil samples were dried in shade, grinded in mortar and pestle, passed through 2 mm sieve for physico-chemical analysis of soil. For enzyme analysis fresh soil samples collected from 0 – 15 cm and 15 – 30 cm from each plot. The physical chemical and biological properties analysis methods described below: -

3.10.3.1 Soil texture

Experimental soil mechanical composition i.e. sand, silt, and clay size proportion were analyzed by hydrometer method (Bouyoucos, 1962). The texture of soil was found out by textural triangle proposed by USDA (Brady and Weil, 2002).

3.10.3.2 Chemical properties

3.10.3.2.1 Soil pH: - pH of soil was analyzed by pH meter in a 1:2.5 soil water suspension (Jackson, 1973). 10 gm of soil was taken in a beaker and then 25 ml distilled water added. The beaker suspension was stirred with glass rod for half an hour. pH meter electrode was calibrated with buffer solution having pH 7 and pH 9. The calibrated pH meter electrode was put into solution and pH value recorded.

3.10.3.2.2 Electric conductivity (dSm^{-1})

Electric conductivity is the measure of the transport of ions between anode and cathode. It is the measurement of the dissolved salts in a solution. The EC of soil was measured by EC meter (Jackson, 1973). The suspension of soil water which was used for the pH water which was used for the pH determination should be kept overnight and utilized to determine soil electric conductivity.

3.10.3.2.3 Organic Carbon (%)

The analysis of soil organic carbon was done by wet oxidation method proposed by Walkley – Black, 1934 (Allison, 1965). 2g of soil was taken in 500ml volumetric flask to which 10 ml $K_2Cr_2O_7$ (Potassium dichromate) was added and shake well. After this 20 ml of concentration H_2SO_4 was slowly added to it followed by shaking for 20 minutes on mechanical shaker. After dilution 1 ml of orthophosphoric acid (H_3PO_4) and 7 – 8 drops of diphenylamine indicator was added to it. The titration with 0.5M $FeSO_4$ solution was done until end point reached by variation in colour from violet – blue to brilliant green colour. The blanks without soil were prepared and organic carbon % analyzed by following formulae.

$$\text{Organic Carbon (\%)} = \frac{(\text{Blank} - \text{Sample reading})}{2} \times 0.003 \times 100$$

3.10.3.2.4 Available Soil Nitrogen analysis

Available nitrogen in soil was determined after Subbiah and Asija (1956) with alkaline potassium permanganate method. 20g of air-dried powdered soil was taken in distillation Kjeldahl's flask. Kjeldahl's flask which contained soil, 100ml of 0.32% $KMnO_4$, NaOH and water was added. After this 250 ml boric acid and 4-5 drops of mixed indicator added to it. The Kjeldahl's flask was kept below the distillation apparatus and volumetric flask below the received tube. The tip of receiver tube dipped into boric acid. Free ammonia released absorbed in boric acid solution, when distillation complete then samples taken out. The boric acid solution was titrated with concentrated H_2SO_4 till the appearance of pink colour. The blank without soil and was prepared in same manner. The readings were filled in formulae: -

$$\text{Available N (Kg ha}^{-1}) = \frac{R \times 0.2 \times 14 \times 2.24 \times 10^6}{W \times 100}$$

R = (Sample reading – Blank reading), 0.02 = Normality of H_2SO_4, 14 = Atomic wt. of N, 2.24 × 10^6 = Wt. of 1 ha soil, W = weight of soil.

3.10.3.2.5 Available Phosphorous

Soil available phosphorous was analyzed by the producer of Olsen., 1954 and Jackson 1973. 5 g of soil sample taken into 250 ml volumetric flask and a pinch of activated charcoal (Darco G – 60) was added. 100 ml of 0.5 M $NaHCO_3$ having pH 8.5 added into the flask containing soil. The flask was shaken for 25 -30 minutes on mechanical shaker and filtered through Whatmann's no. 42 filter paper. 5ml of filtrate was taken and put in 25 ml volumetric flask. In the filtrate 5ml of ammonium molybdate and distilled water was added. The flask was shaken to remove CO_2. The blue colour appeared due to addition of 1ml of working $SnCl_2$ solution. The intensity of blue colour was read at 660 nm.

3.10.3.2.6 Available Potassium

Available potassium in soil was analyzed by procedure given by Jackson, 1973. The flame photometer was used to determine available potassium. 5 g of dried soil weighed and put in a 250 ml volumetric flask. 25 ml of 1 M ammonium acetate having pH 7 was added in volumetric flask containing soil sample. The flask was shaken for 20 minutes on mechanical shaker. The soil suspension was filtered through whatmann's filtered paper no. 1. The potassium content in the filtrate was determined by flame photometer.

3.10.3.2.7 Available Sulphur

Available sulphur in soil sample was analyzed by turbid metric method given by Chesnin and Yien, 1950. 20 g of soil sample was taken in 250 ml conical flask. 100 ml of monocalcium phosphate in conical flask was added and shaken for 1hour. The soil suspension was filtered through whatmann's filter paper. 10ml of filtrate was taken into 25 ml volumetric flask and 2.5 ml of HNO_3 and 2 ml of acetic phosphoric acid added. The solution was diluted with 22 ml of distilled water, stopper the flask and shaken properly. 0.5 ml $BaSO_4$ suspension and 0.2 g of $BaCl_2$ crystals was added to it. The flask covered with stopper and stir it for 3 times. After 10 minutes, tubes stirred 10 times. The tubes left undisturbed for 15 minutes and 1ml of gum acacia acetic acid solution added. The suspension was shaken for 10 times and left samples undisturbed for 90 minutes. The sample shaken for 10 times and the intensity read at 440 nm on spectrophotometer. Also blank was prepared by taking 2.5, 5.0, and 7.5 ml portion of working standard solution. The formulae used for turbid metric of sulphate in soil.

$$\text{Available S (mg kg}^{-1}\text{)} = -\frac{R \times 100}{10 \times 20}$$

R = Quantity of sulphur in mg as obtained on X axis against reading.

3.10.3.2.8 Available Zinc

Available zinc was analyzed by DTPA extraction. It interacts with the free metal ions in soil solution. The DTPA extractable zinc extracted by 0.005 m DTPA, 0.01 m $CaCl_2$ and triethanal amine by adjust pH 7.3. The amount of Zn was measured by Atomic Absorption spectrophotometer (Lind say and Norwell, 1978).

3.10.3.3 Soil Biochemical Analysis

3.10.3.3.1 Dehydrogenase activity: -

Procedure given by Tatabati 1982 was used to determine dehydrogenase activity in soils. Modified 2, 3, 5 triphenyl tetrazolium chloride reduction technique was followed to analyses dehydrogenase activity (Casida, 1977). 5 g of fresh soil sample weighed and put it in a test tube. 0.1 g $CaCO_3$ (100 mg) and 1.5 ml distilled water added into test tube. After this 1 ml of 2, 3, 5 triphenyl tetrazolium chloride 1% solution added into test tubes. The test tube was plugged with stoppers and incubates at 30^0C for 24 hours. After 24 hours, the resulted slurry was shifted to Whatmann's filtered paper No. 1 with the help of concentrated methanol; the triphenyl formazon was extracted in 50 ml volumetric flask. The filtrate was of light pink colour. The intensity of pink colour was read out with spectrophotometer at 485 nm. For control, methanol was used for calculation of dehydrogenase, following formulae used: -

$$\underset{(\mu g\ TPF\ g^{-1}\ dry\ soil\ 24\ hr^{-1})}{\text{Dehydrogenase activity}} = \frac{C \times 50}{W}$$

C = Corrected reading from standard curve, 50 = Extractant volume, W = Dry Wt. of soil.

3.10.3.3.2 Urease activity

The activity of urease enzyme was analyzed by urea reduction method of Mc-Garity and Myers (1967). Weight 10 g of fresh soil and put it in 100 ml volumetric flask. The soil in flask was treated with 1 ml Toluene, 10 ml buffer (pH 7) and 5 ml of 10% urea solution. For the control, 5 ml of distilled water added instead of 10% urea in volumetric flask. After this, the volumetric flask was shaken thoroughly and the flask was incubated for 3 hours at 37^0C in dark. After 3 hours, flasks were taken out from incubator and volume made up to 100 ml with distilled water. The flask was shaken thoroughly and shifted the suspension to Whatmann's No. 5 filter paper. Indophenol blue method was used for measurement of ammonia released due to urease activity. 0.5 ml of the extractant was shifted to 25 ml volumetric flask and adds 5 ml distilled water.

After this 2 ml of phenolate solution and 1.5ml of sodium hypochlorite solution was added. The volume made up to 25 ml with distilled water and blue colour appeared which was read out with Spectro photo meter at 630 nm. The obtained values were put in formulae for the estimation of urease activity.

$$\text{Urease activity } = \frac{\mathrm{C} \times 25 \times 100}{\mathrm{W}}$$

C = Corrected reading of mg $NH^{+}{}_{4}$ – N ml^{-1} from standard curve, 25 = extractant volume (ml^{-1} 100 = Solution volume, W = Wt. of soil.

3.10.3.3.3 Acid Phosphatase and Alkaline Phosphatase

The phosphatase activity in soil was determined by procedure given by Tatabai and Bremner (1969). Weight 1 gm. of soil sample and put it in a 100 ml conical flask. The soil samples treated with 0.25 ml toluene and 4 ml of modified universal buffer having pH 6.5 for acid phosphatase and pH 11 for alkaline phosphatase. After this 1 ml of p-pnitrophenol phosphate solution added. The flask was shaken properly for few seconds and plugged the flask with stopper. The flasks were kept in an incubator at 37^{0}C for 1 hour. After 1 hour, unplugged the stoppers and 1 ml of $CaCl_2$ and 4 ml of NaOH added , the flask swirled for few seconds and filtered through filter paper. Yellow colour filtrate intensity was recorded with the help of Spectro photo meter at 430 nm. For the preparation of control (without soil), 1 ml $CaCl_2$ + 4 ml NaOH + 1 ml p-NPP added. Formulae used for calculation was:

$$Acid/Alkaline\ phosphatase \mu g\ p - NPP\ g - 1\ dry\ soil\ h - 1) = \frac{C \times 10}{W}$$

Where C = Corrected reading, 10 = Solution volume (ml), W = Dry weight of soil (g).

3.10.3.3.4 Nitrate reductase:

Soil nitrate reductase activity was assayed by use of diazotizing agent (Sulfa nil amide) and coupling reagent (N – 1 – napthyl ethylene diamine which has ability to convert NO_2 into Azo compound of reddish-brown colour). The intensity of reddish-brown colour was measured calorimetrically (Keeney *et al.*, 1982). In 250 ml volumetric flask 5 g of soil was taken which was treated drop wise with 2 ml of 2, 4 – Dinitrophenol solution containing absolute ethanol.

The ethanol with the use of air flow for 2 hours was evaporated after this, add 10 ml of KNO_3. Swirled the flask for some seconds to mix the contents and kept in dark in incubator for 24 hours. After 24 hours, the samples were migrated to light and add 40 ml of 2.5 M KCL. The flasks were shaken on mechanical shaker for 30 minutes and suspension was filtered through Whatmann's filter paper. 1 ml of filtrate was taken into 50 ml volumetric flask and 1 ml sulphanilamide acid having pH 1.73 added to it, left the sample undisturbed for 10 minutes after this 1 ml of N – (1 – napthyl ethylene diamine hydrochloride) having pH 1.7 added to it. 1 ml of buffer solution of acetic acid having pH 2.5 added into flasks. Make up volume up to 25 ml with distilled water. The sample left undisturbed for 15 minutes. The intensity of reddish -brown resultant product read on Spectro photo meter at 540 nm.

3.10.3.3.5 Arylsulfatase

Aryl sulfatase activity was determined by the method given by Tatabai and Bremner (1970). 1 gm of soil was taken in 50 ml conical flask which was treated with 2.5 ml toluene and 4 ml buffer solution of acetate having pH 5.8. after this add 1 ml of p-nitrophenyl sulfate. Shake the flask so that contents mixed properly and incubate it for 1 hour at 37^0 C. After 1 hour the sample flasks were taken out from incubator and add 1 ml of $CaCl_2$ and 4 ml of NaOH. Add 1 ml of p-nitrophenyl phosphate was added. The suspension was filtered through filter paper. The filtrate was of yellow colour whose intensity read with the help of spectro photo meter at 440 nm.

3.10.3.4 Nutrient concentration and plant uptake

(1). Plant Sampling: - The samples of plant were taken randomly from each plot at harvesting. The plant samples were washed properly and dried in oven at 65^0C till constant weight achieved. The dried samples were grinded in pestle mortar and processed samples were used for further analysis.

(2). Digestion of plant samples: - After processing the samples analyzed by micro - Kjeldahl's method to find Nitrogen for Phosphorous and Potassium uptake in plant wet digestion method used. Vanda – molybdate yellow colour technique also used for analysis of phosphorous by Spectro photo meter and flame photometer for potassium (Jackson, 1973).

3.10.3.4.1 Total nitrogen content in plant

The total nitrogen content estimation of grain and straw was done by taking 0.5 gm of (grain/straw) expertly prepared sample in 250 ml digestion tube. 20 ml of sulphuric salicylic acid mixture put in digestion tube and left the tube undisturbed for 2 hours. After this 2.5 g sodium thio-sulphate added in tube containing content, the tube swirled for few seconds and left the sample undisturbed for one night. 4 g catalyst mixture and 3 – 4 granules of pumice mixed and the material digested at 400^0C. The mouth of tubes kept in a small conical flask to ensure proper digestion and prevent loss of H_2SO_4 and digestion continued till the colorless material appeared. The digestion tubes removed from digester block and cooled for 20 minutes properly. After digestion no particulate matter left in tube. The digest mixture allowed to cool and distilled water added, tube shaken properly, and volume 250 ml made. Blank was also prepared for each batch of samples. After this, with 0.1 N H_2SO_4 titration was done until the appearance of purple colour.

3.10.3.4.2 Total Phosphorous and Potassium content in plant sample

1 gram of grain and straw sample were weighed and taken in digestion tube. 10 ml of di-acid mixture of concentration HNO_3 + $HClO_4$ added. The content was digested at 150^0C in KEL plus digestion block until the material become colorless. The digestion content was shifted to 100 ml volumetric flask and adds distilled water to make volume up to mark. The digested content was used for the determination of phosphorous and potassium. Total phosphorous content was analyzed by Vando-molebdo phosphoric acid yellow colour (Jackson, 1973). 10 ml of digested material was taken and add 10 ml of vando – molebdate yellow colour reagent. Volume made up to 5 ml. The intensity was measured after half an hour by use of Spectro photo meter. The potassium content was determined by flame photo meter (Chapman and Pratt (1961). Blanks were also prepared without soil.

3.10.3.4.3 Sulphur content in plants

1 gm of plant sample material weighed and put it in digestion tube. 10 – 15 ml of Di – acid mixture of nitric acid + per chloric acid in 3:1 added to 150 ml volumetric flask. The contents

in tube shaken and placed the flask on the hot plate to complete the digestion. Filtered the content solution in 100 ml flask; the filter paper containing residues washed with hot water. The volume mixed by distilled water and the samples analyzed for sulphur content in plant by Spectro photo meter at 440 nm (Hunter, 1984).

3.10.3.4.4 Nutrient use efficiency

The nutrient (N, P, K, and S) uptake by grain and straw was estimated by following formulae

$$\text{Nutrient use efficiency (\%)} = \frac{\text{Uptake from treated plot} - \text{Uptake from control plot}}{\text{Total fertilizer applied}} \times 100$$

3.10.3.4.5 Agronomic efficiency (AE_N) (Kg ha^{-1})

$$AE_N \text{ (Kg ha}^{-1}\text{)} = \frac{GY_F - GY_C}{AE_N}$$

GY_F = Grain yield under fertilized plot (Kg ha^{-1}), GY_C = Grain yield under control (Kg ha^{-1})

AF_N = Units of applied nutrients in test treatment (Kg ha^{-1})

3.11 Pot experiment

The pot study was conducted to "Improve Nitrogen and Phosphorous Use Efficiency in rice – wheat cropping system through application of modified fertilizers" for two years 2018-2019 and 2019-2020. Rice crop was sown in kharif season and wheat crop was sown in Rabi season by following the recommended package and practices. The soil was taken from agriculture farms of Lovely Professional University. Chemical properties of soil were determined before planting. The total number of 9 treatments which were replicated thrice. In completely randomized block design. Total number of pots was 27. The plastic pots were used, which had 16 cm upper diameter, 14 cm lower diameter and 17 cm height. Total volume of pot was 2752 cm^3. The pots were filled with 2 kg air dried soil passed through 4 mm sieve and mixed with the amendments. Irrigation was given to the pots and filled the pot up to field capacity. The recommended doses of fertilizers were applied to both crops. The set of treatments were similar as field experiment. Full dose of phosphorous and potassium as SSP and MOP were added as basal dose to both crops. $ZnSO_4$ and Zn -EDTA applied 14 DAT and 14 DAS in rice and wheat.Sulphur applied also as basal dose. Anhydrous ammonia injected 15 -20 cm deep in soil after germination in wheat and before flooding in rice. Nitrogen as neem coated urea and normal urea applied in 2 – 3 splits at critical stages. In rice applied nitrogen at planting, tillering and panicle initiation and in wheat as basal at CRI and heading stage (60 DAS) during both years. The planting material used for rice crop was Pusa Basmati 1121 and for wheat PBW 550. Rice crop nursery was raised after 15th of June and 25 days old seedlings were transplanted during second week of July. The total 4 plants were transplanted in each pot. The pots were irrigated as and when needed. The crop was harvested during first week of November. The wheat crop was raised from seeds. The 8 seeds per pot were planted at 2 cm – 3 cm depth. The four plants were maintained in each pot after emergence. Irrigated the pots based on the emergence. Irrigate the pots based on the requirement. The wheat crop was harvested in end of April during both seasons. During second week of November by digging the soil of pot with Khurpi. The main objective of conducting pot experiment was to check the leaching amount of nutrients. So, that we can estimate the uptake of nutrients by plants and less of nutrients. So, for this objective the holes of pots covered with gauze to prevent loss of particulate matter but allow leaching of soil suspension. Each pot from bottom covered by sealable plastic bag for collection of leachates. The collected leachate samples were transferred to plastic tubes and stored to 4^0C. Samples were collected at 5, 9 DAT and after top dressing at panicles initiation stage in rice and 5 DAS, 25 DAS and at heading stage after top dressing in wheat crop. The NH^+_4 – N and NO^-_3 - N determination was calculated by the method given by Bremner and Keeney 1965. The plant parameters related to growth and yield; soil parameters all were recorded at same time when recorded from field. The same procedure was followed which were explained in previous section 3.10.3.

3.12 Economics analysis

The adoption and recommendation of any practices by farmer depends upon its economics. So, it is important to calculate the economics for different treatments.

3.12.1 Cost of cultivation

The cost of cultivation defined as the money invested to produce any crop from land preparation to harvesting of crop. Cost of cultivation was computed by considering cost of seed, fertilizers, herbicides and wages of labour, machines, and irrigation. The cost of cultivation was calculated based on market price.

3.12.2 Gross returns

Gross returns were calculated by income earned by selling the grain and straw. The current price was taken to calculate gross returns.

3.12.3 Net returns

Cost of cultivation subtracted from gross returns to calculate net returns.

3.12.4 Benefit cost ratio

$$\text{Benefit cost ratio} = \frac{\text{Net returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

B: C ratio was calculated for each treatment.

3.13 Statistical analysis

The obtained experimental data were assessed by Duncan's multiple range tests with a probability $p < 0.05$. Difference between the mean values was examined by one-way analysis of variance (ANOVA) using software SPSS 22. The variation components for tests of significance were tested as Fisher's LSD test as post hoc test. The significant difference among the means was estimated based on least significant difference at 5% level of probability.

Demonstration

Plate1: Ploughing of field

Plate2: Pre sowing irrigation

Plate3: Prepration of bunds for demarcation of plots

Plate 4: Line sowing of wheat by manual seed drill

Plate5: Germination of wheat

Plate 6: Irrigation to wheat field

Plate7 : Crown root initiation stage in wheat crop

Plate8: Tillring stagein wheat

Plate9: Wheat at booting stage

Plate10: Wheat at heading stage

Plate11,12: Comparison of anhydrous ammonia treated plots with neem coated urea treated plots

Plate13: Prepration of bunds in rice fields

Plate 14: Transplanting of rice seedlings

Plate 15: Transplanted rice field

Plate16: Recording data in rice field

Plate17: recording data with SPAD meter

Plate18: Recording plant height

Plate19: Harvesting of rice crop

Plate20: Injecting anhydrous ammonia in soil

Plate21: Volumetric analysis of soil samples

Plate 22: MicroKjeldahl apparatus setup

Plate 23: Spectrophotometer reading

Plate 24: Solution prepration for testing avaialable P in soil

Plate25: Nitrate reductase enzyme analysis in soil sample

Plate 26: Available Sulphur in soil analysis

Plate 27: Dehydrogenase enzyme activities in soil

Plate28: Organic carbon testing in soil samples indicating green colour

Plate29

Plate 30

Plate 31

Plate 32

Plate 29,30,31,32: Pot experiment of rice and wheat

Chapter 4

Results and discussion

The observation noted in the field experiments and pot experiments related to "Improving nitrogen and phosphorous use efficiency in rice-wheat cropping system by use of modified fertilizers have been tabulated, figured, statistically processed and discussed under this chapter. The results obtained in field experiment in respect to yield and yield contributing parameter, nutrient uptake by crop, enzymatic activities, soil nutrient status, physico-chemical properties and nutrient use efficiencies are discussed as below. The results obtained during present study presented in this chapter under appropriate heads.

4.1 Effect of modified fertilizers, crop yield attributing characters, crop growth parameters and yield

4.2 Effect of modified fertilizers on nutrient uptake

4.3 Effect of modified fertilizers on nutrient use efficiency

4.4 Effect of modified fertilizers on soil physico chemical properties

4.5 Effect of modified fertilizers on soil biological indicators

4.6 Economics

4.7 Pot experiment

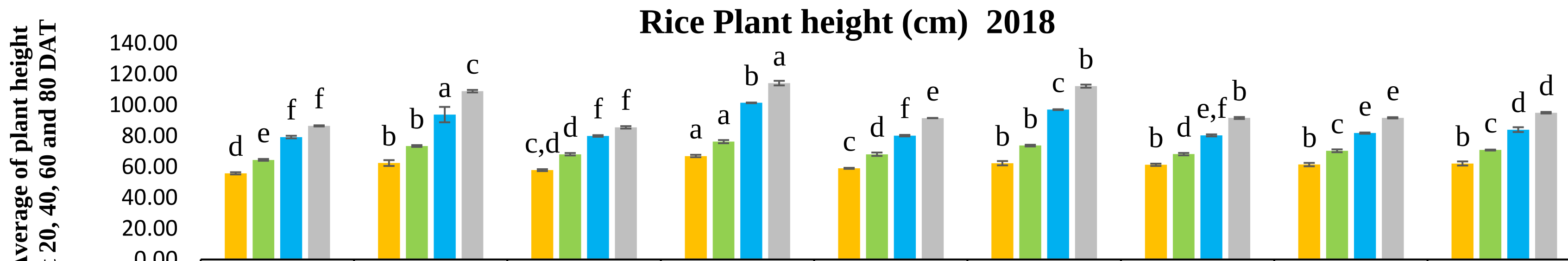
4.8 Discussion

4.1 Effect of modified fertilizers, crop yield attributing characters, crop growth parameters and yield

4.1.1 Crop growth parameters: - The application of modified fertilizers to rice – wheat cropping influenced the vegetative growth and other growth characters. However modified fertilizers are more useful to different growth characters of both crops. The coated fertilizers provide the nitrogen regularly and match with the physiological growth stages of rice-wheat which are reflecting in growth characteristics of crop. The performance of growth characters i.e. plant height, number of tillers, fresh weight, dry weight, chlorophyll index, leaf area, flag leaf length, CGR, RGR, NAR presented in tables, figures and discussed below-

4.1.1.1 Plant height (cm):- To evaluate the effect of different treatments plant height is important factor. The data on the effect of modified fertilizers on plant height of rice recorded at 20, 40, 60 and 80 DAT and wheat at 30, 60, 90 and 120 DAS presented in table 4.1.1.1 (a and b) . Rice plants attained maximum plant height during initiation of growth phase and slow increment in the later stages was observed during the period of investigation. During 2018, for rice crop maximum plant height recorded in T3- neem coated urea + PK + S + Zn-EDTA. In T3, the plant height at 20, 40, 60 and 80 DAT was 67.03, 76.31, 101.45 and 114.23 cm respectively which were significantly higher to all the treatments (Fig 4.1.1a, b). The second highest plant height was recorded by T5- by application of NCU + PK+ $ZnSO_4$ was (62.37, 73.77, 97.05, 11227 cm) at 20,40,60 and 80 DAT respectively. These two treatments were statistically superior over other treatments. All the treatments were significantly different from each other. The minimum plant height (55.8, 64.53, 79.3, 86.5 cm) recorded by the application of 100% RDF (T0) at 20, 40, 60 and 80 DAT respectively. In consecutive wheat crop of 2018-19, the plant height ranged from 32.03 cm to 79.27 cm. All the treatments were statistically significantly different from each other. The maximum plant height (38.17, 51.677, 69.27, 79.27 cm) recorded due to application of NCU + PK + S + Zn-EDTA-T3 at 30, 60, 90 and 120 DAS respectively which was significantly superior over all other treatments. The second highest plant height (35.83, 50.2, 66.27 and 74.9 cm) at 30, 60, 90 and 120 DAS recorded with the application of NCU + PK + $ZnSO_4$ which was followed by T8 with plant height (35.83, 50.27, 67.4, 77.17 cm). The lowest plant height (32.03, 45.77, 59.57, 65.23 cm) recorded with control (T0). All treatments showed superiority in plant height over control. During 2019 rice crop the plant height ranged from 58.3 cm to 113.73 cm. The highest plant height (66.2, 74.27, 103.33, 113.73 cm) recorded with the application of NCU + PK + S + Zn-EDTA (T3) at 20, 40, 60 and 80 DAT which was followed by T5 with plant height at 20, 40 DAT (57.3, 63.3 cm)).

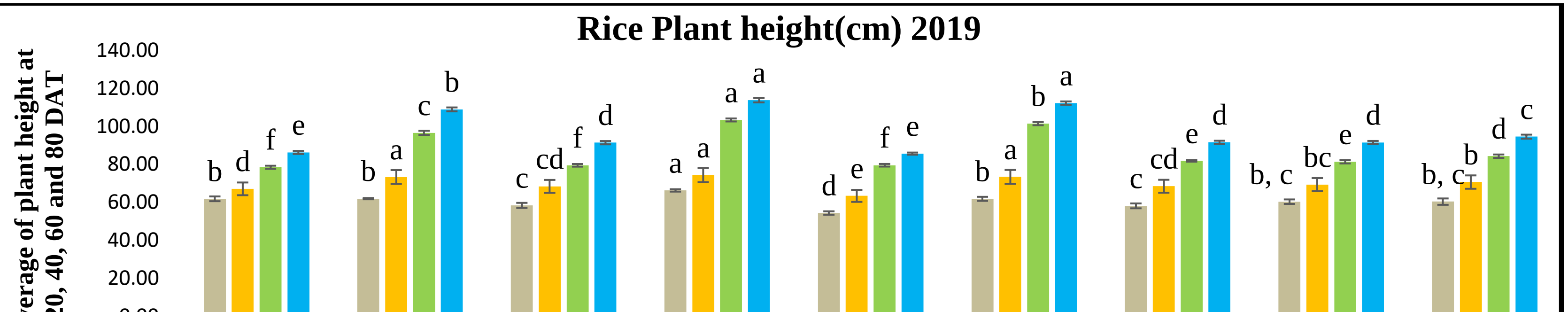
The trend of maximum plant height in rice is shown in Fig4.1.1 (b). The order of maximum plant height during 2018, 2019 in rice crop was T3> T5> T8> T1> T7> T6> T4>T2>T0.In consecutive wheat crop of 2019-2020, plant height ranges from 30.7 cm – 80.23 cm. The maximum plant height (37.93, 52.10, 71.43, 80.23 cm) at 30, 60, 90 and 120 DAS with T3 which was followed by T5 with plant height (36.87, 49, 68.13, 78.63 cm). The minimum plant height recorded with the application of AA + PK (T2) at 30, 60 DAS (30.7, 44.03 cm) and at 90 and 120 DAS with T0 (control) having plant height 59.07, 65.5 cm.The data is presented in fig 4.1. (b) And Table 4.1 b. The trend of plant height in wheat was T3> T5>T8>T1>T7>T6>T4>T2>T0.



	T0	T1	T2	T3	T4	T5	T6	T7	T8
20 DAT	55.80	62.47	57.87	67.03	59.03	62.37	61.33	61.47	62.18
40 DAT	64.53	73.50	68.17	76.31	68.18	73.77	68.23	70.40	70.88
60 DAT	79.30	93.84	80.00	101.45	80.20	97.05	80.37	81.85	84.10
80 DAT	86.53	109.00	85.57	114.23	91.59	112.27	91.63	91.77	95.07

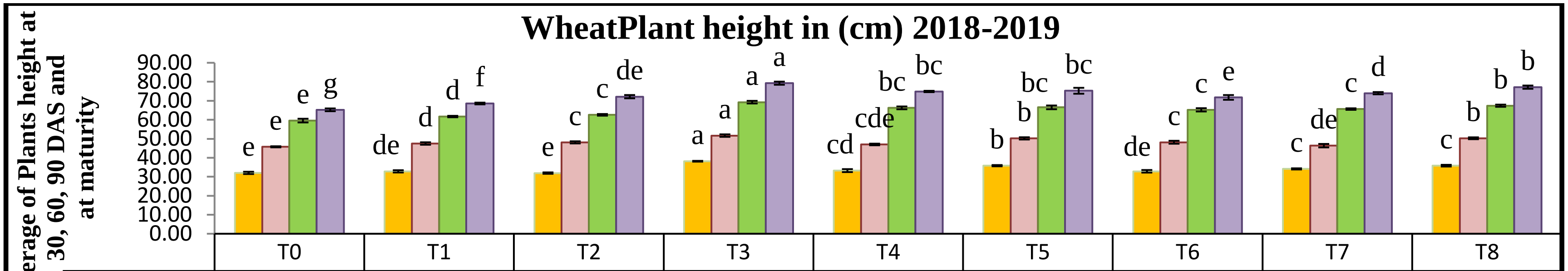
Treatments

4.1.1 a,b



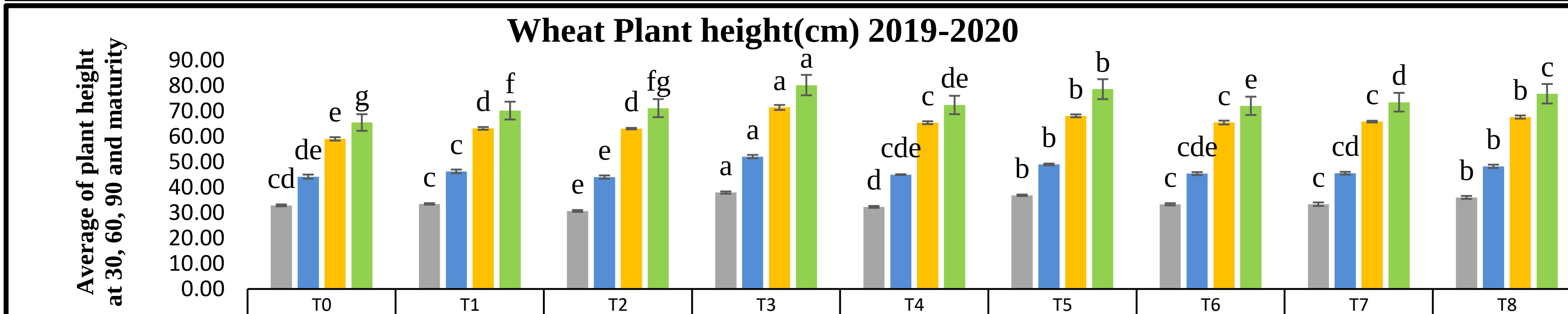
	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 20 DAT	61.78	61.87	58.30	66.20	54.30	61.77	58.07	60.27	60.30
Avg. of 40 DAT	67.03	73.27	68.33	74.27	63.33	73.33	68.40	69.27	70.60
Avg. of 60 DAT	78.40	96.53	79.43	103.33	79.47	101.40	81.77	81.27	84.23
Avg. of 80 DAT	86.23	108.90	91.37	113.73	85.60	112.23	91.57	91.50	94.53

Treatments



	T0	T1	T2	T3	T4	T5	T6	T7	T8
30 DAS	32.03	32.83	31.93	38.17	33.23	35.83	32.87	34.13	35.83
60 DAS	45.77	47.50	48.10	51.67	47.00	50.20	48.17	46.37	50.27
90 DAS	59.57	61.70	62.60	69.27	66.27	66.53	65.23	65.63	67.40
At maturity	65.23	68.57	72.17	79.27	74.90	75.27	71.77	74.00	77.17

4.1.1.1c, d



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 30 DAS	32.90	33.47	30.70	37.93	32.30	36.87	33.33	33.37	36.03
Avg. of 60 DAS	44.20	46.27	44.03	52.10	45.00	49.00	45.40	45.57	48.27
Avg. of 90 DAS	59.07	63.20	63.10	71.43	65.43	68.13	65.50	65.87	67.67
Avg. of maturity	65.50	70.20	71.17	80.23	72.40	78.63	72.07	73.50	76.83

Fig.4.4.1 (a, b, c &d) depicted the plant height of rice and wheat during 2018-2019& 2019-2020 at different intervals. The similar letters above the standard bars indicate that treatments are non- significant according to DMRT ($p<0.05$).

Table 4.1.1.1(a) Effect of modified fertilizers on plant height (cm) (mean± S.E) of rice at (20, 40, 60& 80 DAT) during 2018-2019

Treatments	2018				2019			
	20DAT	**40DAT**	**60DAT**	**80DAT**	**20DAT**	**40DAT**	**60DAT**	**80DAT**
T0- Control (RDF)	55.80±0.71d	64.53±0.58e	79.30±0.83f	86.53±0.36f	61.78±1.25b	67.03±1.37d	78.40±0.83f	86.23±0.82e
T1- Neem coated urea + PK recommended	62.47±1.88b	73.50±0.5b	93.84±4.98a	109.00±0.8c	61.87±0.33b	73.27±0.56a	96.53±1.10c	108.90±1.4b
T2- Anhydrous ammonia + PK recommended	57.87±0.62cd	68.17±0.78d	80.00±0.51f	85.57±0.78f	58.30±1.34c	68.33±0.74cd	79.43±0.70f	91.37±0.87d
T3- Neem coated urea + PK+S+ Zn-EDTA	67.03±0.78a	76.31±1.03a	101.45±0.21b	114.23±1.48a	66.20±0.62a	74.27±0.90a	103.33±0.7a	113.73±1.15a
T4- Anhydrous ammonia + PK+ S+ Zn-EDTA	59.03±0.33c	68.18±1.10d	80.20±0.49f	91.59±0.08e	54.30±0.90d	63.33±0.78e	79.47±0.69f	85.60±0.57e
T5- Neem coated urea + PK+$ZnSO_4$	62.37±1.39b	73.77±0.54b	97.05±0.25c	112.27±1.00b	61.77±1.08b	73.33±0.74a	101.40±0.8b	112.23±0.87a
T6- Anhydrous ammonia + PK+ $ZnSO_4$	61.33±0.74b	68.23±0.78d	80.37±0.65ef	91.63±0.63e	58.07±1.28c	68.40±0.91cd	81.77±0.39e	91.57±0.82d
T7- RDF + $ZnSO_4$	61.47±1.09b	70.40±0.91c	81.85±0.40e	91.77±0.39e	60.27±1.19bc	69.27±1.11bc	81.27±0.86e	91.50±0.78d
T8- RDF+ S+ Zn EDTA	62.18±1.33b	70.88±0.30c	84.10±1.55d	95.07±0.50d	60.30±1.68bc	70.60±0.83b	84.23±0.90d	94.53±1.06c

Table 4.1.1.1(b) Effect of modified fertilizers on plant height (cm) (mean± S.E) of wheat at (30, 60, 90& 1200 DAS) during 2018-19, 2019-20

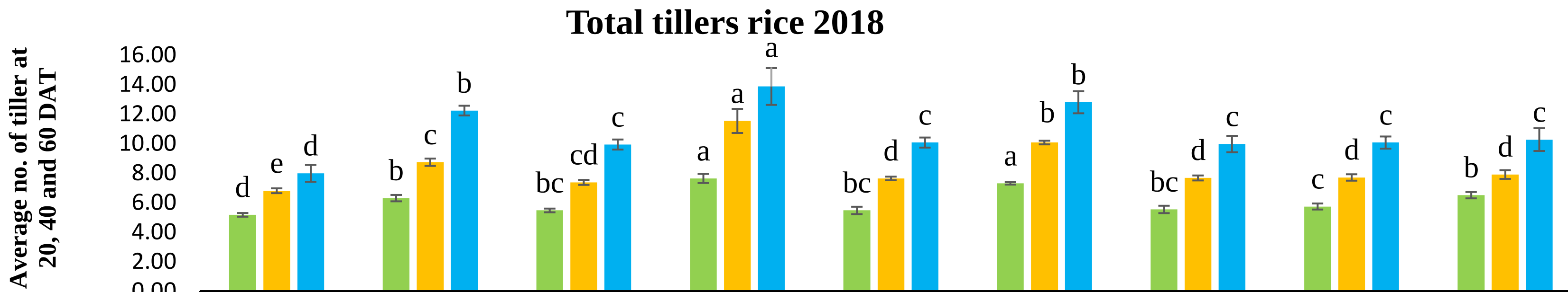
Treatments	2018				2019			
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T0- Control (RDF)	32.03±0.60e	45.77±0.29e	59.57±0.97e	65.23±0.74g	32.90±0.37cd	44.20±0.82de	59.07±0.66e	65.50±0.42g
T1 - Neem coated urea + PK recommended	32.83±0.60de	47.50±0.65cd	61.70±0.37d	68.57±0.46f	33.47±0.29c	46.27±0.74c	63.20±0.5d	70.20±0.78f
T2 - Anhydrous ammonia + PK recommended	31.93±0.37e	48.10±0.57c	62.60±0.43c	72.17±0.86de	30.70±0.37e	44.03±0.65e	63.10±0.2d	71.17±0.33fg
T3 - Neem coated urea + PK+S+ Zn-EDTA	38.17±0.21a	51.67±0.66a	69.27±0.69a	79.27±0.82a	37.93±0.45a	52.10±0.67a	71.43±0.9a	80.23±0.74a
T4 - Anhydrous ammonia + PK+ S+ Zn-EDTA	33.23±0.78cd	47.00±0.43cde	66.27±0.74bc	74.90±0.36bc	32.30±0.37d	45.00±0.16cde	65.43±0.58c	72.40±0.86de
T5- Neem coated urea + PK+$ZnSO_4$	35.83±0.33b	50.20±0.59b	66.53±0.98bc	75.27±1.55bc	36.87±0.29b	49.00±0.36b	68.13±0.5b	78.63±0.54b
T6 - Anhydrous ammonia + PK+ $ZnSO_4$	32.87±0.68de	48.17±0.78c	65.23±0.87c	71.77±1.25e	33.33±0.41c	45.40±0.59cde	65.50±0.75c	72.07±0.74e
T7 - RDF + $ZnSO_4$	34.13±0.31c	46.37±0.91de	65.63±0.40c	74.00±0.59cd	33.37±0.69c	45.57±0.53d	65.87±0.34c	73.50±0.57d
T8 - RDF+ S+ Zn-EDTA	35.83±0.45c	50.27±0.49b	67.40±0.57b	77.17±0.86b	36.03±0.59b	48.27±0.65b	67.67±0.6b	76.83±0.52c

4.1.1.2 Total tillers and Productive tillers

Total tillers: Total tillers per plant are the vital parameter for observing the effect of any treatment on the growth and yield of crop. The mean data of tillers were computed at 20, 40, 60DAT is presented in table 4.1.1.2 (a and b). The maximum number of tillers in rice at 20, 40, 60 DAT (7.63, 11.53, 13.87) recorded with the application of neem coated urea + PK + S + Zn-EDTA during 2018. The second highest number of tillers (7.30, 10.07, 12.8) observed by T5-NCU + PK + $ZnSO_4$ which was followed by T1 (NCU + PK) having tillers (6.30, 8.73, 12.23). The remaining all treatments were significantly different from each other. The lowest number of tillers during all intervals recorded by (T0) -100% NPK having 5.17, 6.80, 7.98 tillers at 20, 40, 60 DAT. During 2019, the number of tillers ranged from 4.47 to 13.33. The maximum number of tillers per plant (7.60, 9.37, 13.33) recorded due to application of NCU + PK + S + Zn-EDTA –T3 which was at par with T5 having tillers (7.40, 8.33, 12.97) at 20, 40, and 60 DAT. The minimum number of tillers at 20, 40 DAT (4.47, 5.27) recorded with application of AA + PK + S + Zn-EDTA and at 60 DAT minimum tillers (6.53) with T0 (100% NPK). The order of maximum tillers during both years was T3> T5> T1> T8> T7> T6> T2> T4> T0 presented in fig 4.1.1.2 (b). During 2018 wheat crop the number of tillers m^{-2} ranged from 379 to 451.32. The total number of tillers was significantly affected by the modified fertilizers. The highest number of tillers (451.32) observed with NCU + PK + S + Zn-EDTA which were followed by T5 with 444.33 tillers. The other treatments also contained more number of tillers over control. The minimum number of total (379) tillers m^{-2} observed in T2 (AA + PK) which was at par with T0 with 388.3 tillers. During 2019 wheat, the total number of tillers m^{-2} ranged from 375 to 443. With the application of neem coated urea + PK + S + Zn-EDTA recorded maximum number of tillers (443) which was followed by T5 with 434 tillers m^{-2}. The minimum (375) tillers recorded with T2 which was at par with T0. The trend of maximum tillers in rice and wheat was: - T3 > T5 > T8 > T7> T1> T6> T4> T0> T2 presented in fig. 4.1.1.2(c), 4.1.1.2 (d).

Productive tillers: All the treatments produced significantly more effective tillers. In case of productive tillers in 2018 rice crop ranged from 6.93 to 11.97. The highest productive tillers (11.97) recorded with the application of NCU + PK + S + Zn-EDTA-T3 which was followed by

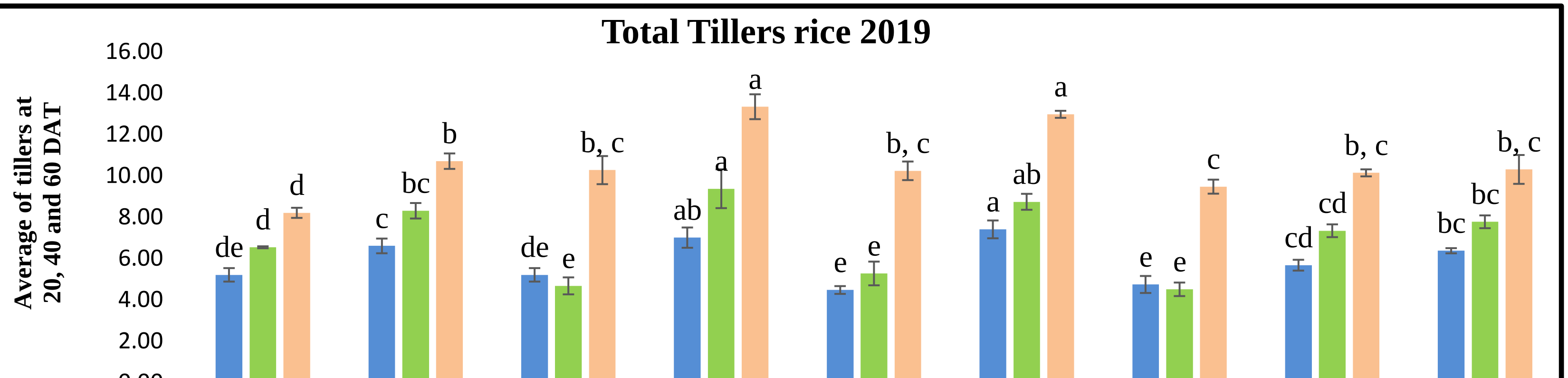
T5 with 10.53 tillers. All the other treatments were significantly different from each other. The minimum number of effective tillers (6.93) recorded with T0 which was followed by T2 with 7.70 tillers. In case of 2019 maximum productive tillers (11.50) recorded with T3 treatment which was followed by T5 with 11.03 tillers. Rest of the treatments has more number of tillers as compared to control. The lowest productive tillers (6.77) recorded with T0. The same trend followed in case of productive tillers. During 2018 with the application of NCU + PK + S + Zn-EDTA maximum number of effective tillers (423) recorded followed by T5 with 418 tillers. The lowest effective tillers (360.0) recorded with T2 which was at par with T4 and T0 with 360.33 and 362 tillers. During 2019-2020, the maximum number of effective tillers m^{-2} recorded with T3 (416.27) followed by T5 (408). The rest of treatments showed more number of tillers over control. The lowest tillers (349) recorded with T2 which was at par with T4 with 353.67 tillers. The order of effective tillers in rice and wheat was T3 > T5 > T8 > T7 > T1 > T6 > T0 > T4 > T2 respectively. The data of effective tillers was presented in table and fig. 4.1.1.2a, b.



	T0	T1	T2	T3	T4	T5	T6	T7	T8
AVRG 20 DAS	5.17	6.30	5.47	7.63	5.47	7.30	5.53	5.73	6.50
AVRG 40 DAS	6.80	8.73	7.37	11.53	7.63	10.07	7.67	7.70	7.90
Avg. of 60 DAT	7.98	12.23	9.93	13.87	10.07	12.80	9.97	10.07	10.27

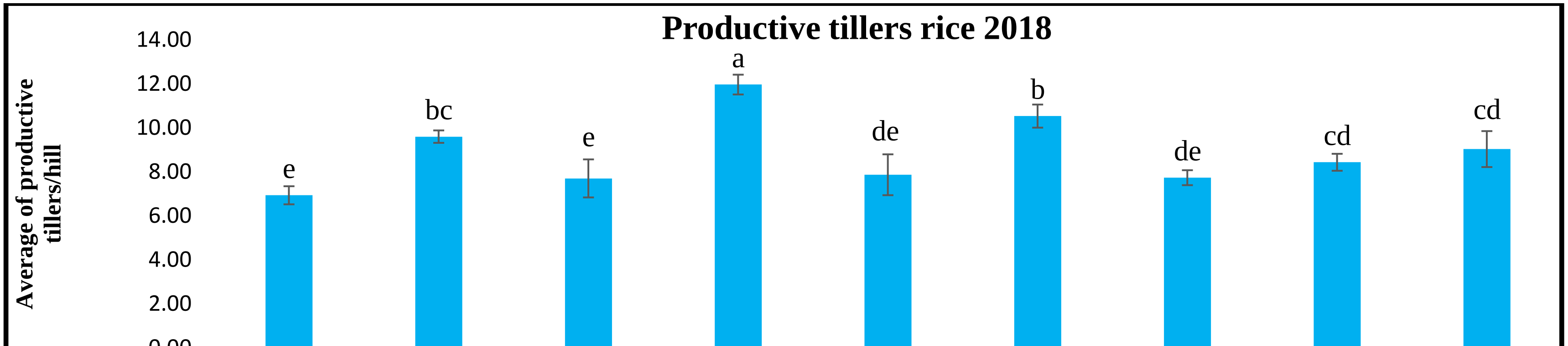
Treatments

4.1.1.2 A, B



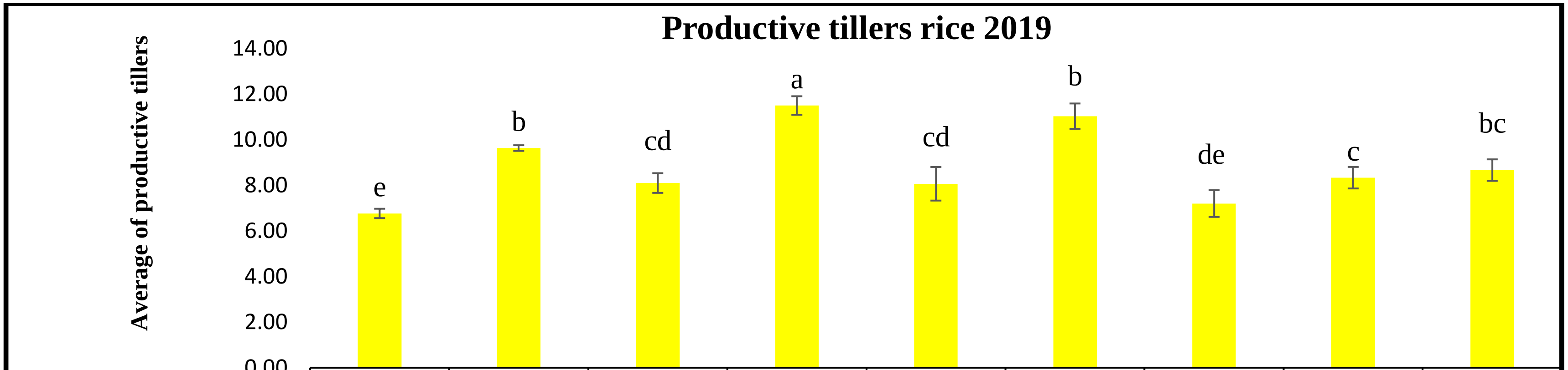
	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 20 DAT	5.20	6.60	5.20	7.00	4.47	7.40	4.73	5.67	6.37
Avg. of 40 DAT	6.53	8.30	4.67	9.37	5.27	8.73	4.50	7.33	7.77
Avg. of 60 DAT	8.20	10.70	10.27	13.33	10.23	12.97	9.47	10.13	10.30

Treatments



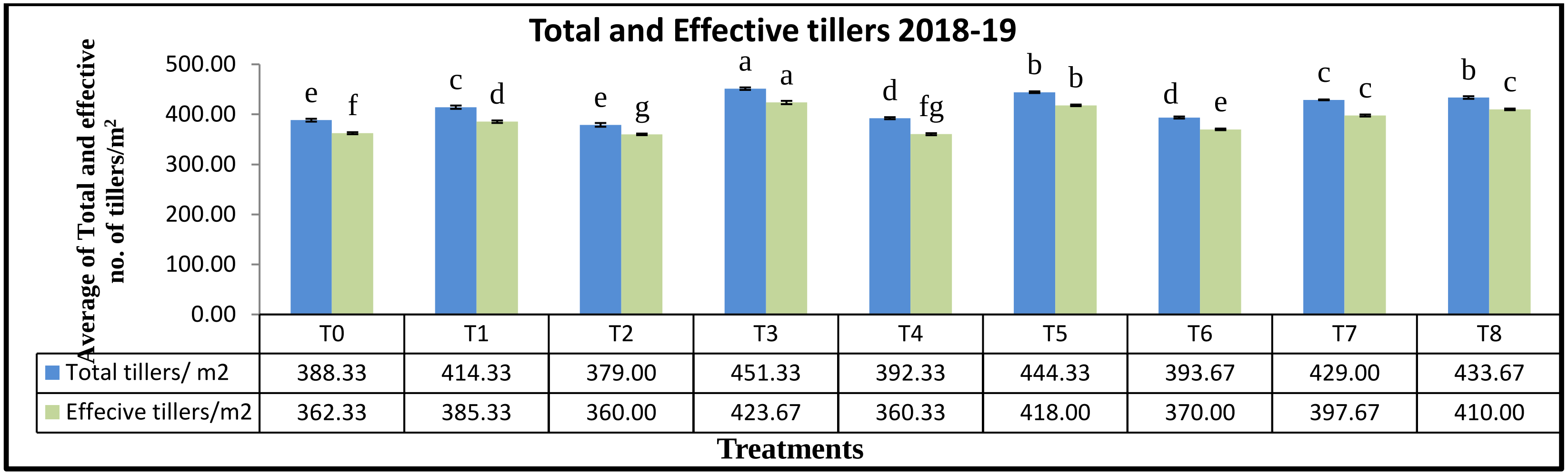
	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 80 DAT	6.93	9.60	7.70	11.97	7.87	10.53	7.73	8.43	9.03

4.1.1. C, D

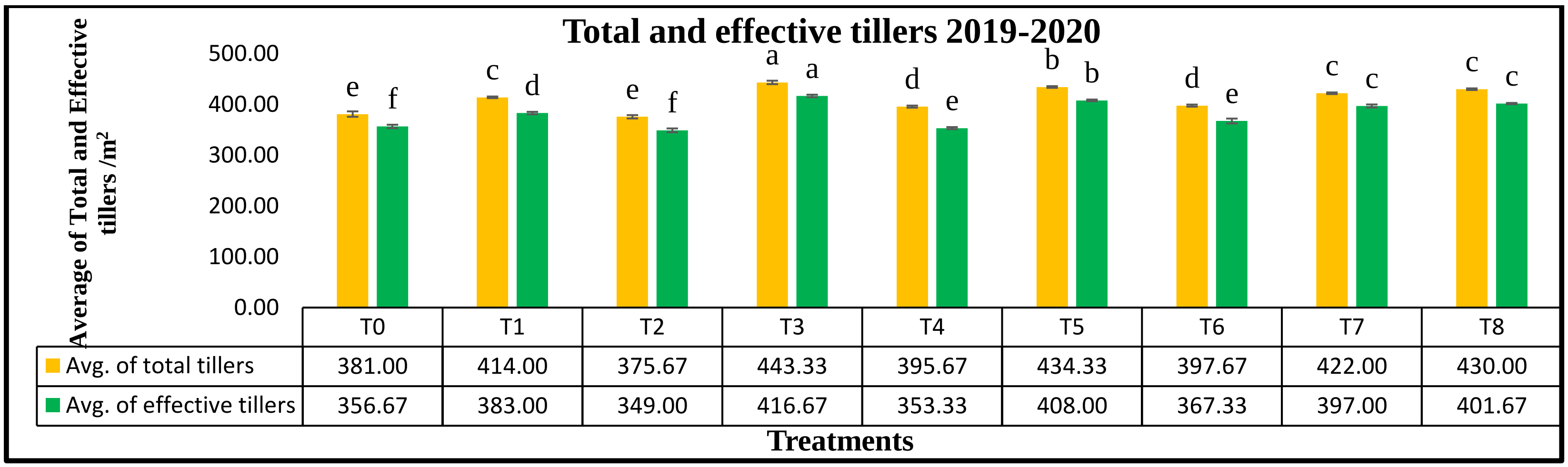


	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of Productive tillers	6.77	9.63	8.10	11.50	8.07	11.03	7.20	8.33	8.67

4.1.1.2 E, F



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Total tillers/ m2	388.33	414.33	379.00	451.33	392.33	444.33	393.67	429.00	433.67
Effecive tillers/m2	362.33	385.33	360.00	423.67	360.33	418.00	370.00	397.67	410.00



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of total tillers	381.00	414.00	375.67	443.33	395.67	434.33	397.67	422.00	430.00
Avg. of effective tillers	356.67	383.00	349.00	416.67	353.33	408.00	367.33	397.00	401.67

Fig. 4.1.1.2A&B ,C&D, E,F representing total and effective tillers in rice and wheat crop during 2018-2019&2019-2020. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at p<0.05

Table 4.1.1.2(a) Effect of modified fertilizers on number of tillers and effective tillers (mean± S.E) of rice crop at different intervals during 2018-2019

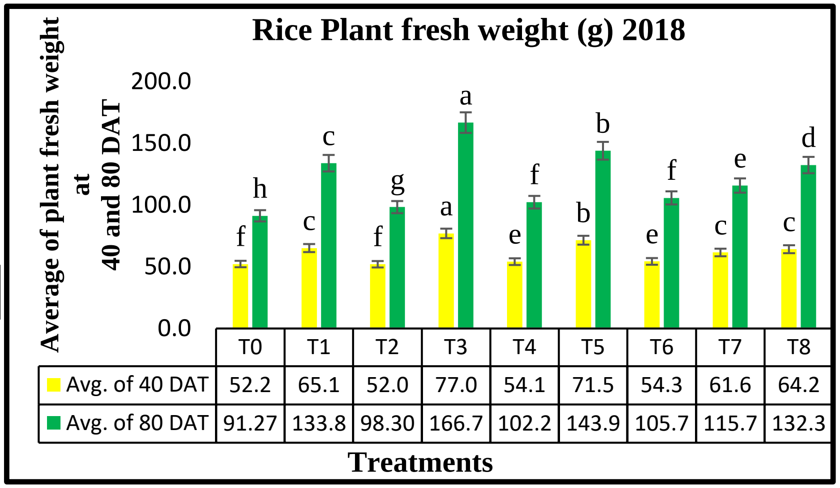
Treatments	2018				2019			
	20 DAT	**40 DAT**	**60 DAT**	**Productive tillers**	**20 DAT**	**40 DAT**	**60 DAT**	**Productive tillers**
T0- Control (RDF)	5.17±0.12d	6.80±0.16e	7.98 ±0.57d	6.93 ±0.41e	5.20±0.33de	6.53±0.05d	8.20±0.24d	6.77±0.21e
T1- Neem coated urea + PK recommended	6.30±0.22b	8.73±0.25c	12.23±0.33b	9.60±0.28bc	6.60±0.36c	8.30±0.37bc	10.70±0.37b	9.63±0.12b
T2- Anhydrous ammonia + PK recommended	5.47±0.12bc	7.37±0.17cd	9.93±0.34c	7.70±0.86de	5.20±0.33de	4.67±0.41e	10.27±0.68bc	8.10±0.43cd
T3- Neem coated urea + PK+S+ Zn-EDTA	7.63±0.31a	11.53±0.82a	13.87±1.25a	11.97±0.45a	7.00±0.49ab	9.37±0.94a	13.33±0.60a	11.50±0.41a
T4- Anhydrous ammonia + PK+ S+ Zn-EDTA	5.47±0.25bc	7.63±0.12d	10.07±0.34c	7.87±0.93de	4.47±0.19e	5.27±0.57e	10.23±0.45bc	8.07±0.74cd
T5- Neem coated urea + PK+$ZnSO_4$	7.30±0.08a	10.07±0.12b	12.80±0.75ab	10.53±0.52b	7.40±0.43a	8.73±0.39ab	12.97±0.17a	11.03±0.56b
T6- Anhydrous ammonia + PK+ $ZnSO_4$	5.53±0.25bc	7.67±0.17d	9.97±0.56c	7.73±0.34de	4.73±0.41e	4.50±0.33e	9.47±0.34c	7.20±0.59de
T7- RDF + $ZnSO_4$	5.73±0.21c	7.70±0.22d	10.07±0.41c	8.43±0.39cd	5.67±0.26cd	7.33±0.31cd	10.13±0.17bc	8.33±0.47c
T8- RDF+ S+ Zn-EDTA	6.50±0.22b	7.90±0.29d	10.27±0.77c	9.03±0.82cd	6.37±0.12bc	7.77±0.31bc	10.30±0.70bc	8.67±0.47bc

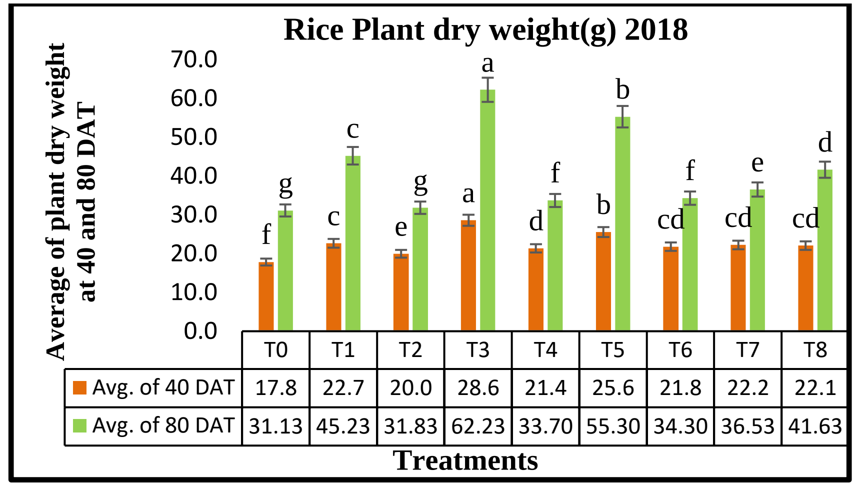
Table 4.1.1.2(b) Effect of modified fertilizers on total tillers and effective tillers (mean± S.E) of wheat crop during 2018 -2019& 2019-2020.

Treatments	2018		2019	
	Total tillers/m^2	**Effective tillers/m^2**	**Total tillers/m^2**	**Effective tillers/m^2**
T0- Control (RDF)	388.33±2.87e	362.33±2.05f	381.00±5.35e	356.67±3.40f
T1 - Neem coated urea + PK recommended	414.33±3.30c	385.33±2.49d	414.00±1.63c	383.00±2.45d
T2 - Anhydrous ammonia + PK recommended	379.00±3.74e	360.00±1.63g	375.67±3.30e	349.00±3.74f
T3 - Neem coated urea + PK + S + Zn-EDTA	451.33±2.49a	423.67±3.30a	443.33±3.40a	416.67±2.49a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	392.33±2.05d	360.33±2.05fg	395.67±2.05d	353.33±2.05e
T5- Neem coated urea + PK + $ZnSO_4$	444.33±1.70b	418.00±1.63b	434.33±1.70b	408.00±1.63b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	393.67±2.05d	370.00±1.63e	397.67±2.05d	367.33±4.78e
T7 - RDF + $ZnSO_4$	429.00±0.82c	397.67±2.05c	422.00±1.63c	397.00±2.94c
T8 – RDF + S+ Zn-EDTA	433.67±2.62b	410.00±1.63c	430.00±1.63c	401.67±1.25c

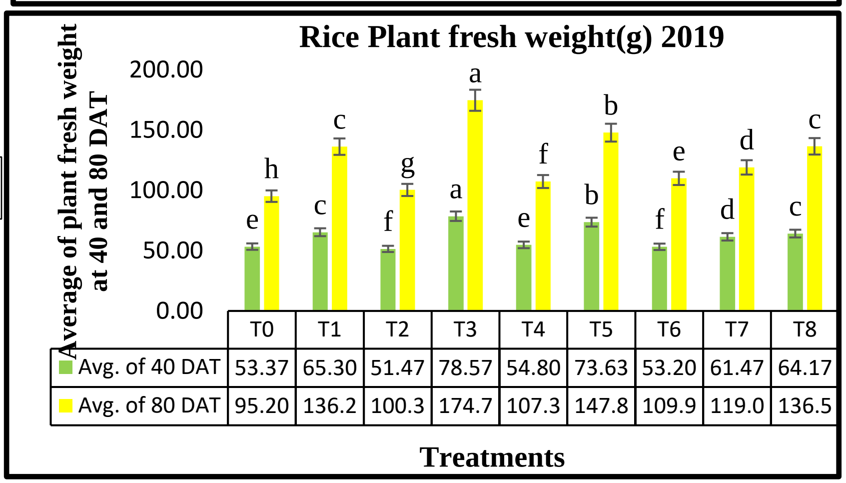
4.1.1.3 Fresh weight and Dry weight of plant (g): - Fresh weight and dry weight of rice crop recorded at 40 and 80 DAT and in wheat at 60 and 75 DAS presented in table 4.1.1.3 (a) and 4.1.1.3 (b). The weight of plants recorded to know the dry matter accumulation which indicates towards the photosynthesis left behind after respiration. So, it is a best indicator of growth of crop. The fresh and dry weight of plant was significantly affected by modified fertilizers during 2018 rice crop, the significantly highest fresh weight at 40 and 80 DAT (77g and 166.3g) due to the neem coated urea + PK + S + Zn-EDTA-T3 which was followed by T5 with 71.5 and 143.93 g weight of plant. The minimum fresh weight (52.0 and 91.27 g) recorded in T2 which was at par with T2 (52.2g) at 40 DAT followed by T2 at 80 DAT with 98.3 g. The maximum dry weight (28.6 and 62.23g) observed in T3 at 40 and 80 DAT. Second highest dry weight (25.6, 55.3g) recorded in T5 followed by T1 with 22.7 and 45.23 g dry weight at 40 and 80 DAT respectively. The minimum dry weight (7.3 g, 31.1 g) recorded under T0. During 2019 rice crop, the same trend was followed in case of fresh and dry weight of crop. The maximum fresh weight (78.8, 74.3 g) recorded in T3 at 40 and 80 DAT which was followed by T5 with 73.63 and 147.87 g. The lowest fresh weight (51.47 g at 40 DAT recorded in T2 and 95.20 g at 80 DAT recorded under T0. In case of dry weight maximum dry weight (29.3, 64.4 g) recorded by application of NCU + PK + S + Zn-EDTA. Second highest dry weight recorded (28.6, 56.6 g) recorded with T5. The lowest dry weight (19.37 g) at 40 DAT recorded under T0 and 31.79 g recorded under T2. Rest of the treatments was influenced by modified fertilizers. The trend of fresh weight and dry weight in case of rice during both years was T3> T5> T1> T8> T7> T6> T4> T2> T0 presented in fig. 4.1.1.3 (a, b) and 4.1.3 (c, d). In following wheat crop of 2018, the fresh weight recorded at 60 and 75 DAS presented in fig. 4.1.3 (e). The maximum fresh weight 33.2 g and 40.9 g recorded due to application of NCU + PK + S + Zn-EDTA (T3) at 60 and 75 DAS which was followed by T5 with 31.77 g and 40.23 g. All the treatments were significantly different from each other. The minimum fresh weight (28.9 g and 33 g) recorded in T2. The maximum dry weight (23.13 g and 28.93 g) recorded in T3 at 60 and 75 DAS which was followed by T5 with 21.23 and 26.93 g respectively at 60 DAS and 75 DAS. The lowest dry weight (15.63, 21.13 g) recorded in T2. During 2019 and 2020 the same trend was followed in maximum fresh and dry weight (35.23, 43.0 g) and (22.13 and 28.7 g) recorded in T3 which was followed by T5 with (32.13, 41.37 g) and (20.53, 27 g) fresh weight and dry weight at 60 and 75 DAS. The lowest fresh weight and dry weight (26.43 g and 32.4 g) (16.13 and 21.1 g) recorded in T2. The data of fresh weight and dry weight represented in fig. 4.1.1.3 (g) and 4.1.1.3 (h). The order of fresh weight and dry weight was T3> T5> T8> T1> T7> T6> T4> T0> T2 respectively.

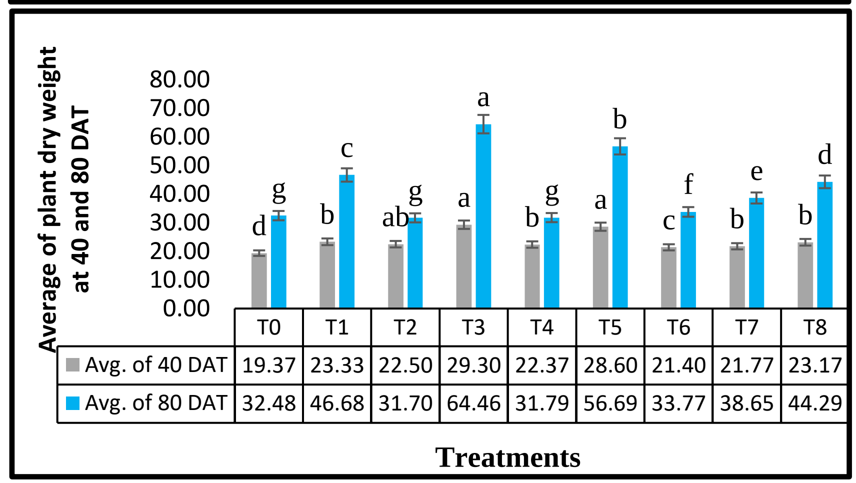
4.1.1.3 A, b



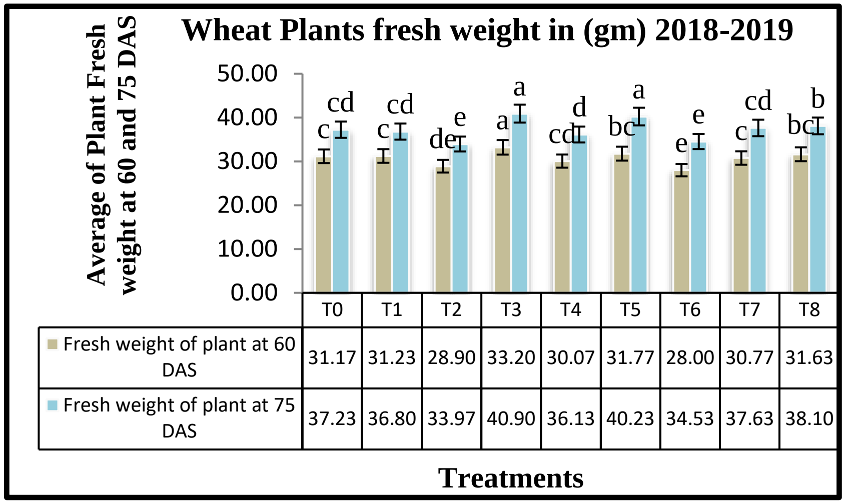


4.1.1.3 C, d

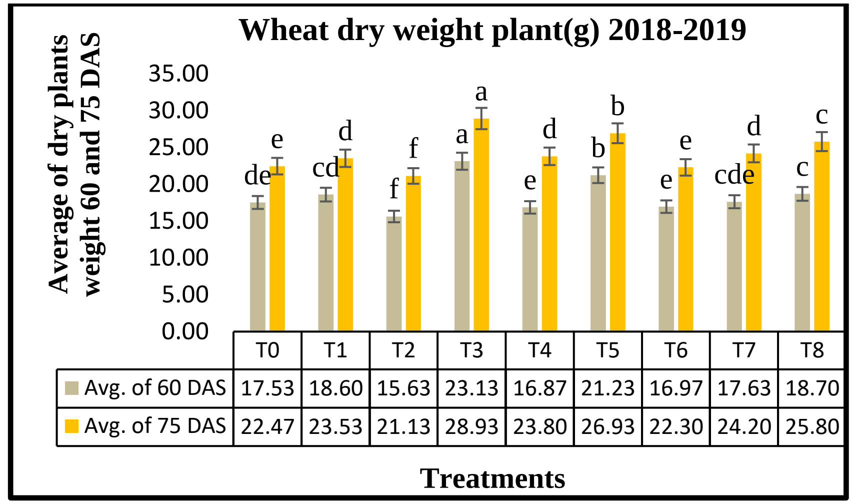




4.1.1.3 e ,f

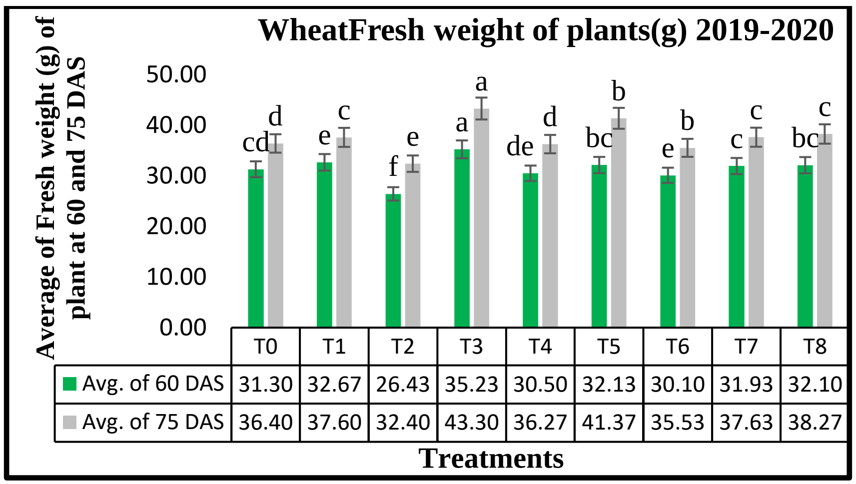


	T0	T1	T2	T3	T4	T5	T6	T7	T8
Fresh weight of plant at 60 DAS	31.17	31.23	28.90	33.20	30.07	31.77	28.00	30.77	31.63
Fresh weight of plant at 75 DAS	37.23	36.80	33.97	40.90	36.13	40.23	34.53	37.63	38.10

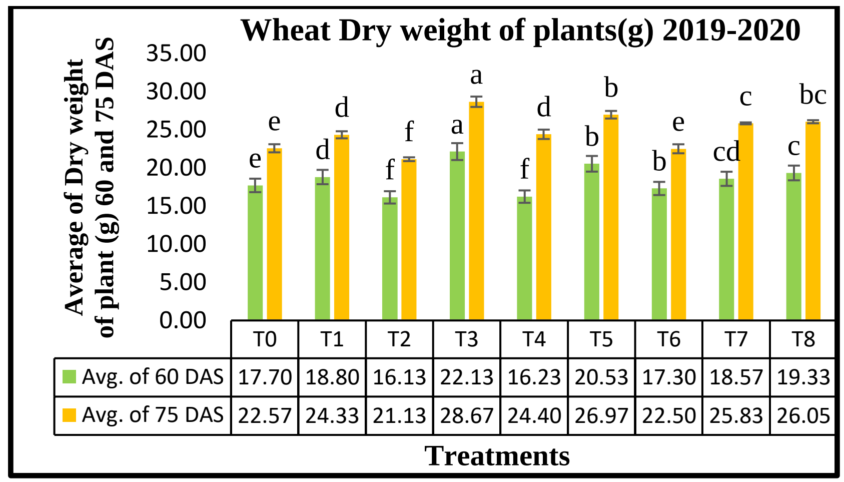


	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	17.53	18.60	15.63	23.13	16.87	21.23	16.97	17.63	18.70
Avg. of 75 DAS	22.47	23.53	21.13	28.93	23.80	26.93	22.30	24.20	25.80

4.1.13 g, h



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	31.30	32.67	26.43	35.23	30.50	32.13	30.10	31.93	32.10
Avg. of 75 DAS	36.40	37.60	32.40	43.30	36.27	41.37	35.53	37.63	38.27



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	17.70	18.80	16.13	22.13	16.23	20.53	17.30	18.57	19.33
Avg. of 75 DAS	22.57	24.33	21.13	28.67	24.40	26.97	22.50	25.83	26.05

Fig.4.1.1.3.3 a,b ,e &f representing the fresh weight(g) at different intervals and Fig. 4.4.3 c, d, g& h representing dry weight (g) of rice and wheat crop .Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

Table 4.1.1.3(a) Effect of different modified fertilizers on fresh and dry weight of rice plants at 40, 80 DAT during 2018-2019.

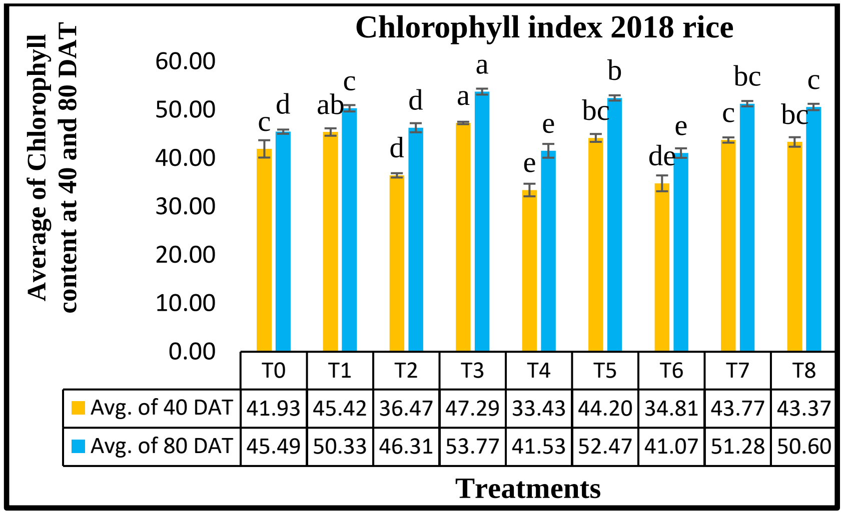
Treatments	2018				2019			
	Fresh weight (g) 40 DAT	Dry weight (g) 40 DAT	Fresh weight (g) 80 DAT	Dry weight (g) 80 DAT	Fresh weight (g) 40 DAT	Dry weight (g) 40 DAT	Fresh weight (g) 80 DAT	Dry weight (g) 80 DAT
T0- Control (RDF)	52.2±0.78f	17.8±0.29f	91.27±0.82h	31.13±0.82g	53.37±0.70e	19.37±0.54d	95.20±0.90h	32.48±0.77g
T1- Neem coated urea + PK recommended	65.1±0.86c	22.7±0.90c	133.87±0.47c	45.23±0.86c	65.30±0.82c	23.33±1.11b	136.27±0.87c	46.68±0.33c
T2-Anhydrous ammonia + PK recommended	52.0±0.60f	20.0±0.29e	98.30±0.78g	31.83±1.16g	51.47±0.93f	22.50±0.57ab	100.37±0.70g	31.70±0.38g
T3- Neem coated urea + PK+S+ Zn-EDTA	77.0±0.37a	28.6±0.90a	166.73±1.52a	62.23±0.82a	78.57±0.92a	29.30±0.73a	174.73±1.96a	64.46±0.68a
T4-Anhydrous ammonia +PK+ S+ Zn-EDTA	54.1±0.98e	21.4±0.33d	102.27±0.78f	33.70±0.37f	54.80±0.37e	22.37±0.41ab	107.33±1.27f	31.79±0.51g
T5- Neem coated urea + PK+$ZnSO_4$	71.5±0.67b	25.6±0.54b	143.93±1.21b	55.30±0.94b	73.63±0.69b	28.60±0.70a	147.87±1.45b	56.69±0.40b
T6-Anhydrous ammonia +PK+ $ZnSO_4$	54.3±0.66e	21.8±0.22cd	105.77±1.48e	34.30±0.67f	53.20±0.78ef	21.40±0.94c	109.97±1.17e	33.77±0.24f
T7 - RDF + $ZnSO_4$	61.6±0.41d	22.2±0.33cd	115.77±1.80d	36.53±0.69e	61.47±1.24d	21.77±0.45ab	119.07±1.13d	38.65±0.41e
T8 -RDF+ S+ Zn-EDTA	64.2±0.82c	22.1±0.17cd	132.37±0.83c	41.63±1.14d	64.17±0.82c	23.17±0.29b	136.53±1.10c	44.29±0.48d

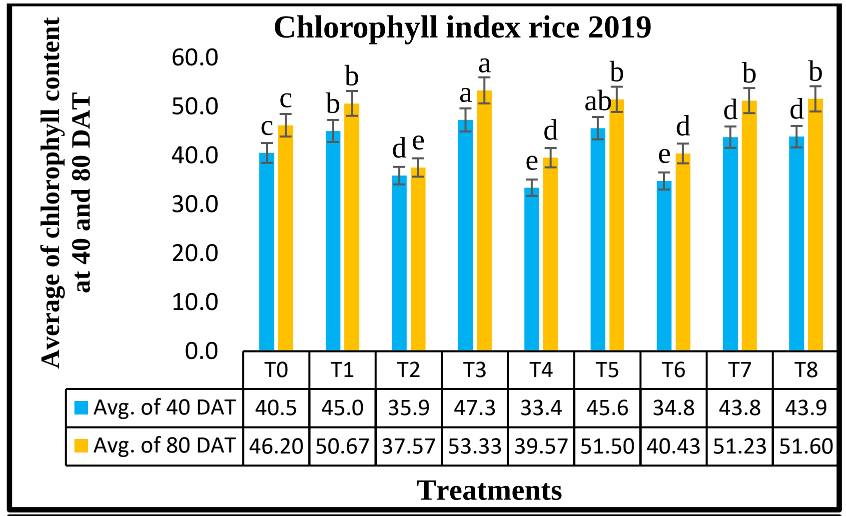
Table 4.1.1.3 (b) Effect of different modified fertilizers on fresh and dry weight of plants at 60, 75 DAS in wheat crop during 2018-2019& 2019-2020

Treatments	2018				2019			
	Fresh weight (g) 60 DAS	**Dry weight (g) 60 DAS**	**Fresh weight (g) 75 DAS**	**Dry weight (g) 75 DAS**	**Fresh weight (g) 60 DAS**	**Dry weight (g) 60 DAS**	**Fresh weight (g) 75 DAS**	**Dry weight (g) 75DAS**
T0- Control (RDF)	31.17±0.48c	17.53±0.22de	36.73±0.39cd	22.47±0.53e	31.30±0.37cd	17.70±0.22e	36.40±0.43d	22.6±0.53e
T1 - Neem coated urea + PK recommended	31.23±0.94c	18.60±0.22cd	36.80±0.50cd	23.53±0.46d	32.67±0.33e	18.80±0.22d	37.60±0.37c	24.3±0.46d
T2-Anhydrous ammonia + PK recommended	28.90±0.45de	15.63±0.34f	33.97±0.56e	21.13±0.25f	26.43±0.68f	16.13±0.34f	32.40±0.57e	21.1±0.25f
T3 - Neem coated urea + PK + S+ Zn-EDTA	33.20±0.70a	23.13±0.26a	40.90±0.57a	28.93±0.68a	35.23±0.53a	22.13±0.26a	43.30±0.37a	28.7±0.68a
T4-Anhydrous ammonia + PK+ S+ Zn-EDTA	30.07±1.33cd	16.87±0.29e	36.13±0.25d	23.80±0.62d	30.50±0.73de	16.23±0.29f	36.27±0.79d	24.4±0.62d
T5- Neem coated urea + PK + $ZnSO_4$	31.77±1.11bc	21.23±0.21b	40.23±0.74a	26.93±0.5b	32.13±0.29bc	20.53±0.21b	41.37±0.17b	27.0±0.50b
T6-Anahydrous ammonia+PK + $ZnSO_4$	28.00±0.43e	16.97±0.37e	34.53±0.42e	22.30±0.59e	30.10±0.37e	17.30±0.37e	35.53±0.68b	22.5±0.59e
T7 - RDF + $ZnSO_4$	30.77±0.33bc	17.63±0.33cde	37.63±0.37cd	24.20±0.12d	31.93±0.54bc	18.57±0.33cd	37.63±0.45c	25.8±0.12c
T8 - RDF+ S+ Zn-EDTA	31.63±0.41bc	18.70±0.34c	38.10±0.24b	25.80±0.2c	32.10±0.29bc	19.33±0.34c	38.27±0.49c	26.0±0.20bc

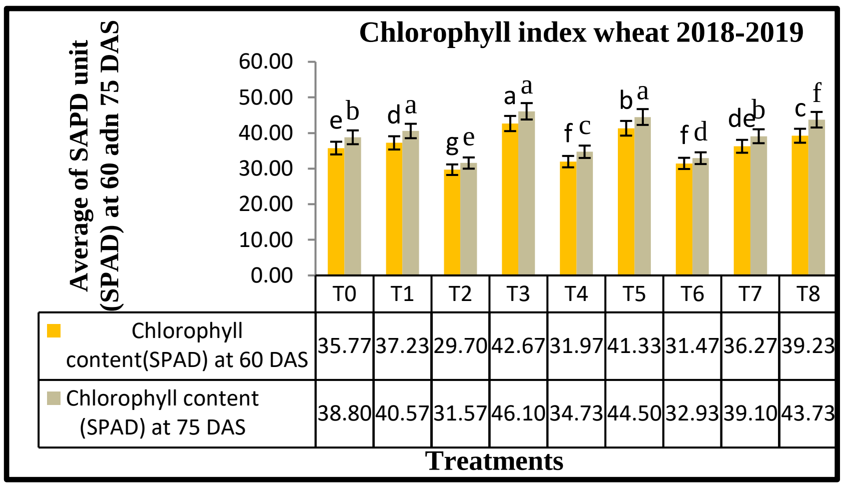
4.1.1.4 Chlorophyll index (SPAD): - Data of table 4.1.14(a, b) showed the effect of different treatments on the chlorophyll index (SPAD) of rice and wheat crop at various growth periods. The result revealed that the chlorophyll index of rice and wheat increased significantly and consistently with the modified fertilizers during 2018-19. In rice crop chlorophyll content recorded at 40 DAT and 80 DAT but in wheat crop it was recorded at 60 and 75 DAS. During 2018 rice crop, the chlorophyll index ranged from 33.4 to 53.77 SPAD. The maximum chlorophyll content (47.3, 53.77 SPAD) found under T3 which was followed by T5 with (44.2, 52.47) at 40 and 80 DAT. The lowest chlorophyll content (33.4, 41.53 SPAD) recorded under T4 during both intervals. The data was presented in fig. 4.1.1.4 (a). During 2019 rice crop, all the treatments were significantly different from each other. The significantly highest chlorophyll content (47.3, 53.33 SPAD) recorded in T3 which was followed by T5 (45.6, 51.5 SPAD) chlorophyll content recorded at 40 DAT (33.4 SPAD) under T4 and at 80 DAT under T2 with 37.57 SPAD content. The order of chlorophyll index in rice was T3>T5>T1>T8>T7>T0>T6>T4>T2.The data presented in fig. 4.1.1.4 (b).The data of chlorophyll content of wheat 2019-2020 presented in fig. 4.1.1.4 (c,d). In 2018-2019 and 2019-2020 wheat crop at 60 DAS, the application of NCU + PK + S + Zn-EDTA – T3 recorded highest chlorophyll index (42.67, 43.75) which was significantly better than all other treatments. At 75 DAS also T3 recorded highest chlorophyll index (46.10, 47.23). The treatment T3 was followed by T5, T1, T8 and T7. The minimum chlorophyll index at 60 DAS (29.7, 30.83) and at 75 DAS (31.57, 35.20) recorded in T2. All the data presented in table 4.1.1.4(b) .The order of chlorophyll index in wheat crop at both intervals during both years was T3>T5>T1>T8>T7>T0>T6>T4>T2.

4.1.1.4 a,b





4.1.1.4 C, d



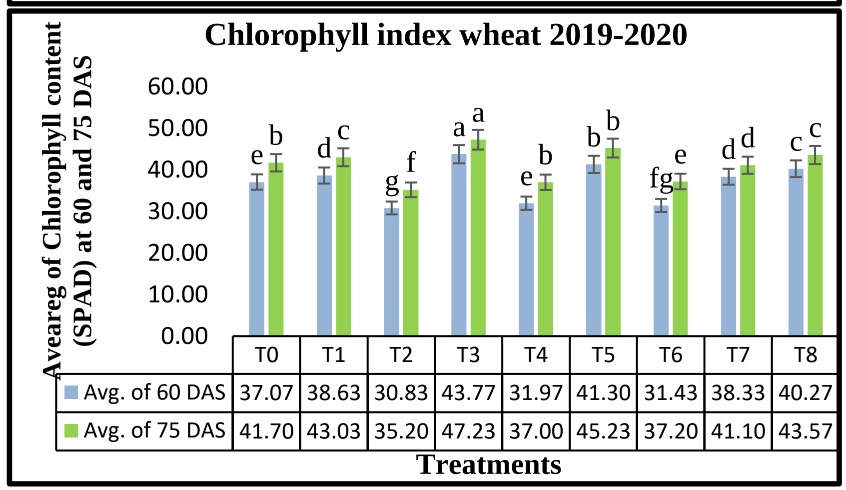


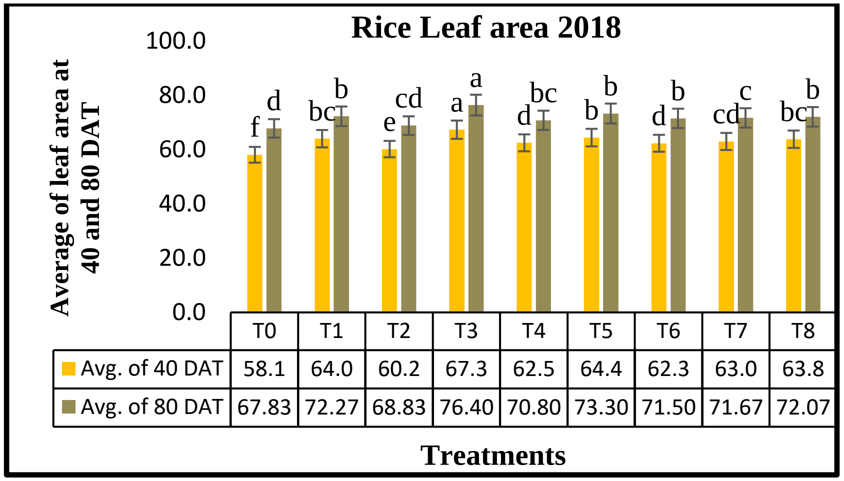
Fig. 4.1.1.4 A&B, C&D representing the chlorophyll index (SPAD) at different intervals in rice and wheat crop during both years.

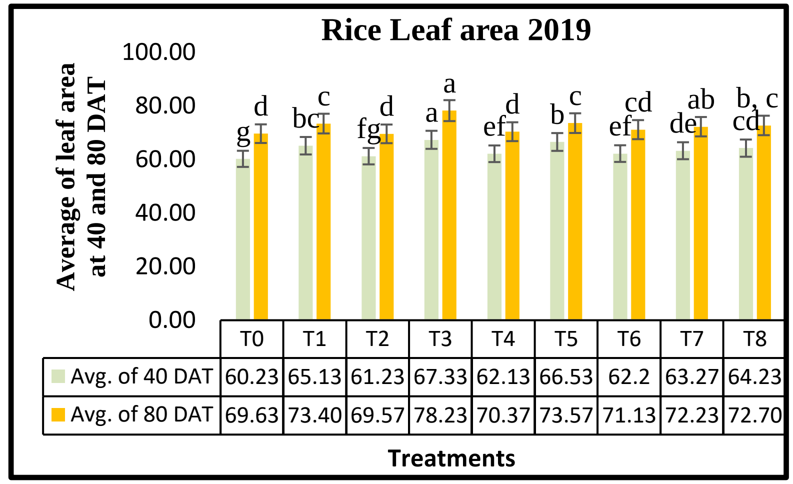
Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

4.1.1.5 Leaf area cm^{-2}: - Leaf area represented the photosynthetic efficiency of crop. It was measured at two intervals in both crops to calculate CGR, RGR and NAR. The leaf area was also influenced by the various combinations of modified fertilizers. In rice crop, leaf area was measured at 40 and 80 DAT. During 2018 rice crop, all the treatments statistically different from each other. Significantly highest leaf area (67.3, 76.4 cm^{-2}) recorded due to the application of NCU + PK + S + Zn-EDTA (T3) which was followed by T5 (NCU + PK + $ZnSO_4$) with 64.4, 73.3 cm^{-2} leaf area at 40 and 80 DAT. The data presented in fig. 4.1.1.4 (a). The similar trend in case of leaf area followed during 2019 rice, maximum leaf area during both intervals (67.33, 78.23 cm^{-2}) recorded in T3, followed by T5 with 66.53, 73.57 cm^{-2}. The minimum leaf area (60.23, 69.63 cm^{-2}) recorded under T0. The trend of leaf area in rice crop was T3> T5> T8> T1> T7> T6> T4> T0> T2 as presented in fig. 4.1.1.4 (a, b). In case of wheat crop the leaf area recorded at 60 and 75 DAS was significantly influenced by the combinations of fertilizers. During 2018-2019, application of NCU + PK + S + Zn-EDTA-T3 recorded highest leaf area (62.4, 71.23 cm^{-2}) at 60 and 75 DAS. The treatment T3 was immediately followed by T5 with leaf area (57.1, 68.27 cm^{-2}). The minimum leaf area (41.2, 51.67) recorded under T2 which was followed by T0 with 42.2 and 51.73 cm^{-2} leaf areas at 60 and 75 DAS. The data of wheat leaf area 2018-2019 presented in fig. 4.1.1. (c). During 2019-2020, the similar trend was followed with slight variation in data. Maximum leaf area (61.87, 72.83 cm^{-2}) recorded under T3 at 60 and 75 DAS. The second highest leaf area 58.37, 70.20 cm^{-2} recorded with the application of AA + PK. The trend of leaf area in both crops were T3> T5> T8> T1> T7> T6> T4> T0> T2 as presented in fig. 4.1.1.4 (d).

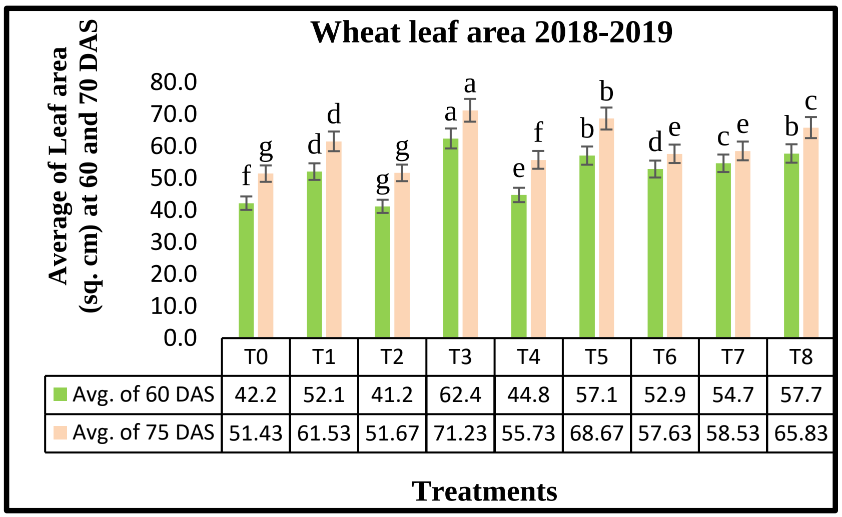
4.1.1.6 Flag leaf length (cm) in wheat: - Flag leaf is the longest leaf of the plant. Most commonly, we measure flag leaf length in case of wheat crop. Flag leaf length measured in cm at 60 and 75 DAS presented in fig 4.1.1.6 (a) and 4.1.1.6 (b). The longest flag leaf length (35.43, 41.2 cm) at 60 and 75 DAS during 2018-2019 recorded under T3 which was followed by T5 with 34.27, 40.20 cm at 60 and 75 DAS. The least flag leaf length 29.23, 32.9 cm recorded under T0. During 2019-2020, the maximum flag leaf length 35.07, 41.33 cm recorded under T3 which was immediately followed by T5 with 33.98 and 38.4 cm flag leaf length at 60 and 75 DAS. The Minimum flag leaf length (cm) 28.20 And 32.37 cm recorded under T0 at 60 and 75 DAS. . The trend of flag leaf length was T3> T5> T8> T1> T7> T6> T4>T2>T0.

4.1.1.5 A, b





4.1.15 c, d



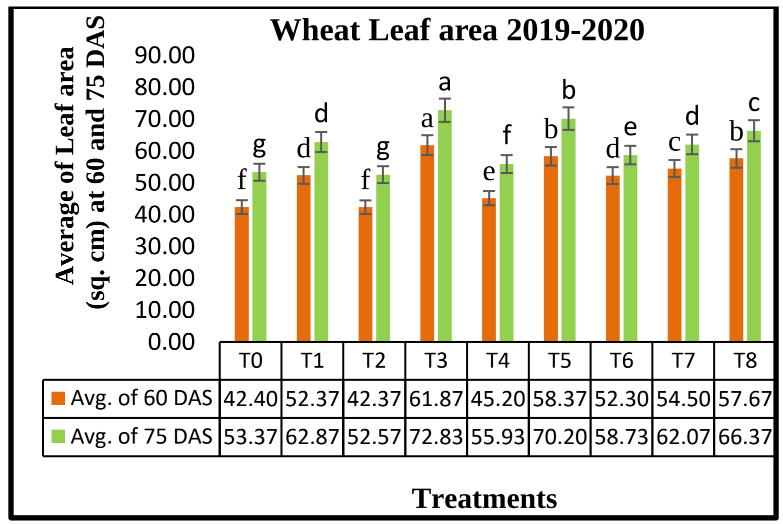
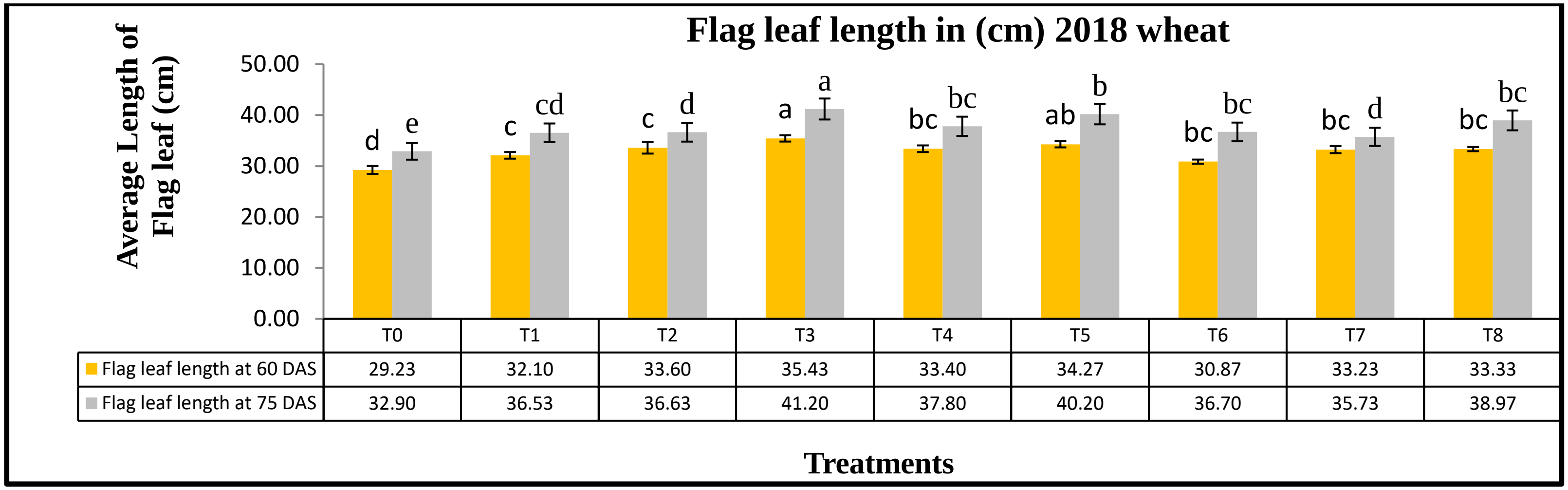


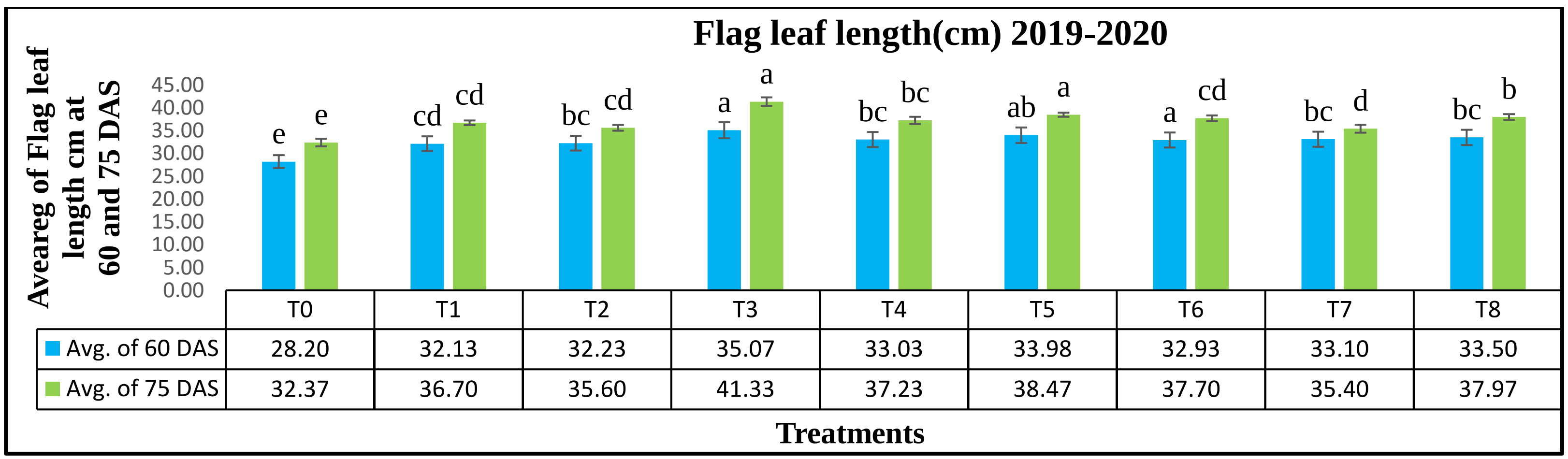
Fig. 4.1.15 6 a& b, c& d representing leaf area at different intervals in rice and wheat crop. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at p<0.05.

A



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Flag leaf length at 60 DAS	29.23	32.10	33.60	35.43	33.40	34.27	30.87	33.23	33.33
Flag leaf length at 75 DAS	32.90	36.53	36.63	41.20	37.80	40.20	36.70	35.73	38.97

B



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	28.20	32.13	32.23	35.07	33.03	33.98	32.93	33.10	33.50
Avg. of 75 DAS	32.37	36.70	35.60	41.33	37.23	38.47	37.70	35.40	37.97

Fig. 4.1.1.6 A&B, representing Flag leaf length(cm) at different intervals wheat crop .Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at p<0.05.

Table 4.1.1.4. (a) Effect of modified fertilizers on chlorophyll index (SPAD) and leaf area (cm^2) of rice crop at 40, 80 DAT during 2018-2019

Treatments	2018				2019			
	Chlorophyll content (SPAD) 40 DAT	**Chlorophyll content (SPAD) 80 DAT**	**Leaf area (cm^2) at 40 DAT**	**Leaf area (cm^2) at 80 DAT**	**Chlorophyll content (SPAD) 40 DAT**	**Chlorophyll content (SPAD) 80 DAT**	**Leaf area (cm^2) at 40 DAT**	**Leaf area (cm^2) at 80 DAT**
T0- Control (RDF)	41.9±1.79c	45.49±0.43d	58.10±.33f	67.8±1.46d	40.5±0.5c	46.20±0.70c	60.23±0.82g	69.63±0.93d
T1- Neem coated urea + PK recommended	45.4±0.77ab	50.33±0.66c	64.0±0.2bc	72.3±0.71b	45.0±1.2b	50.67±0.41b	65.13±0.39bc	73.40±0.59c
T2-Anhydrous ammonia + PK recommended	36.5±0.45d	46.31±0.94d	60.2±0.37e	68.8±0.46cd	35.9±1.2d	37.57±1.10e	61.23±0.94fg	69.57±1.00d
T3- Neem coated urea+ PK+S+ Zn-EDTA	47.3±0.25a	53.77±0.62a	67.3±0.69a	76.4±2.53a	47.3±0.2a	53.33±0.76a	67.33±0.78a	78.23±0.79a
T - Anhydrous ammonia + PK+ S+ Zn-EDTA	33.4±1.30e	41.53±1.43e	62.5±0.57d	70.8±0.57bc	33.4±1.3e	39.57±0.86d	62.13±0.59ef	70.37±0.79d
T5- Neem coated urea + PK+$ZnSO_4$	44.2±0.82bc	52.47±0.54ab	64.4±0.63b	73.3±0.70b	45.6±0.5ab	51.50±0.83b	66.53±0.53ab	73.57±1.23c
T6- Anhydrous ammonia + PK+ $ZnSO_4$	34.8±1.64de	41.07±0.98e	62.3±0.87d	71.5±0.36b	34.8±1.6de	40.43±0.58d	62.2±0.24ef	71.13±0.25cd
T7- RDF + $ZnSO_4$	43.8±0.54bc	51.28±0.55bc	63.0±0.16cd	71.7±0.34b	43.8±0.5d	51.23±0.86b	63.27±0.98de	72.23±0.82ab
T8- RDF+ S+ Zn-EDTA	43.4±0.98bc	50.60±0.65c	63.8±0.25bc	72.1±0.54b	43.9±0.4d	51.60±0.75b	64.23±0.71cd	72.70±0.37bc

Table 4.1.1.4(b) Effect of modified fertilizers on chlorophyll index (SPAD) and leaf area(cm^2) of wheat crop at 60,75 DAS during 2018-2019& 2019-2020.

Treatments	2018				2019			
	Chlorophyll index (SPAD) 60 DAS	**Chlorophyll index (SPAD) 75 DAS**	**Leaf area (cm^2) at 60 DAS**	**Leaf area (cm^2) at 75 DAS**	**Chlorophyll index (SPAD) 60 DAS**	**Chlorophyll index(SPAD) 75 DAS**	**Leaf area (cm^2) at 60 DAS**	**Leaf area (cm^2) at 75DAS**
T0- Control (RDF)	35.77±0.29e	38.80±0.49b	42.2±0.24f	51.43±0.63g	37.07±0.25e	41.70±0.37b	42.40±0.45f	53.37±0.79g
T1 - Neem coated urea +PK recommended	37.23±0.69d	40.57±0.56a	52.1±0.60d	61.53±0.76d	38.63±0.39d	43.03±0.62c	52.37±0.98d	62.87±0.29d
T2 - Anhydrous ammonia+ PK recommended	29.70±0.80g	31.57±0.39e	41.2±0.29g	51.67±0.34g	30.83±0.29g	35.20±0.57f	42.37±0.42f	52.57±0.29g
T3 - Neem coated urea+ PK+S+ Zn-EDTA	42.67±0.31a	46.10±0.24a	62.4±0.58a	71.23±0.76a	43.77±0.57a	47.23±0.29a	61.87±0.49a	72.83±0.33a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	31.97±0.42f	34.73±0.29c	44.8±0.45e	55.73±0.41f	31.97±0.42e	37.00±0.37e	45.20±0.82e	55.93±0.21f
T5- Neem coated urea + PK + $ZnSO_4$	41.33±0.65b	44.50±0.65a	57.1±0.66b	68.67±0.41b	41.30±0.37b	45.23±0.48b	58.37±0.33b	70.20±0.78b
T6- Anhydrous ammonia + PK + $ZnSO_4$	31.47±0.58f	32.93±0.26d	52.9±0.25d	57.63±0.48e	31.43±0.33fg	37.20±0.67e	52.30±0.24d	58.73±0.62e
T7 - RDF + $ZnSO_4$	36.27±0.63de	39.10±0.67b	54.7±0.34c	58.53±0.82e	38.33±0.56d	41.10±0.78d	54.50±0.57c	62.07±1.44d
T8 - RDF+ S+ Zn-EDTA	39.23±0.31c	43.73±0.29f	57.7±0.41b	65.83±0.46c	40.27±0.39c	43.57±0.42c	57.67±0.76b	66.37±0.94c

4.1.1.7 Crop growth rate (CGR), Relative growth rate (RGR), Net assimilation rate (NAR):- CGR was significantly affected by the response of modified fertilizers in case of both rice and wheat crop presented in table 4.1.1.7 (a) and 4.1.1.7 (b). In rice crop of 2018, 2019 the maximum CGR (0.84, 0.88 gcm^{-2}) recorded in T3 which was immediately followed by T5 with (0.74, 0.70 g g^{-1} cm^{-2}) during 2018 and 2019 respectively. The minimum CGR (0.30, 0.23 g g^{-1} cm^{-2}) recorded under T2. All the other treatments were significantly different from each other in case of CGR in rice crop. In wheat crop of 2018-2019, 2019-2020 the maximum CGR (0.474, 0.436) recorded with the application of NCU + PK + S + Zn-EDTA-T3 which was at par with T5 with CGR 0.462, 0.429 g cm^{-2}. These treatments were immediately followed by T8 with 0.42 g^{-1} cm^{-2}. The lowest CGR (0.329 g cm^{-2}) recorded under T2 during 2018-2019 and (0.324) recorded under T0 during 2019-2020 which was at par with T2 with 0.333 g cm^{-2} CGR.RGR was significantly affected by the modified fertilizers. RGR in case of rice crop during 2018 ranged from 0.0049 to 0.0084 g^{-1} cm^{-2}. The RGR recorded maximum (0.0084, 0.0090 g^{-1} cm^{-2}) under T3 which was at par by T5 with (0.0084, 0.007 g^{-1} cm^{-2}) during 2018-2019. The minimum CGR (0.0049, 0.0040) recorded under T4. In case of wheat crop during 2018-2019 and 2019-2020 highest RGR (0.096, 0.0958 g cm^{-2}) was recorded with the application of NCU + PK + S + Zn-EDTA-T3 which was immediately followed by T5 with 0.094 and 0.0939 g^{-1} cm^{-2}. The lowest RGR (0.087, 0.0866) was recorded under T2. Net assimilation rate (NAR) in rice crop significantly affected by various fertilizer combinations. In rice crop, highest NAR (0.196) during 2018 recorded under T3 and (0.189) during 2019 under T5. The second highest NAR (0.155) recorded with T5. The lowest NAR (0.063, 0.053) recorded under T2. In case of wheat crop, the highest NAR (0.174) during 2018 recorded under T3 and (0.1220 during 2019-2020 recorded under T7. The minimum NAR (0.056) during 2018 recorded under T2 and 0.051 during 2019-2020 recorded under T0. The data of CGR, RGR, and NAR was presented in fig. 4.1.1.7 (a) and 4.1.1.7 (b).

4.1.1.7a,b

4.1.1.7c, d

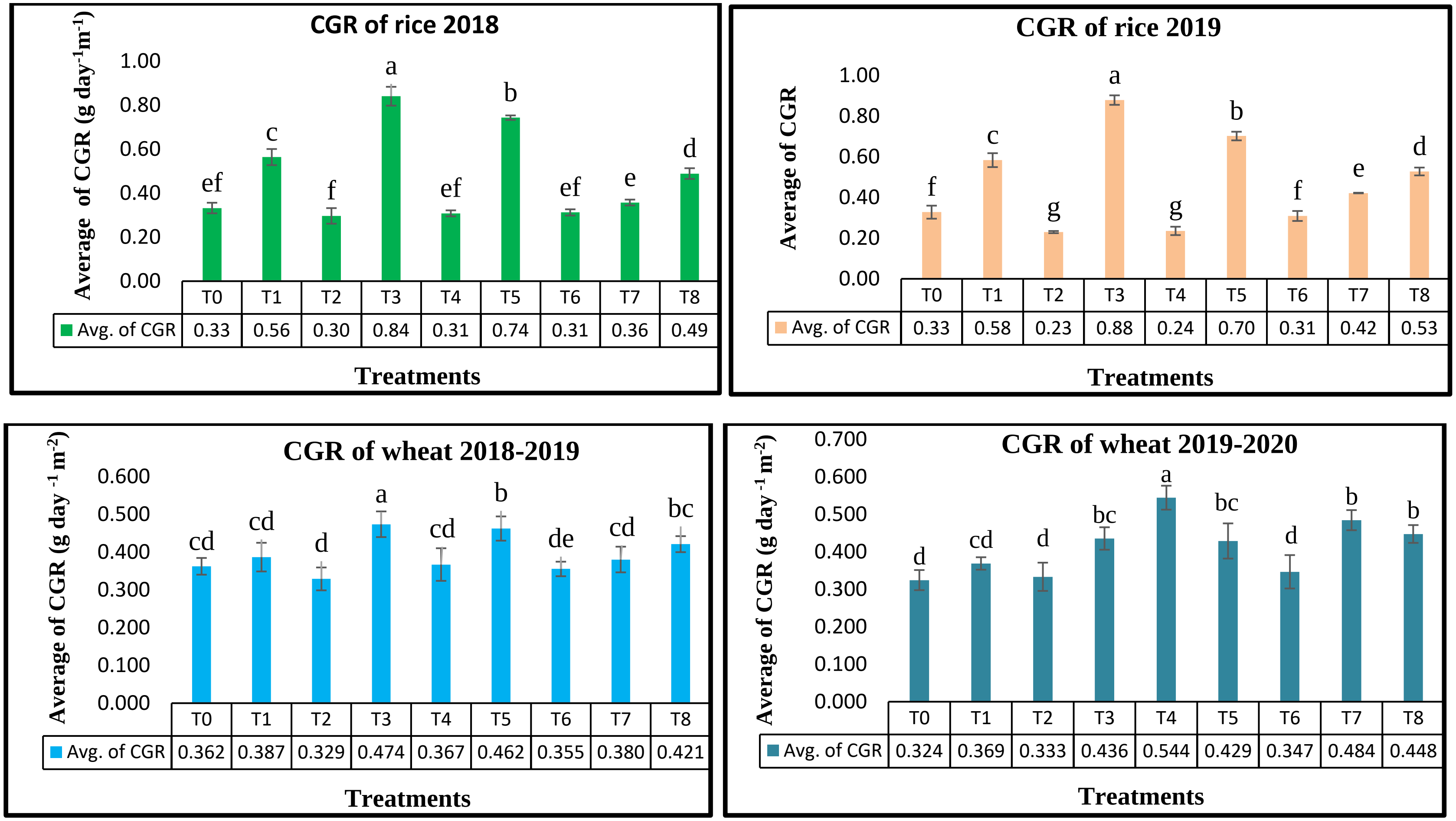


Fig. 4.1.1.7 a, b & c, d representing CGR of rice- wheat crop during 2018-2019, 2019-2020. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at p<0.05.

4.1.1.7 E, F

4.1.1.7 G, h

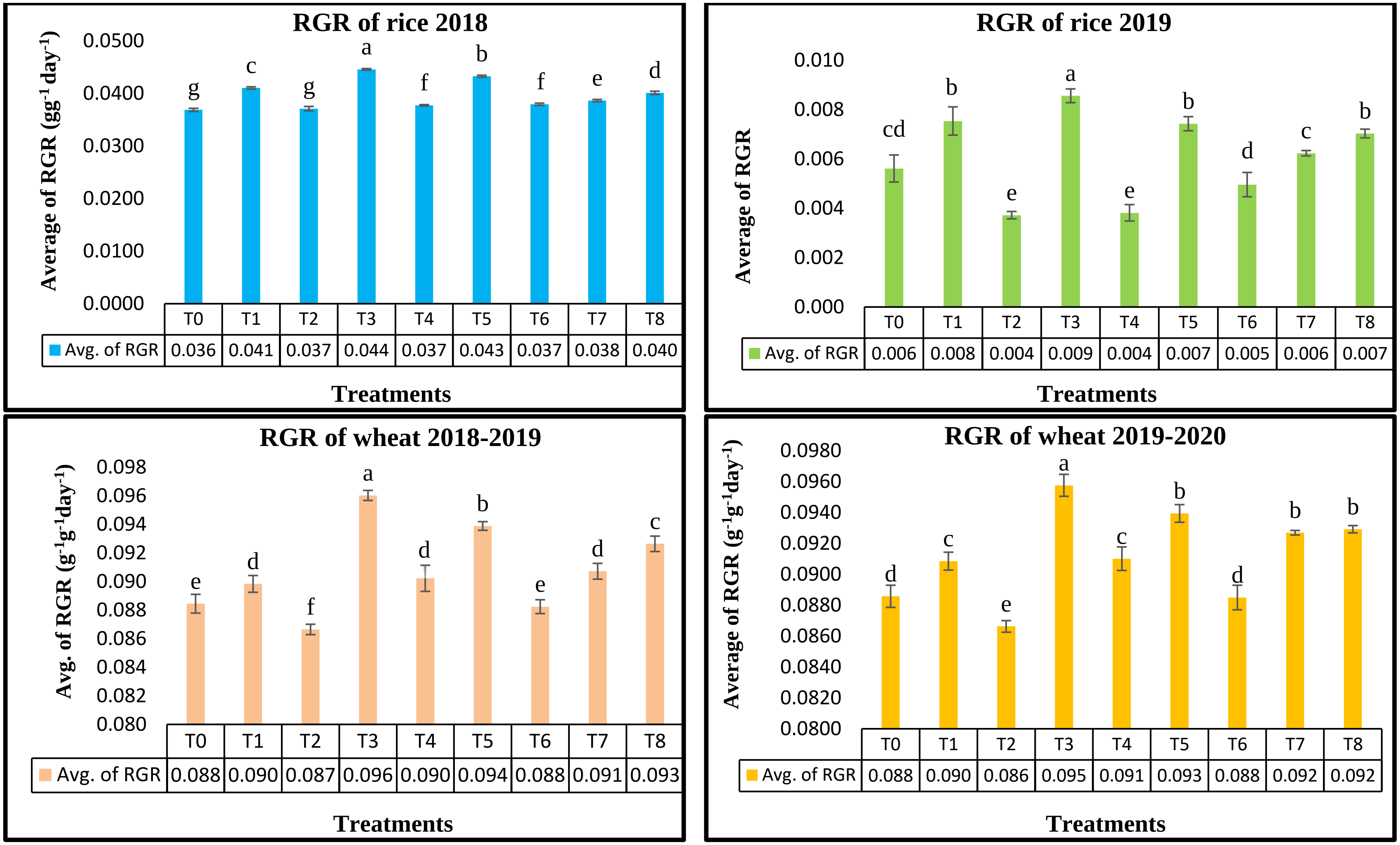


Fig. 4.1.1..7 e, f & g, h representing CGR, RGR, NAR of rice- wheat crop during 2018-2019, 2019-2020. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

4.1.17 I, J

4.1.1.7 K, L

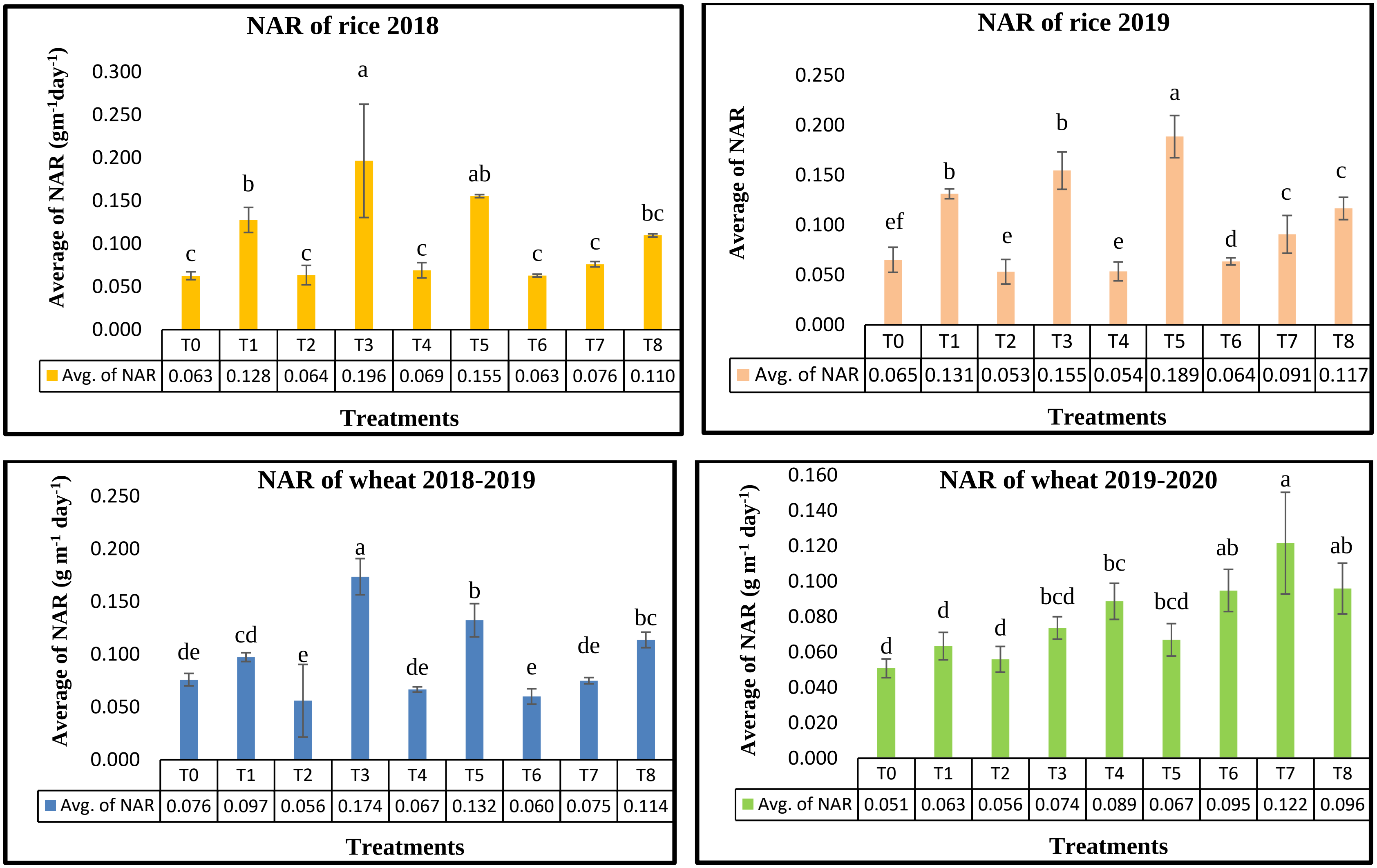


Fig. 4.1.1.7 i, j & k, l representing NAR of rice- wheat crop during 2018-2019, 2019-2020. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

Table 4.1.1.7(a) Effect of modified fertilizers on CGR, RGR & NAR (mean ± S.E) of rice crop during both years of experimentation

Treatments	2018			2019		
	CGR	**RGR**	**NAR**	**CGR**	**RGR**	**NAR**
T0- Control (RDF)	0.33±0.02ef	0.0369±0.00030g	0.063±0.005c	0.33±0.032f	0.006±0.001cd	0.065±0.013ef
T1 - Neem coated urea +PK recommended	0.56±0.04c	0.0411±0.00021c	0.128±0.015b	0.58±0.034c	0.008±0.001b	0.131±0.005b
T2- Anhydrous ammonia+ PK recommended	0.30±0.04f	0.0371±0.00042g	0.064±0.011c	0.23±0.005g	0.004±0.000e	0.053±0.012e
T3- Neem coated urea+ PK+S+ Zn-EDTA	0.84±0.04a	0.0446±0.00015a	0.196±0.066a	0.88±0.023a	0.009±0.000a	0.155±0.019a
T4- Anhydrous ammonia +PK+ S+ Zn-EDTA	0.31±0.01ef	0.0378±0.00013f	0.069±0.009c	0.24±0.021g	0.004±0.000e	0.054±0.009e
T5- Neem coated urea + PK + $ZnSO_4$	0.74±0.01b	0.0433±0.00019b	0.155±0.002ab	0.70±0.021b	0.007±0.000b	0.189±0.021b
T6- Anhydrous ammonia +PK+ $ZnSO_4$	0.31±0.01ef	0.0379±0.00022f	0.063±0.002c	0.31±0.025f	0.005±0.000d	0.064±0.004d
T7 - RDF + $ZnSO_4$	0.36±0.01e	0.0387±0.00021e	0.076±0.003c	0.42±0.001e	0.006±0.000c	0.091±0.019c
T8- RDF+ S+ Zn-EDTA	0.49±0.02d	0.0401±0.00031d	0.110±0.002bc	0.53±0.019d	0.007±0.000b	0.117±0.011b

Table 4.1.1.7(b) Effect of modified fertilizers on CGR, RGR & NAR (mean ± S.E) of wheat crop during both years of experimentation.

Treatments	2018			2019		
	CGR	**RGR**	**NAR**	**CGR**	**RGR**	**NAR**
T0- Control (RDF)	0.362±0.02cd	0.088±0.0007e	0.076±0.006de	0.324±0.027d	0.0886±0.0007d	0.051±0.005d
T1 - Neem coated urea + PK recommended	0.387±0.04cd	0.090±0.0006d	0.097±0.004cd	0.369±0.017cd	0.0909±0.0006c	0.063±0.008cd
T2- Anhydrous ammonia + PK recommended	0.329±0.03d	0.087±0.0004f	0.056±0.034e	0.333±0.038d	0.0866±0.0004e	0.056±0.007d
T3 - Neem coated urea+ PK+S+ Zn-EDTA	0.474±0.03a	0.096±0.0004a	0.174±0.017a	0.436±0.030bc	0.0958±0.0007a	0.074±0.006bcd
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	0.367±0.04cd	0.090±0.0009d	0.067±0.002de	0.544±0.032a	0.0910±0.0008c	0.089±0.010bc
T5- Neem coated urea + PK + $ZnSO_4$	0.462±0.03b	0.094±0.0003b	0.132±0.016b	0.429±0.047bc	0.0939±0.0006b	0.067±0.009bcd
T6- Anhydrous ammonia +PK+ $ZnSO_4$	0.355±0.02de	0.088±0.0005e	0.060±0.007e	0.347±0.045d	0.0885±0.0008d	0.095±0.012ab
T7 - RDF + $ZnSO_4$	0.380±0.03cd	0.091±0.0006d	0.075±0.003de	0.484±0.027ab	0.0927±0.0002b	0.122±0.029a
T8 - RDF+ S+ Zn-EDTA	0.421±0.02bc	0.093±0.0005c	0.114±0.007bc	0.448±0.024b	0.0929±0.0002b	0.096±0.014ab

4.1.2 Yield attributing parameters and yield: - The performance of yield attributing parameters i.e. panicle/spike length, number of filled grains per panicle/spike, test weight grain yield, straw yield and harvest index presented in tables and figures and discussed below:

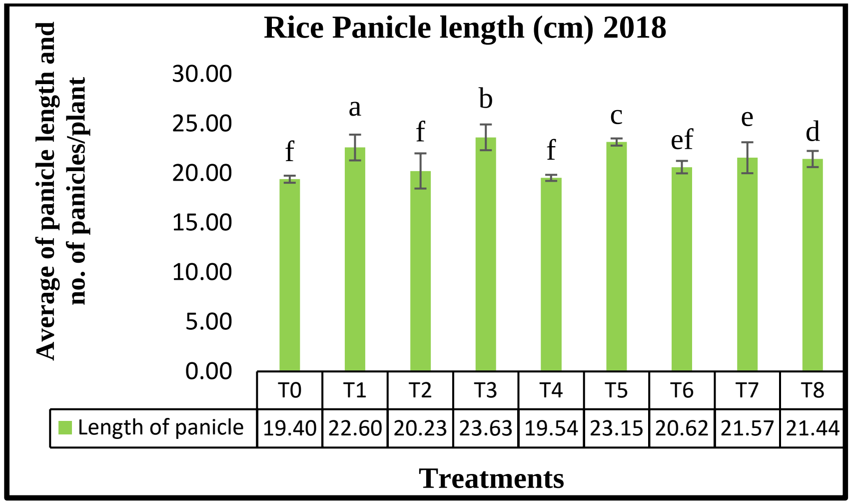
4.1.2.1 Panicle/spike length (cm): - The data on the effect of various combinations of modified fertilizers on panicle length and spike length presented in table 4.1.2.1 (a) and 4.1.2.1 (b). The panicle length in case of rice during 2018 ranged from 19.4-23.63cm. The panicle length in control (T0) was 19.4 cm which increased up to 23.15 to 23.63 cm with the application of NCU + S + $ZnSO_4$- T3 and NCU + PK + S + Zn-EDTA-T5. There was significant difference in panicle length due to NCU, S and Zn. The highest panicle length (23.63, 23.53 cm) during 2018 and 2019 recorded due to application of NCU + PK + S + Zn-EDTA (T3) and it was significantly higher than control. This treatment was immediately followed by T5 with panicle length (23.15, 22.6 cm). The minimum panicle length recorded in T0 (19.4 cm) during 2018. The order of panicle length in rice was T3> T5> T1> T8> T6> T7> T0> T2> T4 during 2018 and (19.2 cm) under T4 during 2019. In case of wheat, the spike length ranged from 7.40 cm to 10.10 cm during 2018-2019 and 7.57 to 10.77 cm during 2019-2020. The highest spike length was recorded 10.10 cm, 10.77 cm in T3 NCU + PK + S + Zn-EDTA followed by 9.93, 10.30 cm in T8 and 9.77, 10.07 cm in T5 during 2018-2019 and 2019-2020. The minimum spike length (7.40, 7.57 cm) recorded in T2 (AA + PK). The order of spike length in wheat was T3> T5> T8> T1> T7> T6> T0> T4> T2. The spike length was presented in fig. 4.1.2.1 (c) and 4.1.2.1 (d).

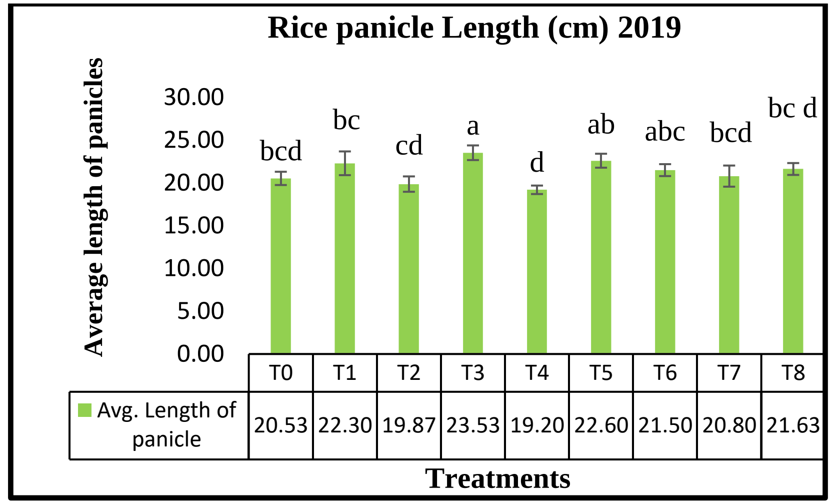
4.1.2.2 Number of grains/panicle or spike: -: The grain is fertilized fully ripened ovule of a spike in a panicle which contributes to yield. In case of rice crop filled and unfilled grains per panicle significantly affected by modified fertilizers. The filled grains and unfilled grains per panicle presented in table 4.1.1.1 (a). The filled grains per panicle ranged from 42.83-63.63 during 2018 and 44.2 to 62.2 during 2019. During 2018, 2019 the maximum filled grains per panicle (63.63, 62.2) recorded in T3 which was at par with T5 with 62.57, 60.60 filled grains per panicle. These treatments were immediately followed by T1 with 61.63 and 54.27 filled grains during panicle (42.83, 44.33) recorded in T0 during both years. In case of unfilled grains per panicle, the maximum (14.27) unfilled grains per panicle recorded in T0 during 2018 and

11.97 in T2 during 2019. The minimum number of unfilled grains per panicle 7.63, 6.93 recorded in T3 which was at par with T5 with 8.03 and 7.57 unfilled grains per panicle during both years. The data of filled and unfilled grains per panicle presented in fig. 4.1.1.2 (a) and 4.1.1.2 (b). In case of wheat, number of grains per spike recorded which was significantly affected by different treatments. The number of grains per spike ranged from 37 to 52 during 2018 and 37 to 51 during 2019. The maximum number of grains per spike (52, 51) recorded in T3 which was followed by T5 with 49, 48 filled grains per spike. The minimum number of grains 37 during 2018 recorded in T2 and 37 during 2019-2020 recorded in T4. The trend of grains per spike in wheat was T3> T5> T8> T1> T7> T0> T2> T6> T4. The data presented in fig. 4.1.1.2 (c) and 4.1.1.2 (d).

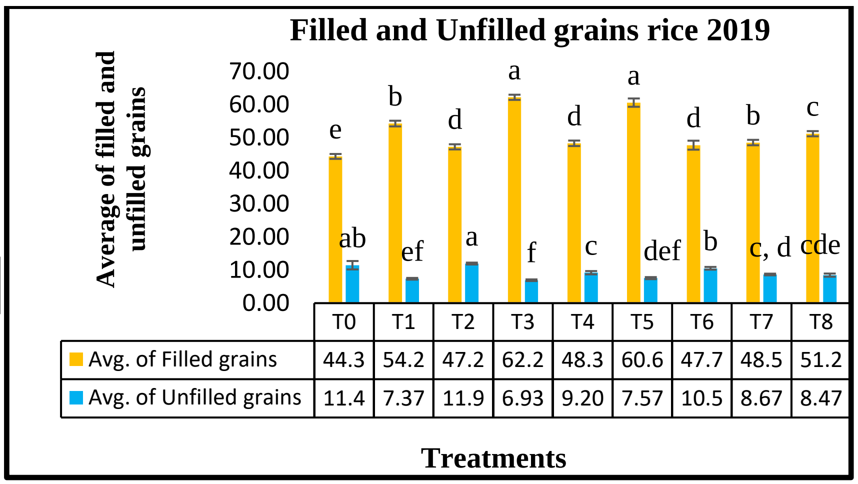
4.1.2.3 1000 grain weight (g): - The thousand grain weight is the weight of 1000 seeds which is an important yield attribute which gave the information regarding the efficiency of grain filling process. 1000 grain weight is the desired output which referred as one of the most important agronomic parameters which contributes in grain yield. Data pertaining to 1000 grain weight is presented in table 4.1.2.3(a) and Fig 4.1.2.3(a). The maximum test weight (21g, 21.03g) recorded with the application of NCU + PK + S + Zn-EDTA-T3 which was at par with T5 with 20.77 and 20.57 g. This treatment was immediately followed by T1 with 20.13 and 19.93 g weight during both years. The minimum test weight (18.97, 19.13 g) recorded in T0 during both years. The test weight order in rice crop was T3> T5> T1> T8> T7> T6> T4> T2> T0. In case of wheat crop during 2018-2019, all the treatments were significantly different from each other. The test weight of wheat ranged from 31.53 - 44.67 g during 2018 - 2019 and 31.90 - 42.67 g during 2019 – 2020. The maximum test weight (44.67, 42.67 g) recorded with the application of NCU + PK + S + Zn- EDTA (T3). These treatments was immediately followed by T5 with 42.7, 41.83.,31.53 g.Lowest testweight (31.53g) recorded in T6 during 2018 – 2019 and (31.90 g) during 2019 – 2020. The order of maximum test weight was T3> T5> T8> T1> T0> T4> T6> T2. The data presented in fig. 4.1.2.3 (b).

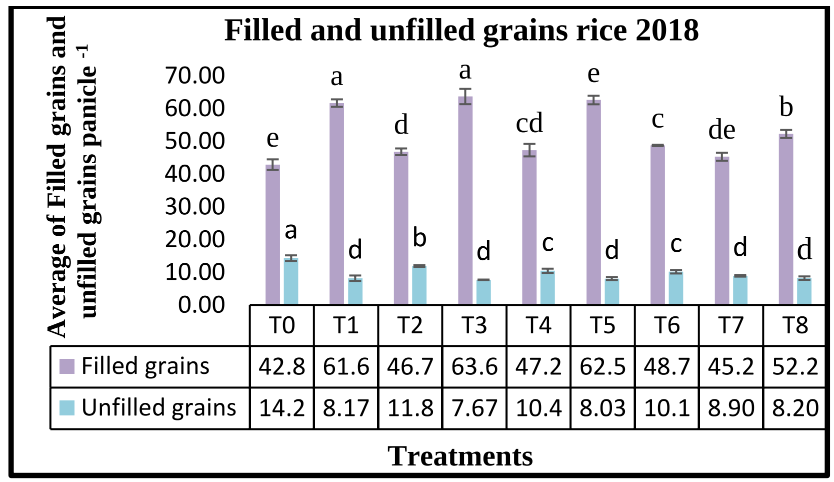
4.1.2.1 a,b



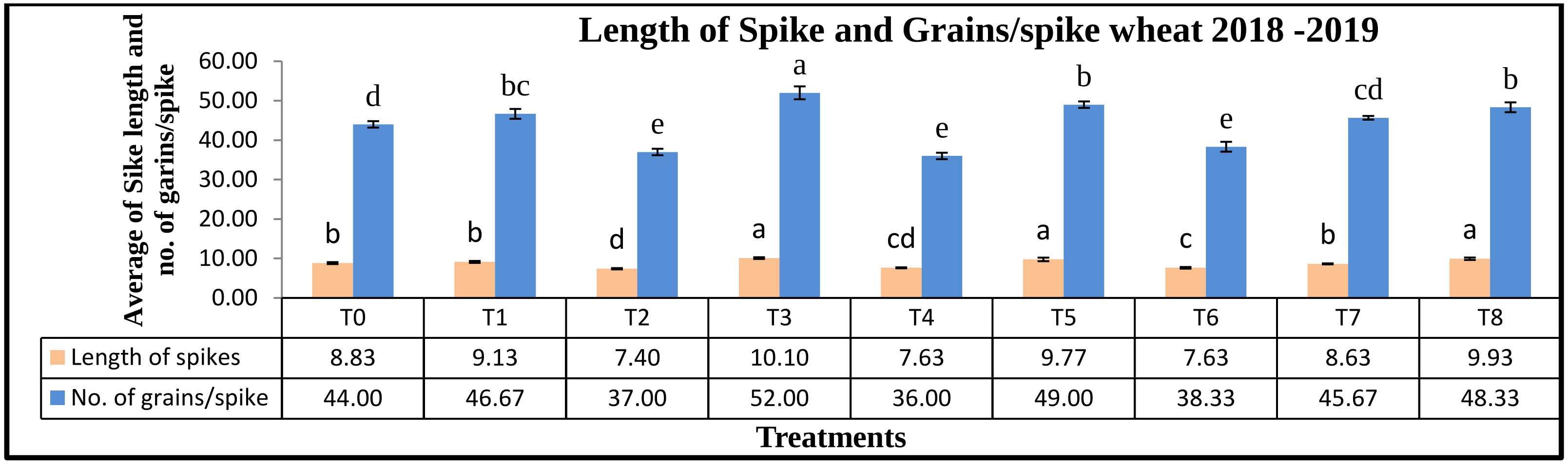


4.1.2 .1 c, d





4.1.2.1 E, F



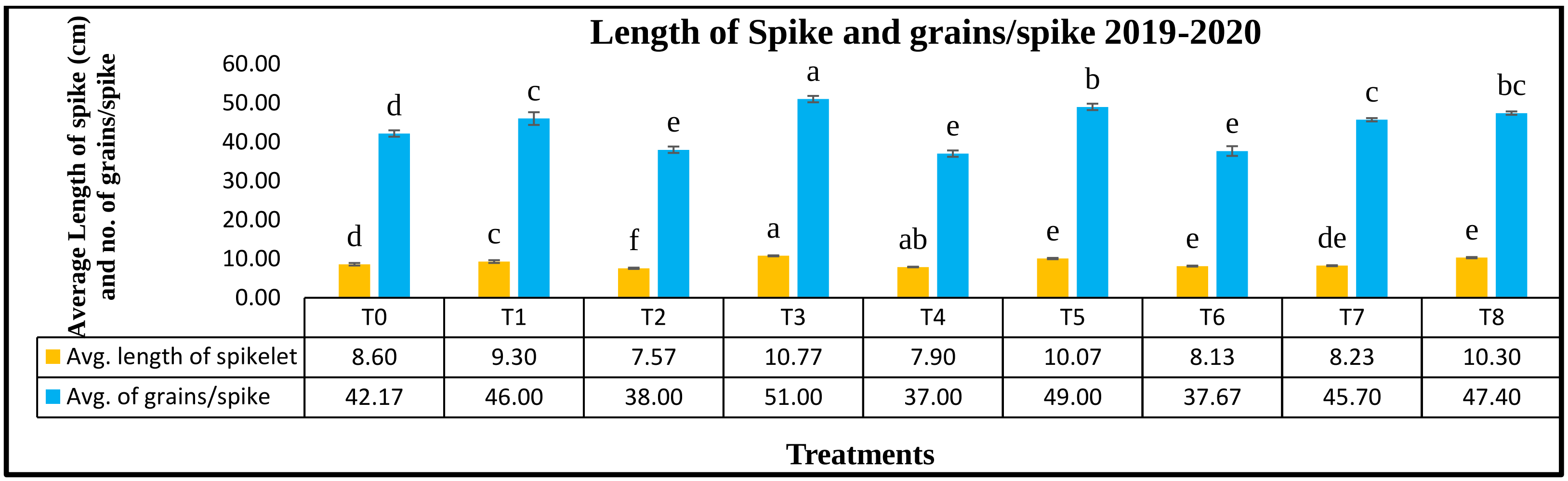


Fig.4.1.2.1 A& B representing the panicle length (cm) of rice crop and Fig. 4.1.2.1 C,D representing filled and unfilled grains per panicle and 4.1..2.1 E,F representing spike length and grins per spike of wheat crop .Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at p<0.05

4.1.2.3 A, B

4.1.2.3 C, D

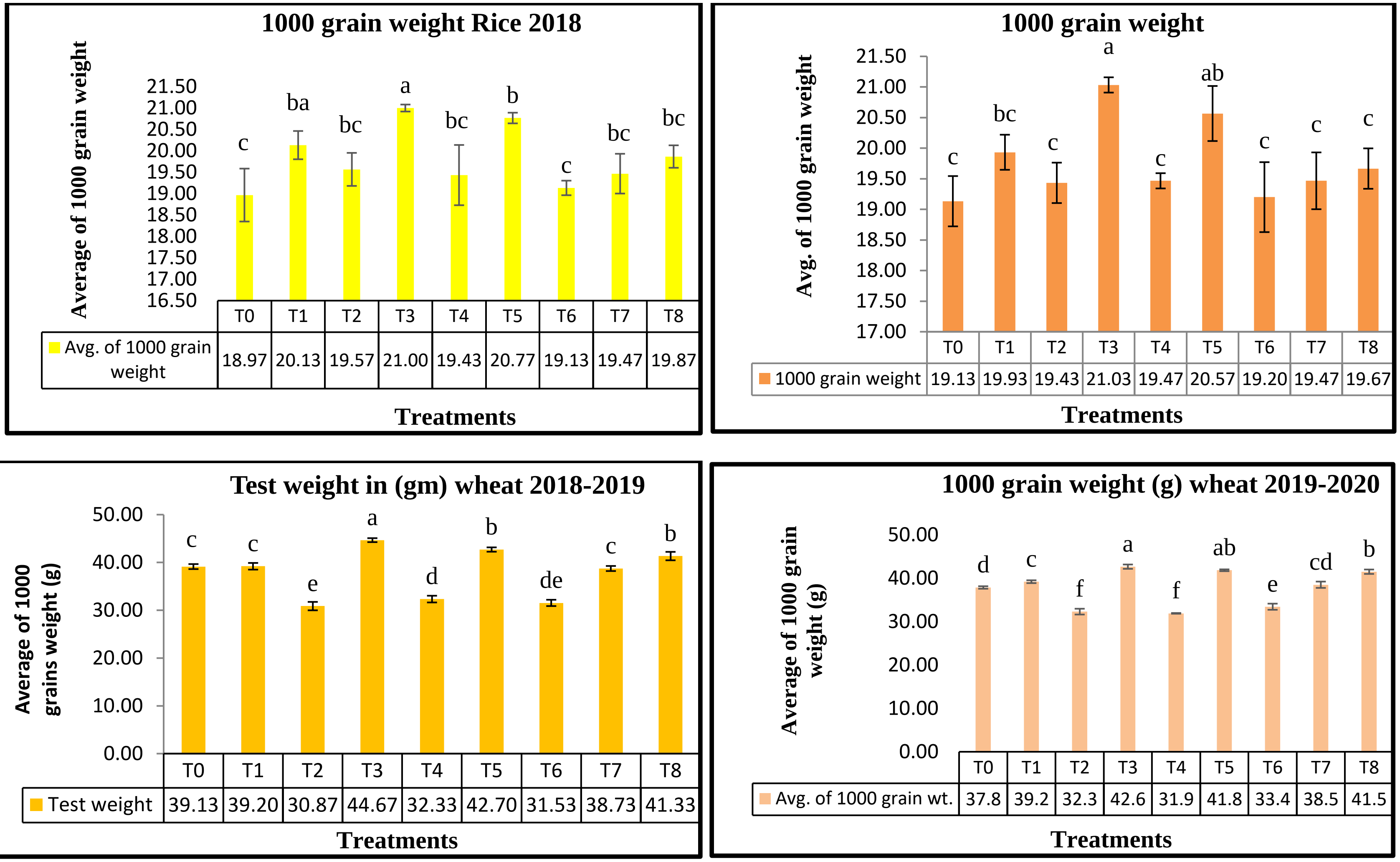


Fig. 4.1.2.3 A&B, C, D representing tests weight (g) of rice and wheat crop during 2018-2019& 2019-2020. Data shown as mean of S.E. Means with similar letters for each figure are not significantly different according to LSD at $p<0.05$.

Table 4.1.2.1(a) Effect of modified fertilizers on panicle length, filled grains per panicle and unfilled grains per panicle in rice (mean± S.E) during 2018-19.

Treatments	2018			2019		
	Panicle length (cm)	**Filled grains**	**Unfilled grains**	**Panicle length (cm)**	**Filled grains**	**Unfilled grains**
T0- Control (RDF)	19.40±0.36f	42.83±1.62e	14.27±0.87a	20.53±0.78bcd	44.33±0.74e	11.47±1.27ab
T1 - Neem coated urea + PK recommended	22.60±1.30a	61.63±1.14a	8.17±0.83d	22.30±1.39bc	54.27±0.86b	7.37±0.26ef
T2 - Anhydrous ammonia + PK recommended	20.23±1.77f	46.77±1.03cd	11.87±0.25b	19.87±0.90cd	47.23±0.78d	11.97±0.29a
T3 - Neem coated urea + PK + S + Zn-EDTA	23.63±1.30b	63.63±2.34a	7.67±0.09d	23.53±0.86a	62.20±0.78a	6.93±0.25f
T4 - Anhydrous ammonia + PK+ S+ Zn-EDTA	19.54±0.31f	47.27±1.91cd	10.43±0.65c	19.20±0.50d	48.30±0.83d	9.20±0.50c
T5 Neem coated urea + PK+$ZnSO_4$	23.15±0.36c	62.57±1.31a	8.03±0.45d	22.60±0.82ab	60.60±1.26a	7.57±0.31def
T6 - Anhydrous ammonia + PK+ $ZnSO_4$	20.62±0.63ef	48.70±0.22c	10.13±0.52c	21.50±0.70abc	47.73±1.36d	10.53±0.41b
T7 - RDF + $ZnSO_4$	21.57±1.56e	45.27±1.23de	8.90±0.24d	20.80±1.24bcd	48.53±0.82b	8.67±0.25cd
T8 - RDF+ S+ Zn-EDTA	21.44±0.81d	52.20±1.23b	8.20±0.51d	21.63±0.69bcd	51.20±0.78c	8.47±0.48cde

Table 4.1.2.1 (b) Effect of modified fertilizers on Flag leaf, spike length and number of grains per spike in wheat (mean± S.E)

Treatments	2018				2019			
	Flag leaf length (cm) 60 DAS	**Flag leaf length (cm) 75 DAS**	**Spike length (cm)**	**Number of grains per spike**	**Flag leaf length (cm) 60 DAS**	**Flag leaf length (cm) 75 DAS**	**Spike length (cm)**	**Number of grains per spike**
T0- Control (RDF)	29.23±0.78d	32.90±0.51e	8.83±0.25b	44.00±0.82d	28.20±0.65e	32.37±0.83e	8.60±0.33d	42.2±0.82d
T1 - Neem coated urea +PK recommended	32.10±0.65c	36.53±0.42cd	9.13±0.25b	46.67±1.25bc	32.13±0.17cd	36.70±0.51cd	9.30±0.36c	46.0±1.63c
T2 - Anhydrous ammonia +PK recommended	33.60±1.15c	36.63±0.42d	7.40±0.16d	37.00±0.82e	32.23±0.91bc	35.60±0.64cd	7.57±0.17f	38.0±0.82e
T3 - Neem coated urea+ PK+S+ Zn-EDTA	35.43±0.62a	41.20±0.94a	10.10±0.22a	52.00±1.63a	35.07±0.66a	41.33±0.94a	10.77±0.12a	51.0±0.82a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	33.40±0.65bc	37.80±0.33bc	7.63±0.12cd	36.00±0.82e	33.03±0.78bc	37.23±0.78bc	7.90±0.08ab	37.0±0.82e
T5- Neem coated urea + PK + $ZnSO_4$	34.27±0.60ab	40.20±0.70b	9.77±0.45a	49.00±0.82b	33.98±0.31ab	38.47±0.45a	10.07±0.17e	48.0±0.82b
T6- Anhydrous ammonia + PK + $ZnSO_4$	30.87±0.41bc	36.70±0.37bc	7.63±0.21c	38.33±1.25e	32.93±0.29a	37.70±0.62cd	8.13±0.12e	37.7±1.25e
T7 - RDF + $ZnSO_4$	33.23±0.69bc	35.73±0.53d	8.63±0.12b	45.67±0.47cd	33.10±0.94bc	35.40±0.86d	8.23±0.12de	45.7±0.42c
T8 - RDF+ S+ Zn-EDTA	33.33±0.41bc	38.97±0.66bc	9.93±0.31a	48.33±1.25b	33.50±0.73bc	37.97±0.63b	10.30±0.16e	47.4±0.43bc

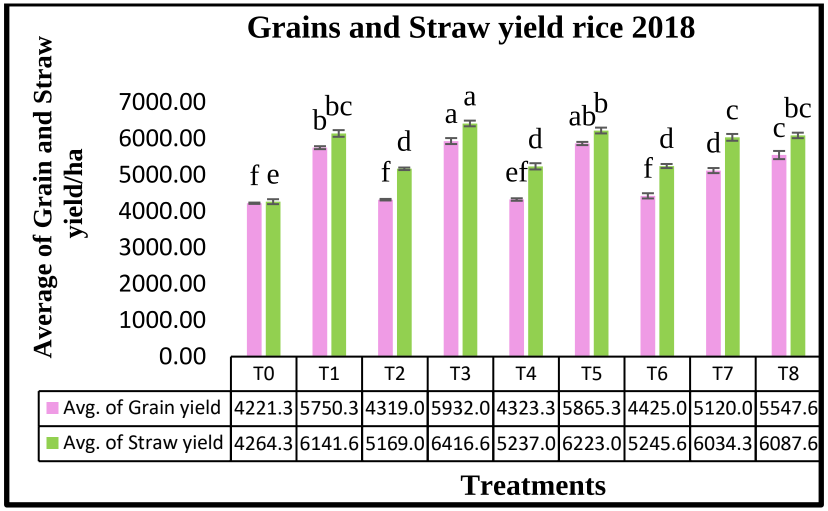
4.1.2.4 Grain yield (Kg ha^{-1}): - Grain yield is the additive effect of number of panicles per plant, panicle/spike length, no. of grains per panicle/spike, test weight. Grain yield of both the crops during both years was presented in table 4.1.2.3 (a) and 4.1.2.3 (b). In case of 2018 rice grain yield was significantly affected by various combination of modified fertilizers. The grain yield of rice ranged from 4221.3 kg ha^{-1} to 5932 kg ha^{-1} during 2018 and during 2019 grain yield ranged from 4161.7 to 5913 kg ha^{-1}. Maximum grain yield recorded with the application of NCU + PK + S + Zn-EDTA (5932, 5913 kg ha^{-1}) respectively during both years. This treatment was immediately followed by T5 with 5865, 5839 Kg ha^{-1} grain yield during both years. The minimum grain yield (4221 Kg ha^{-1}) during 2018 recorded in T0 and 4161 Kg ha^{-1} in T2 (AA + PK). The order of grain yield presented in fig. 4.1.1.4 (a) and order is T3> T5> T1> T8> T6> T4> T0> T2. In consecutive wheat crop during 2018-2019 all the treatments were significantly different from each other. The maximum grain yield (4435, 4531 Kg ha^{-1}) recorded due to the application of NCU + PK + S + Zn-EDTA –T3 during both years. Second highest grain yield (4335, 4448 Kg ha$^{-1)}$ recorded with the application of NCU + PK + $ZnSO_4$. The minimum grain yield (3825 Kg ha$^{-1)}$, during 2018 was recorded with T4 and 3741.6 Kg ha^{-1} under T2. The order of grain yield in wheat was T3> T5> T8> T1> T0> T7> T6> T4> T2. The data presented in fig. 4.1.1.3 (b).

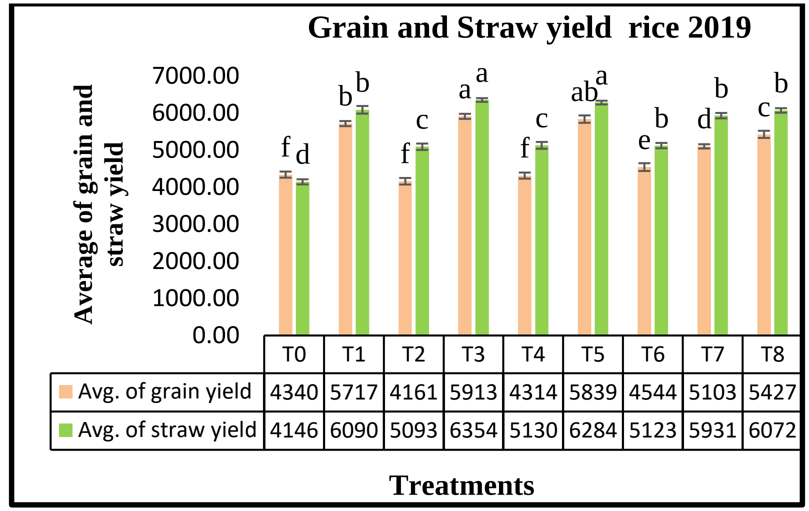
4.1.2.5 Straw yield (Kg ha^{-1}): - Straw yield of rice and wheat crop of two consecutive years presented in table 4.1.2.3 (a) and 4.1.2.3 (b). The data presented in table showed that straw yield was influenced by various combinations of fertilizers. In rice crop, straw yield was ranged from 4263 to 6416 Kg ha^{-1} during 2018 and 4146 to 6354 Kg ha^{-1} during 2019. The maximum straw yield (6416, 6354 Kg ha^{-1}) recorded with the application of NCU + PK + S + Zn-EDTA-T3 which was followed immediately by T5 (6223, 6284 Kg ha^{-1}) during both years. The minimum straw yield (4264, 4146 Kg ha^{-1}) recorded under T0 which was followed by T4 and T6 with straw yield (5237, 5130 and 5245.5 and 4544 Kg ha^{-1}). In case of wheat crop, the straw yield carried from 4597 to 5000 Kg ha^{-1} during 2018-2019 and 4308 to 4906.7 Kg ha^{-1} during 2019-2020. The maximum straw yield (5000, 4906.67 Kg ha^{-1}) recorded with the application of NCU + PK + S + Zn-EDTA. The second highest straw yield (4901, 4781 Kg ha^{-1}) recorded in T5 which was followed by T8 with 4824, 4758 Kg ha^{-1} recorded in T0 during 2018-2019 and 4270

Kg ha^{-1} in T4 during 2019-2020. The order of straw yield in rice and wheat was T3> T5> T8> T7> T6> T1> T0> T2> T4.

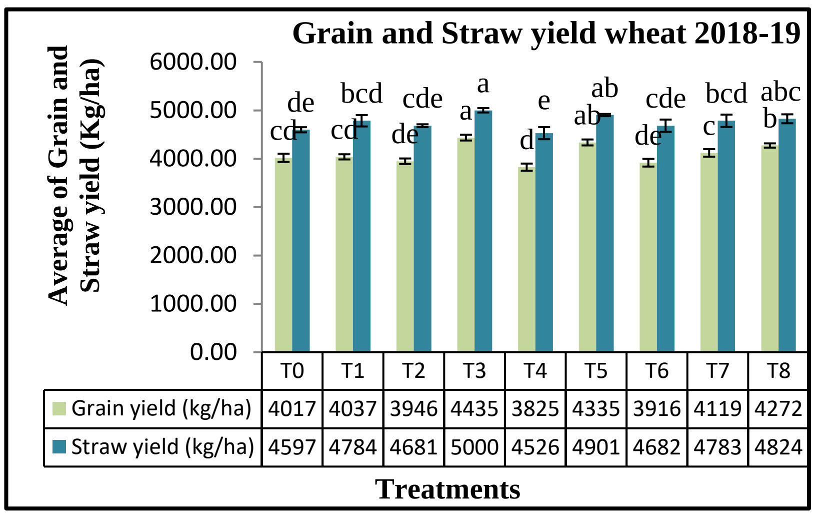
4.1.2.6 Harvest Index (%): - Harvest index is the important parameter which indicates grain to straw ratio. Harvested index % represented in table 4.1.2.3 (a) and 4.1.2.3 (b). In rice crop, harvest index (%) ranged from 45.2 to 48.6 % during 2018 and 45.07 to 48.79% during 2018 and 45.07 to 48.79% during 2019. There was a slight variation in harvest index (%) among all treatments. The maximum harvest index (%) (48.6, 48.79%) recorded due to application of NCU + S + PK + Zn-EDTA which was at par with T5 with 48.5 and 48.67% during both years. The lowest harvest index (42.7% and 45.07%) recorded under T0 during both years. In consecutive wheat crop of two years, the harvest index ranged from 45.17 to 47.01% during 2018-2019 and 46.03 to 48.5% during 2019-2020. The maximum harvest index (47.01 and 48.51%) recorded with the application of NCU + PK + S + Zn-EDTA in 2018-2019 and under T0 in 2019-2020. This treatment was immediately followed by T5 during 2018 with 46.36% and T3 during 2019-2020 with 48.01%. The minimum harvest index (43.92 and 46.03%) recorded under T0 (AA + PK + $ZnSO_4$) during both years. The data presented in fig. 4.1.2.6 (a, b) .

4.1.2.4 A, B





4.1.2.4 C, d



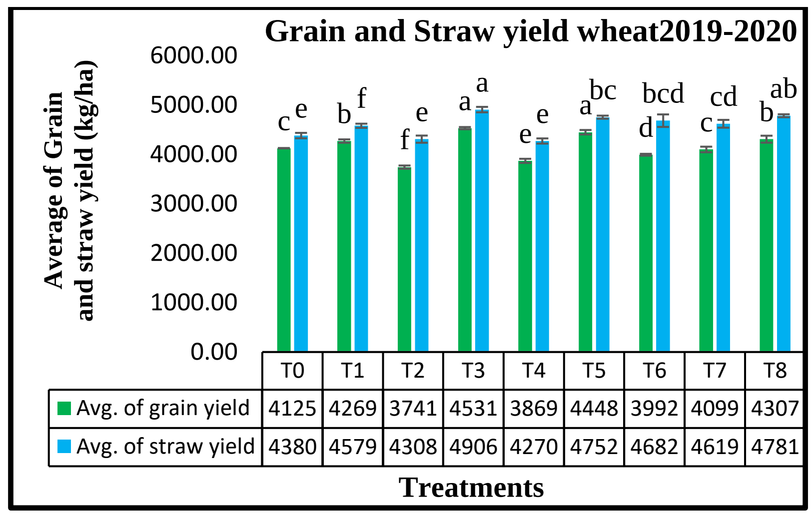


Fig 4.4.1.2.4 a,b. c, d representing the grain yield and straw yield of rice and wheat crop .Data shown as mean of S.E. Means with different letters for each figure are significantly different according to LSD at $p<0.05$.

4.1.2.6 A, B

4.1.2.6 C, D

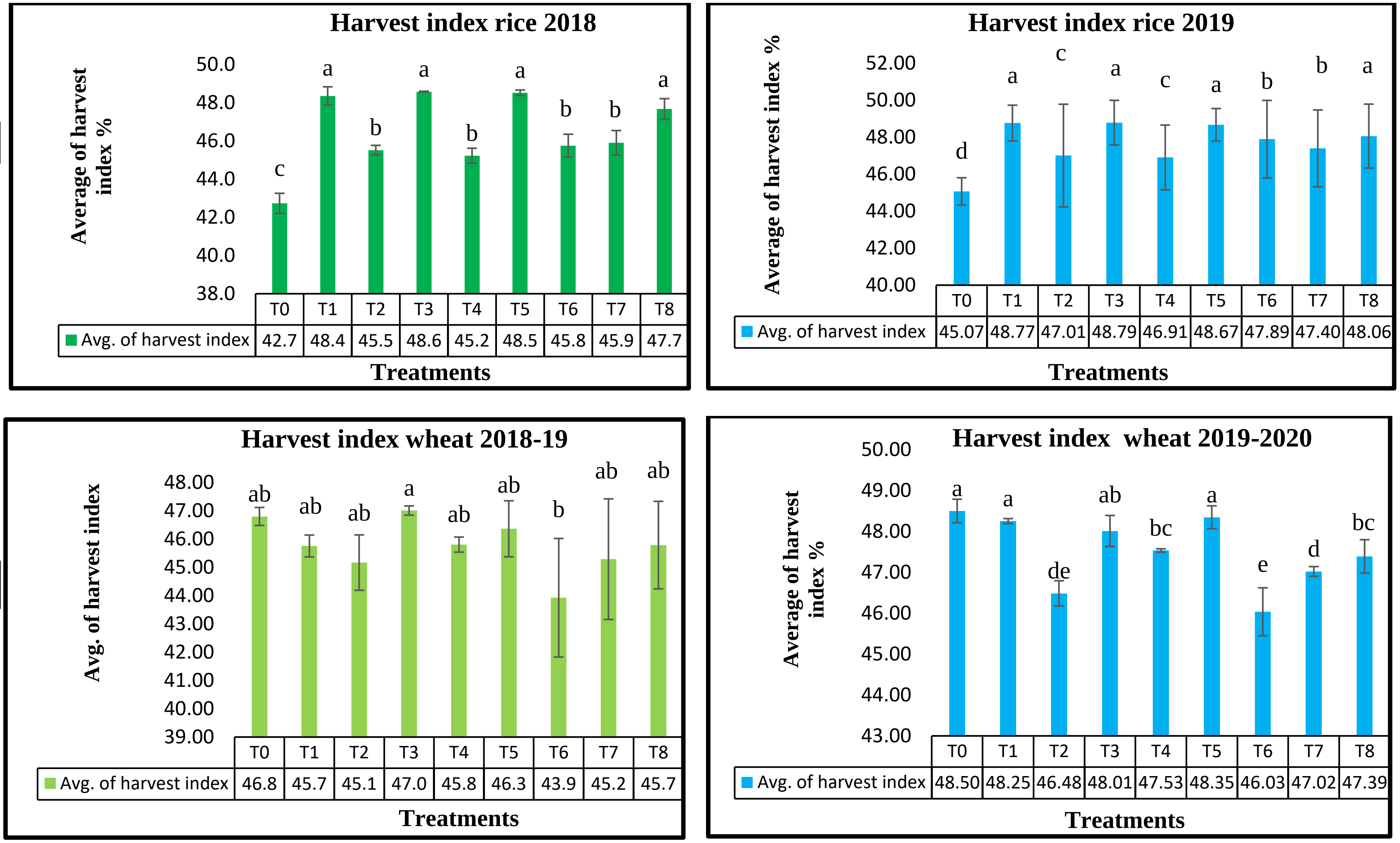


Fig. 4.1.2.6 A&B ,C&D representing harvest index of rice and wheat crop during 2018-19,2019-2020..Data shown as mean of S.E. Means with common letters for each figure are not significantly different according to LSD at $p<0.05$.

Table 4.1.2.4 (a) Effect of modified fertilizers on test weight (g), grain yield (kgha-1), straw yield (kgha-1) and Harvest index (%) of rice crop during 2018-2019.

Treatments	2018				2019			
	Test weight (g)	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Harvest index (%)**	**Test weight (g)**	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Harvest index (%)**
T0- Control (RDF)	18.97±0.62c	4221.3±18.45f	4264.3±68.05e	42.7±0.52c	19.13±0.41c	4340.7±82.4f	4146.0±68.6d	45.07±0.74d
T1 - Neem coated urea + PK recommended	20.13±0.33ba	5750.3±40.83b	6141.7±92.27bc	48.4±0.48a	19.93±0.29bc	5717.3±68.6b	6090.0±102.8b	48.77±0.97a
T2 - Anhydrous ammonia+ PK recommended	19.57±0.39bc	4319.0±21.46ef	5169.0±34.84d	45.5±0.25b	19.43±0.33c	4161.7±88.4f	5093.0±85.9c	47.01±2.78c
T3 - Neem coated urea+ PK+S+ Zn-EDTA	21.00±0.08a	5932.0±82.37a	6416.7±77.98a	48.6±0.02a	21.03±0.12a	5913.0±68.5a	6354.3±50.0a	48.79±1.21a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	19.43±0.70bc	4323.3±34.20ef	5237.0±85.78d	45.2±0.39b	19.47±0.12c	4314.3±82.1f	5130.7±91.8c	46.91±1.75c
T5- Neem coated urea + PK + $ZnSO_4$	20.77±0.12b	5865.3±44.29ab	6223.0±79.99b	48.5±0.15a	20.57±0.45ab	5839.0±100.0ab	6284.3±50.4a	48.67±0.88a
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	19.13±0.17c	4425.0±71.64e	5245.7±56.07d	45.8±0.60b	19.20±0.57c	4544.3±104.8e	5123.7±71.9c	47.89±2.10b
T7 - RDF + $ZnSO_4$	19.47±0.46bc	5120.0±69.76d	6034.3±93.42c	45.9±0.64b	19.47±0.46c	5103.7±57.2d	5931.7±72.8b	47.40±2.08b
T8 - RDF+ S+ Zn-EDTA	19.87±0.26bc	5547.7±112.78c	6087.7±75.78bc	47.7±0.54a	19.67±0.33c	5427.0±96.4c	6072.0±61.0b	48.06±1.73a

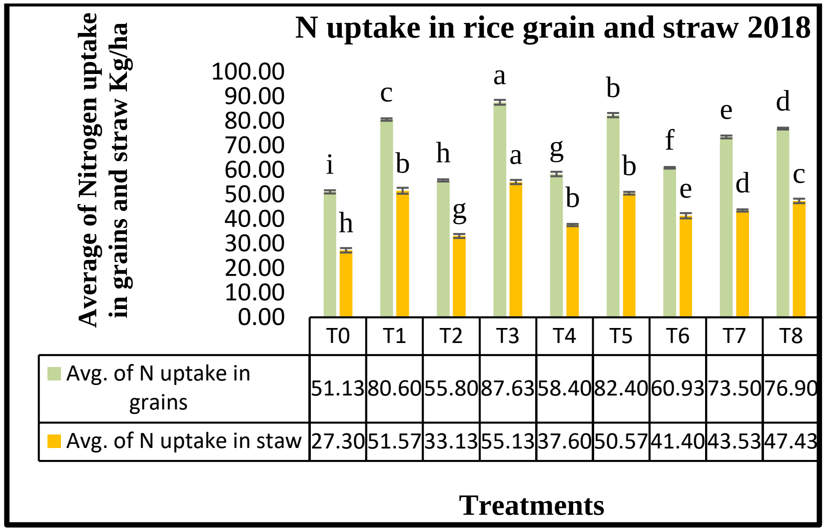
Table 4.1.1.2 (b) Effect of modified fertilizers on test weight (g), grain yield (kgha^{-1}), straw yield (kgha^{-1}) and Harvest index (%) of wheat crop during 2018-2019 & 2019-2020.

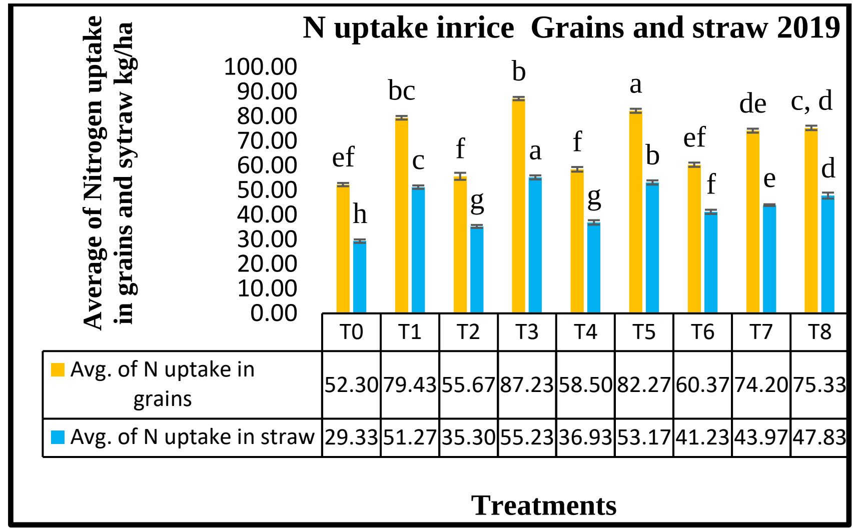
Treatments	2018				2019			
	Test weight (g)	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Harvest index (%)**	**Test weight (g)**	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Harvest index (%)**
T0- Control (RDF)	39.13±0.52c	4017.67±84.95dc	4597.33±53.10de	46.80±0.32ab	37.87±0.29d	4125.00±3.74c	4380.67±54.32e	48.50±0.29a
T1 - Neem coated urea + PK recommended	39.20±0.70c	4037.67±53.39cd	4784.00±117.62bcd	45.75±0.39ab	39.20±0.33c	4269.67±33.91b	4579.00±42.24f	48.25±0.06a
T2 - Anhydrous ammonia + PK recommended	30.87±0.88e	3946.67±57.35de	4681.33±29.63cde	45.17±0.98ab	32.30±0.67f	3741.67±32.74f	4308.00±72.45e	46.48±0.31de
T3 - Neem coated urea + PK+S+ Zn-EDTA	44.67±0.42a	4435.67±59.78a	5000.00±44.90a	47.01±0.16a	42.67±0.50a	4531.00±21.95a	4906.67±54.92a	48.01±0.38ab
T4 - Anhydrous ammonia + PK+ S+ Zn-EDTA	32.33±0.70d	3825.00±73.82d	4526.67±124.72e	45.80±0.27ab	31.90±0.08f	3869.00±41.43e	4270.67±52.32e	47.53±0.04bc
T5 Neem coated urea + PK + $ZnSO_4$	42.70±0.45b	4335.67±61.56ab	4901.33±22.29ab	46.36±0.99ab	41.83±0.21ab	4448.00±45.37a	4752.33±31.54bc	48.35±0.28a
T6- Anhydrous ammonia + PK+ $ZnSO_4$	31.53±0.66de	3916.00±79.21de	4682.00±126.71cde	43.92±2.10b	33.43±0.70e	3992.33±18.80d	4682.00±126.71bcd	46.03±0.59e
T7 - RDF + $ZnSO_4$	38.73±0.53c	4119.33±77.57c	4783.33±128.11bcd	45.29±2.13ab	38.50±0.73cd	4099.67±56.17c	4619.33±78.83cd	47.02±0.12cd
T8 - RDF+ S+ Zn-EDTA	41.33±0.88b	4272.67±44.01b	4824.67±92.32abc	45.79±1.55ab	41.50±0.51b	4307.67±70.24b	4781.67±29.85ab	47.39±0.41bc

4.2 Effect of modified fertilizers on nutrient uptake: - After the harvest grain and straw samples were analyzed for N,P, K ,Zn and S content. The findings of N, P, K, S and Zn content of grain and straw have been discussed under the following subheadings: -

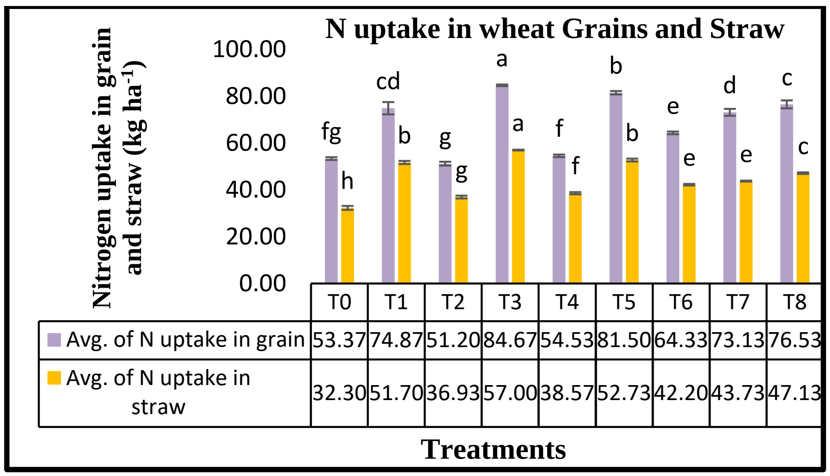
4.2.1 N uptake by grain and straw: - The nitrogen uptake by grain and straw as influenced by the modified fertilizers during 2018-2019, 2019-2020 presented in Table 4.2.1 (a) and 4.2.1 (b) indicated that N uptake were significantly improved due to modified fertilizers. During 2018-2019 rice crop the application of NCU + PK + S + Zn-EDTA –T3 recorded significantly higher N uptake by grain (87.63, 87.23 Kg ha^{-1}) during 2018 and 2019. The second higher N uptake by grain (82.4 and 82.27 Kg ha^{-1}) recorded in T5. The lowest N uptake in grain (51.13, 52.3 Kg ha^{-1}) was recorded in T0 (control In case of N uptake by straw, the value ranged from 27.3 to 55.13 Kg ha^{-1} during 2018, and 29.33 to 55.23 Kg ha^{-1} during 2019. There was significantly variation recorded in N uptake by straw among treatments. The maximum N uptake by straw (55.13, 55.23 Kg ha^{-1}) during 2018,2019 recorded in T3.. The minimum uptake (27.13, 29.33 Kg ha^{-1}) recorded under T0. The order of N uptake was T3> T5> T1> T8> T7> T6> T4> T2> T0 was presented in fig. 4.2.1 (a) and 4.2.1 (b).). In case of wheat crop, during both years, N uptake by grain and straw was significantly different. The N uptake by wheat grain ranged from 51.2 to 84.67 Kg ha^{-1} during 2018-2019 and 53.33 to 85.73 Kg ha^{-1} during 2019-2020. The maximum uptake by grain (84.67, 85.73 Kg ha^{-1}) recorded in T3 which was followed by with 81.5, 80.77 Kg ha^{-1} respectively. The lowest uptake by grain (51.2, 53.33 Kg ha^{-1}) recorded in T2 . The N uptake by straw of wheat ranged from 32.3 to 57 Kg ha^{-1} during 2018-2019 and 33.83 to 58.2 Kg ha^{-1} during 2019-2020. The maximum uptake (57, 58.2 Kg ha^{-1}) by straw recorded under T3 which was immediately followed by T5 with 52.73, 52.13 Kg ha^{-1} uptakes and T1 with 51.7 and 51.43 Kg ha^{-1}. The minimum uptake of N by straw of wheat (32.3, 33.83 Kg ha^{-1}) recorded under T0. The order of N uptake by wheat was T3> T5> T1> T8> T7> T6> T4> T2> T0 as depicted in fig. 4.2.1 (c) and 4.2.1 (d).

4.2.1 A, b





4.2.1c, d



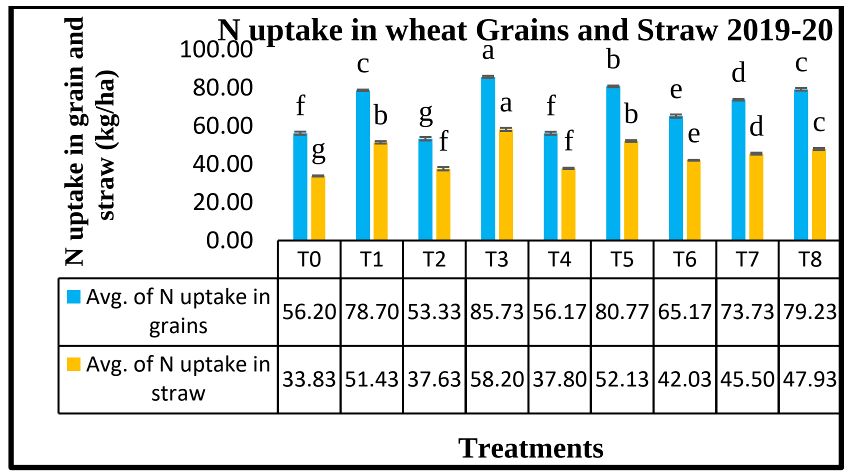
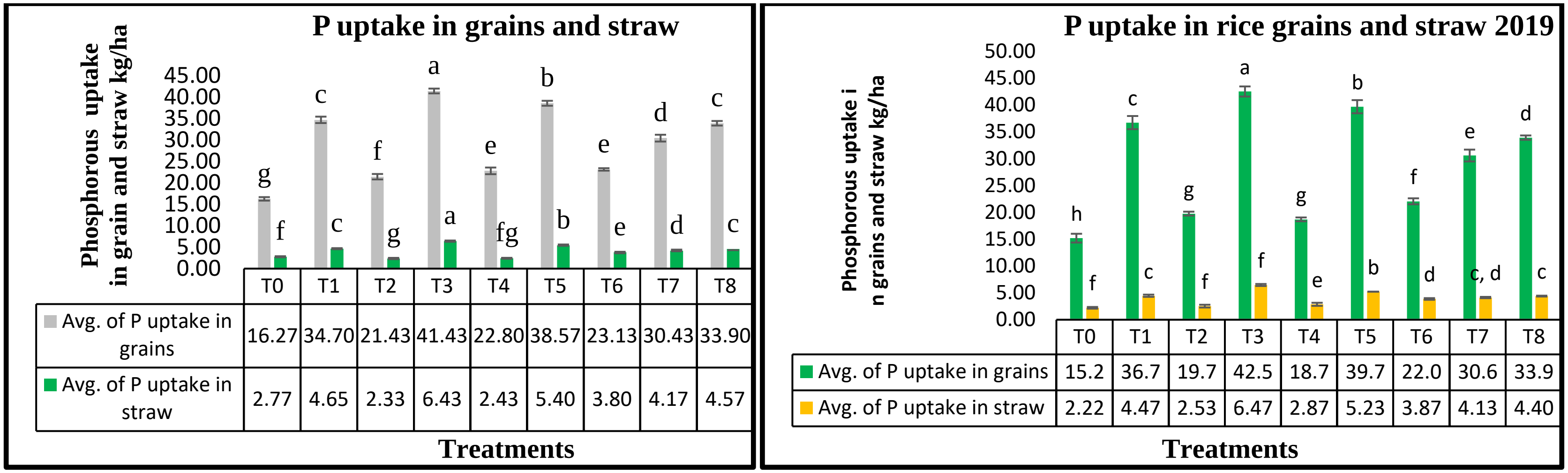


Fig.4.2.1 a& b , c& d representing the N uptake by grain and straw of rice and wheat crop during 2018-2019, 2019-2020. Data shown as mean of S.E. Means with different letters for each figure are significantly different according to LSD at p<0.0

4.2.2 Phosphorous uptake by grain and straw: - The data presented in table 4.2.1 (a), clearly revealed that P content in rice grain slightly increased over control. The highest P uptake in grain (41.43, 42.53) during 2018 and 2019 recorded due to application of NCU + PK + Zn-EDTA + S -T3 which was followed by T5 with 38.57, 39.70 Kg ha^{-1} uptake during both years. All the treatments were significantly different from each other. The minimum P uptake (16.27, 15.2 Kg ha^{-1}) recorded in T0. In case of P uptake by rice straw also significantly influenced by different combinations of modified fertilizers. During 2018, P uptake in rice straw recorded maximum (6.43, 6.47 Kg ha^{-1}) in T3. The application of NCU + PK + $ZnSO_4$ –T5 recorded next highest (5.40, 5.23 Kg ha^{-1}) P uptake by straw. The minimum P uptake (2.33,2.22 Kg ha^{-1}) recorded in T2 during 2018, recorded in T0 during 2019. The data of P uptake by grain and straw of rice was presented in fig. 4.2.2 (a,b). In consecutive wheat crop of 2018-2019 and 2019-2020 all treatments were statistically different from each other. The P uptake by grain of wheat ranged from 12.73 – 43.67 Kg ha^{-1} during 2018-2019 and 13.93-42.40 Kg ha^{-1} during 2019-2020. The maximum P uptake by grain (43.67, 42.40 Kg ha^{-1}) recorded in T5 during both years which were followed by T5 with 37.9, 38.57 Kg ha^{-1} P uptake by grain. The treatments T1- and T8 also recorded significantly more P uptake (34.17, 35.27 Kg ha^{-1} and 33.87, 34.73 Kg ha^{-1}) respectively. The minimum uptake by grain recorded 12.78, 13.93 under T0 which was followed by T2 with 20.79, 21.03 Kg ha^{-1}. The order of P uptake in wheat crop with different treatments was significantly affected .In case of P uptake by straw maximum uptake (6.72, 6.89 Kg ha^{-1}) recorded in T3, which was followed by T5 with 5.34, 5.20 Kg ha^{-1} during both years the minimum P uptake (2.28, 2.20 Kg ha^{-1}) recorded under T0 which was followed by T2 with 2.39, 2.36 Kg ha^{-1} uptake during both years. The data of P uptake by wheat grain and straw was depicted in fig. 4.2.2 (c),4.2.2 (d).

The order of P uptake by straw was T3>T5>T1>T8>T7>T0>T6>T4>T2

4.2.2 A, B



4.2.2 C, D

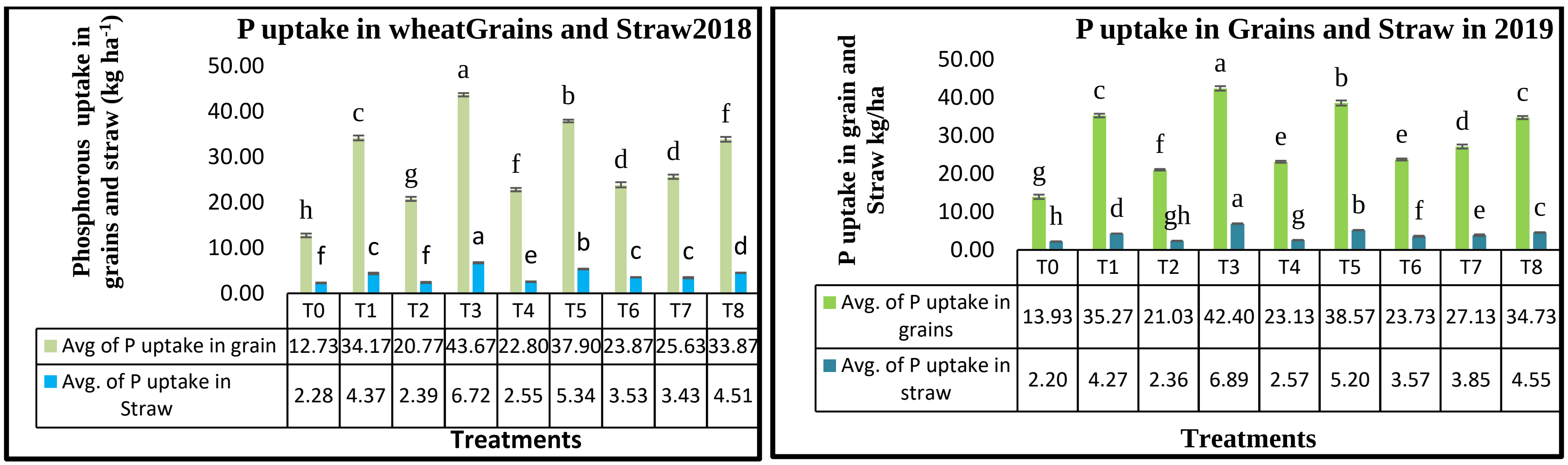


Fig. 4.2.2 A&B ,C&D representing P uptake by grain and straw rice and wheat crop .Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

4.2.3 K uptake by grain and straw: - The results on the effect of modified levels of fertilizers on potassium uptake by grain and straw are presented in table 4.1.1 (a) and 4.1.1 (b). In rice crop, K uptake by grain ranged from 11.3 to 26.7 Kg ha^{-1} during 2018 and 10.3 to 24.3 Kg ha^{-1} during 2019. The maximum K uptake by grain (26.7, 24.3 Kg ha^{-1}) recorded in T3 which was followed by T5 with 22.7, 21.7 Kg ha^{-1} during 2018,2019. (T1) also recorded more k uptake (20.10, 19.1 Kg ha^{-1}) over other treatments. The minimum k uptake (11.3, 10.3 Kg ha^{-1}) was recorded in T0 which was followed by T2 with (12.3, 11.5 Kg ha^{-1}). In case of K uptake by straw maximum uptake (87.3, 88.3 Kg ha^{-1}) recorded due to NCU + PK +S + Zn-EDTA. The second highest K uptake by straw (78.37, 81.33 Kg ha^{-1}) recorded in T5 during both years. The minimum K uptake by straw (54.2, 56.2 Kg ha^{-1}) was recorder in T0. The date of K uptake by grain and straw presented in fig. 4.2.3 (a), 42.3 (c). In case of wheat, the maximum K uptake by grain (25.9, 23.77 Kg ha^{-1}) recorded in T3 which was followed by T5 with 20.9, 22.04 Kg ha^{-1} during 2018,2019 .The minimum K uptake (10.3, 10.17 Kg ha^{-1}) recorded under T2. In case of K uptake by straw, maximum potassium uptake (84.5, 84.17 Kg ha^{-1}) recorded in T3 (NCU + PK + S + Zn-EDTA) during 2018-2019 and 2019-2020. The second highest K uptake by straw record (77, 78.10 Kg ha^{-1}) in T5 (54.7, 55.3 Kg ha^{-1}). The data of K uptake by grain and straw was presented in fig 4.2.3 (c) and 4.2.3 (d).

4.2.3 A, B

4.2.3 C, D

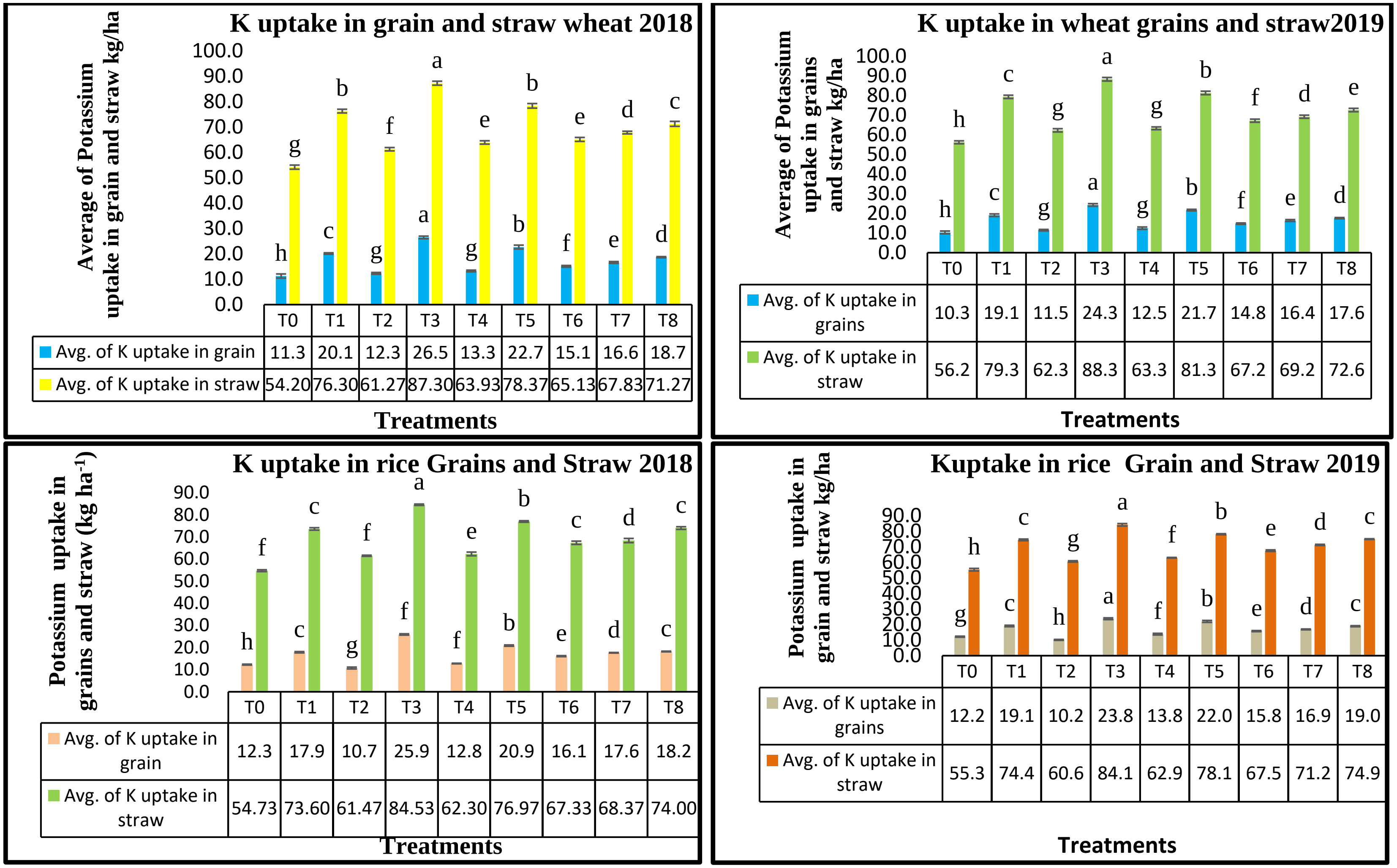


Fig. 4.2.3 A&B ,C&D representing K uptake by grain and straw rice and wheat crop during 2018-19,2019-2020. .Data shown as mean of S.E. Means with same letters for each figure was not significantly different according to LSD at $p<0.05$.

Table 4.2.2a Impact of modified fertilizers on Nutrient uptake by grain and straw (N, P, and K) of rice (mean± S.E).

Treatments	2018						2019					
	N uptake grain (kg/ha)	**N uptake straw (kg/ha)**	**P uptake grain (kg/ha)**	**P uptake straw (kg/ha)**	**K uptake grain (kg/ha)**	**K uptake straw (kg/ha)**	**N uptake grain(kg/ha)**	**N uptake straw (kg/ha)**	**P uptake grain (kg/ha)**	**P uptake straw (kg/ha**	**K uptake grain (kg/ha)**	**K uptake straw (kg/ha)**
T0- Control (RDF)	51.13±0.65i	27.30±0.91h	16.27±0.41g	2.77±0.12f	11.3±0.82h	54.20±0.82g	52.30±0.67ef	29.33±0.69h	15.20±0.82h	2.22±0.16f	10.3±0.70h	56.20±0.73h
T1 - Neem coated urea +PK recommended	80.60±0.49c	51.57±1.21b	34.70±0.75c	4.65±0.12c	20.1±0.29c	76.30±0.73b	79.43±0.74bc	51.27±0.69c	36.73±1.23c	4.47±0.21c	19.1±0.64c	79.33±0.84c
T2 - Anhydrous ammonia+ PK recommended	55.80±0.45h	33.13±0.82g	21.43±0.63f	2.33±0.12g	12.3±0.34g	61.27±0.65f	55.67±1.43f	35.30±0.62g	19.77±0.37g	2.53±0.26ef	11.5±0.37g	62.30±0.83g
T3 - Neem coated urea+ PK+S+ Zn-EDTA	87.63±0.98a	55.13±0.86a	41.43±0.56a	6.43±0.17a	26.5±0.49a	87.30±0.78a	87.23±0.68b	55.23±0.82a	42.53±0.94a	6.47±0.18a	24.3±0.67a	88.30±0.90a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	58.40±0.91g	37.60±0.45f	22.80±0.78e	2.43±0.12fg	13.3±0.33g	63.93±0.66e	58.50±0.94f	36.93±0.91g	18.70±0.36g	2.87±0.29e	12.5±0.57g	63.33±0.69g
T5- Neem coated urea +PK+ZnSO$_4$	82.40±0.86b	50.57±0.56b	38.57±0.58b	5.40±0.08b	22.7±0.75b	78.37±0.90b	82.27±0.82a	53.17±0.86b	39.70±1.22b	5.23±0.01b	21.7±0.37b	81.33±0.88b
T6 - Anhydrous ammonia +PK+ ZnSO$_4$	60.93±0.33f	41.40±1.07e	23.13±0.29e	3.80±0.22e	15.1±0.33f	65.13±0.78e	60.37±0.87ef	41.23±0.86f	22.07±0.56f	3.87±0.15d	14.8±0.33f	67.20±0.78f
T7 - RDF +ZnSO$_4$	73.50±0.57e	43.53±0.46d	30.43±0.79d	4.17±0.12d	16.6±0.34e	67.83±0.52d	74.20±0.82de	43.97±0.34e	30.60±1.10e	4.13±0.12cd	16.4±0.45e	69.23±0.78e
T8 - RDF+ S+ Zn-EDTA	76.90±0.37d	47.43±0.90c	33.90±0.54c	4.57±0.26c	18.7±0.22d	71.27±0.98c	75.33±0.90cd	47.83±1.21d	33.93±0.40d	4.40±0.08c	17.6±0.29d	72.63±0.85d

Table 4.2.2b Impact of modified fertilizers on Nutrient uptake by grain and straw (N, P, and K) of wheat crop (mean± S.E).

Treatments	2018						2019					
	N uptake grain (kg/ha)	N uptake straw (kg/ha)	P uptake grain (kg/ha)	P uptake straw (kg/ha)	K uptake grain (kg/ha)	K uptake straw (kg/ha)	N uptake grain (kg/ha)	N uptake straw (kg/ha)	P uptake grain (kg/ha)	P uptake straw (kg/ha	K uptake grain (kg/ha)	K uptake straw (kg/ha)
T0- Control (RDF)	53.37±0 .60fg	32.30±0 .83h	12.73±0 .41h	2.28±0. 09f	12.3±0. 21h	54.7±0. 41f	56.20±0 .82f	33.83±0 .29g	13.93±0 .57g	2.20±0. 053h	12.20±0 .33g	55.30±0 .82h
T1 - Neem coated urea + PK recommended	74.87±2 .63cd	51.70±0 .67b	34.17±0 .53c	4.37±0. 17c	17.9±0. 29c	73.6±0. 54c	78.70±0 .36c	51.43±0 .63b	35.27±0 .47c	4.27±0. 037d	19.10±0 .45c	74.47±0 .52c
T2 - Anhydrous ammonia + PK recommended	51.20±0 .82g	36.93±0 .60g	20.77±0 .45g	2.39±0. 13ef	10.7±0. 41g	61.5±0. 25ef	53.33±0 .90g	37.63±0 .87f	21.03±0 .21f	2.36±0. 054gh	10.17±0 .29h	60.63±0 .42g
T3 - Neem coated urea + PK + S + Zn-EDTA	84.67±0 .34a	57.00±0 .16a	43.67±0 .37a	6.72±0. 13a	25.9±0. 29a	84.5±0. 31a	85.73±0 .54a	58.20±0 .82a	42.40±0 .59a	6.89±0. 090a	23.77±0 .56a	84.17±0 .78a
T4 - Anhydrous ammonia + PK + S+ Zn-EDTA	54.53±0 .54f	38.57±0 .46f	22.80±0 .37f	2.55±0. 07e	12.8±0. 12f	62.3±0. 83e	56.17±0 .78f	37.80±0 .33f	23.13±0 .26e	2.57±0. 062g	13.83±0 .53f	62.97±0 .21f
T5- Neem coated urea + PK + $ZnSO_4$	81.50±0 .73b	52.73±0 .61b	37.90±0 .29b	5.34±0. 09b	20.9±0. 29b	77.0±0. 33b	80.77±0 .42b	52.13±0 .46b	38.57±0 .66b	5.20±0. 054b	22.04±0 .61b	78.10±0 .33b
T6- Anhydrous ammonia + PK + $ZnSO_4$	64.33±0 .58e	42.20±0 .33e	23.87±0 .57e	3.53±0. 05d	16.1±0. 22e	67.3±0. 74f	65.17±0 .86e	42.03±0 .21e	23.73±0 .26e	3.57±0. 150f	15.80±0 .33e	67.53±0 .50e
T7 - RDF + $ZnSO_4$	73.13±1 .48d	43.73±0 .21d	25.63±0 .47d	3.43±0. 14d	17.6±0. 12d	68.4±0. 94d	73.73±0 .41d	45.50±0 .51d	27.13±0 .53d	3.85±0. 222e	16.90±0 .24d	71.23±0 .37d
T8 - RDF+ S+ Zn-EDTA	76.53±1 .70c	47.13±0 .34c	33.87±0 .53c	4.51±0. 05c	18.2±0. 14c	74.0±0. 59c	79.23±0 .69c	47.93±0 .54c	34.73±0 .41c	4.55±0. 082c	18.95±0 .32c	74.97±0 .21c

4.2.4 Sulphur uptake by grain and straw: - S uptake by grain and straw significantly varied with the different modified fertilizers. The date of S uptake by grain and straw of rice presented in Table 4.2.4 (a) and 4.2.4 (b). The maximum S uptake by grain of rice (46.1, 47.47 Kg ha^{-1}) was recorded in T3 which was followed by T5 (41.53, 43.5 Kg ha^{-1}) during 2018-2019. The minimum S uptake (19.57, 18.6 Kg ha^{-1}) recorded in T6 followed by T4. In case of S uptake by straw, maximum uptake (4.70, 4.77 Kg ha^{-1}) recorded with the application of NCU + PK + S+ Zn-EDTA -T3 which was immediately followed by T5 (4.53, 4.73 Kg ha^{-1}). The minimum S uptake by straw of rice (2.82, 2.89 Kg ha^{-1}) recorded under T6. In case of wheat crop, the maximum S uptake by grain (46.07, 47 Kg ha^{-1}) recorded due to application of NCU + PK + S + Zn-EDTA -T3 which was immediately followed by T5 (45, 45.67 Kg ha^{-1}) respectively. The lowest S uptake (18.80, 18.90 Kg ha^{-1}) recorded under T6 which was followed by T4 with 21.07, 19.80 Kg ha^{-1} S during both years. In case of S uptake by straw of wheat was significantly influenced by the modified fertilizers. The S uptake by straw ranged from 0 to 6.4 Kg ha^{-1} during 2018-2019 and 0 to 6.17 Kg ha^{-1} during 2019-2020. The maximum S uptake by straw (6.4, 6.17 Kg ha^{-1}) recorded in T3 which was immediately followed by NCU + PK + $ZnSO_4$ with 4.5, 4.23 Kg ha^{-1} S. The minimum S uptake 2.4, 2.07 Kg ha^{-1} recorded under T4 which was followed by T6 with 2.5, 2.40 Kg ha^{-1} S. The data of S uptake by rice and wheat during both years presented in fig. 4.2.4 (a), 4.2.4 (b), 4.2.4 (c), 4.2.4 (d).

4.2.4 A, B

4.2.4 C, D

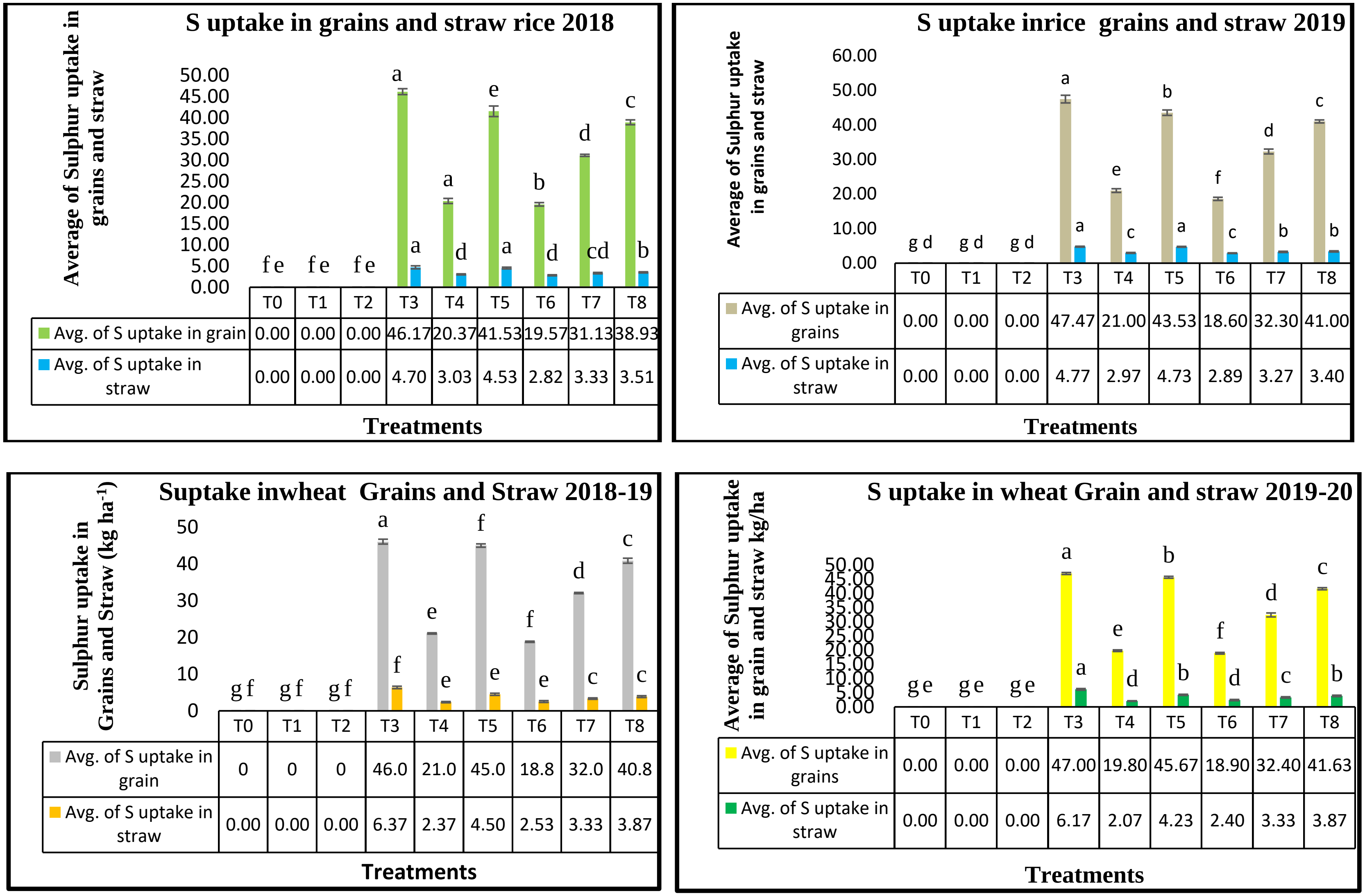


Fig. 4.5.3 A&B ,C&D representing S uptake by grain and straw rice and wheat crop during 2018-19,2019-2020. .Data shown as mean of S.E, mean with same letters for each figure was not significantly different according to LSD at $p<0.05$.

Table 4.2.4 Impact of modified fertilizers on Sulphur uptake by grain and straw of rice crop (mean± S.E)

Treatments	2018		2019	
	S uptake by grain (kg/ha)	**S uptake by straw (kg/ha)**	**S uptake by grain (kg/ha)**	**S uptake by straw (kg/ha)**
T0- Control (RDF)	0.00±0.0f	0.0±0.00e	0.0±0.00g	0.00±0.00d
T1- Neem coated urea +PK recommended	0.00±0.0f	0.00±0.00e	0.00±0.00g	0.0±0.00d
T2- Anhydrous ammonia+ PK recommended	0.00±0.00f	0.00±0.00e	0.00±0.00g	0.0±0.00d
T3- Neem coated urea+ PK+S+ Zn-EDTA	46.1±0.69a	4.70±0.36a	47.47±1.11a	4.77±0.12a
T4- Anhydrous ammonia +PK+ S+ Zn-EDTA	20.37±0.60e	3.03±0.12d	21.00±0.54e	2.97±0.12c
T-5 Neem coated urea +PK+$ZnSO_4$	41.53±1.25b	4.53±0.21a	43.53±0.78b	4.73±0.12a
T6- Anhydrous ammonia +PK+ $ZnSO_4$	19.57±0.41e	2.82±0.12d	18.60±0.45f	2.89±0.09c
T7- RDF + $ZnSO_4$	31.13±0.25d	3.33±0.16cd	32.30±0.70d	3.27±0.17b
T8- RDF+ S+ Zn-EDTA	38.93±0.57c	3.51±0.13b	41.00±0.43c	3.40±0.16b

Table 4.2.4 b Impact of modified fertilizers on Sulphur uptake by grain and straw of wheat crop (mean± S.E)

Treatments	2018			2019		
	S uptake by grain kg/ha	**S uptake by straw**	**SUE (%)**	**S uptake by grain kg/ha**	**S uptake by straw**	**SUE (%)**
T0- Control (RDF)	0±0g	0±0f	0±0g	0.00±0.00g	0.00±0.00e	0.00±0.00f
T1 - Neem coated urea + PK recommended	0±0g	0±0f	0±0g	0.00±0.00g	0.00±0.00e	0.00±0.00f
T2 - Anhydrous ammonia + PK recommended	0±0g	0±0f	0.00±0.00g	0.00±0.00g	0.00±0.00e	0.00±0.00f
T3 - Neem coated urea + PK + S + Zn-EDTA	46.07±0.66a	6.4±0.33a	17.48±0.33a	47.00±0.36a	6.17±0.29a	17.72±0.06f
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	21.07±0.17e	2.4±0.17e	7.81±0.11e	19.80±0.29e	2.07±0.09d	7.29±0.10a
T5- Neem coated urea + PK + $ZnSO_4$	45.00±0.45b	4.5±0.29b	16.50±0.22b	45.67±0.34b	4.23±0.21b	16.63±0.18e
T6- Anhydrous ammonia + PK + $ZnSO_4$	18.80±0.16e	2.5±0.25e	7.11±0.13f	18.90±0.29f	2.40±0.22d	7.10±0.14b
T7 - RDF + $ZnSO_4$	32.07±0.17d	3.3±0.19d	11.80±0.07d	32.40±0.70d	3.33±0.24c	11.91±0.24d
T8 – RDF + S + Zn-EDTA	40.87±0.68c	3.9±0.25c	14.91±0.31c	41.63±0.37c	3.87±0.25b	15.17±0.21c

4.2.5 Zinc uptake by grain and straw: - Zn uptake by grain and straw significantly varied with the different modified fertilizers. The date of Zn uptake by grain and straw of rice presented in Fig.4.2.5 (a) and 4.2.5 (b). The maximum Zn uptake by grain of rice (96.27,97.4 g ha^{-1}) was recorded in T3 which was followed by T5 (84.22,85.6 g ha^{-1}) during 2018-2019. The minimum Zn uptake (40.11,41.1 g ha^{-1}) recorded in T4 followed by T6. In case of Zn uptake by straw, maximum uptake (193.6,194.7g ha^{-1}) recorded with the application of NCU + PK + S+ Zn-EDTA -T3 which was immediately followed by T5 (168,169g ha^{-1}). The minimum Zn uptake by straw of rice (98,99.4 g ha^{-1}) recorded under T4. In case of wheat crop, the maximum Zn uptake by grain (92.58,94.5g ha^{-1}) recorded due to application of NCU + PK + S + Zn-EDTA -T3 which was immediately followed by T5 (77.03,79.4 g ha^{-1}) respectively. The lowest Zn uptake (45.2,47.4 g ha^{-1}) recorded under T4 which was followed by T6 with 49.4, 50.80 g ha^{-1} during both years. In case of Zn uptake by straw of wheat was significantly influenced by the modified fertilizers. The Zn uptake by straw ranged from 0 to 210.4 g ha^{-1} during 2018-2019 and 0 to 211.4 g ha^{-1} during 2019-2020. The maximum Zn uptake by straw (210.4,211.4 g ha^{-1}) recorded in T3 which was immediately followed by NCU + PK + $ZnSO_4$ with 189.4,187.1 g ha^{-1} Zn. The minimum Zn uptake 76.5,79.4 g ha^{-1} recorded under T4 which was followed by T6. The data of Zn uptake by rice and wheat during both years presented in fig. 4.2.5 (c,d).

4.2.5 a.b

4.2.5 c.d

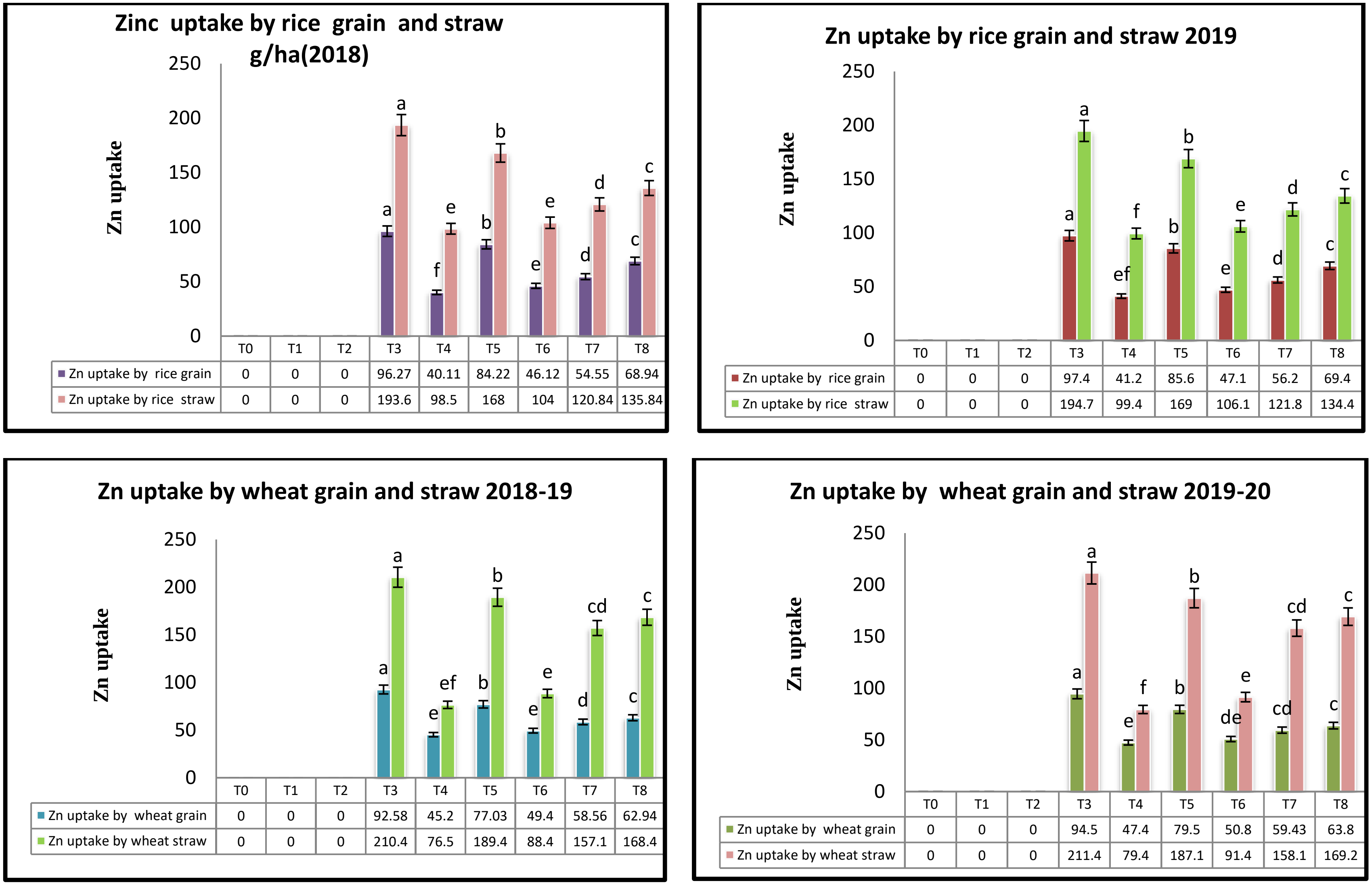


Fig. 4.2.5 (abcd) Impact of modified fertilizers on Zinc uptake by rice and wheat grain and straw.

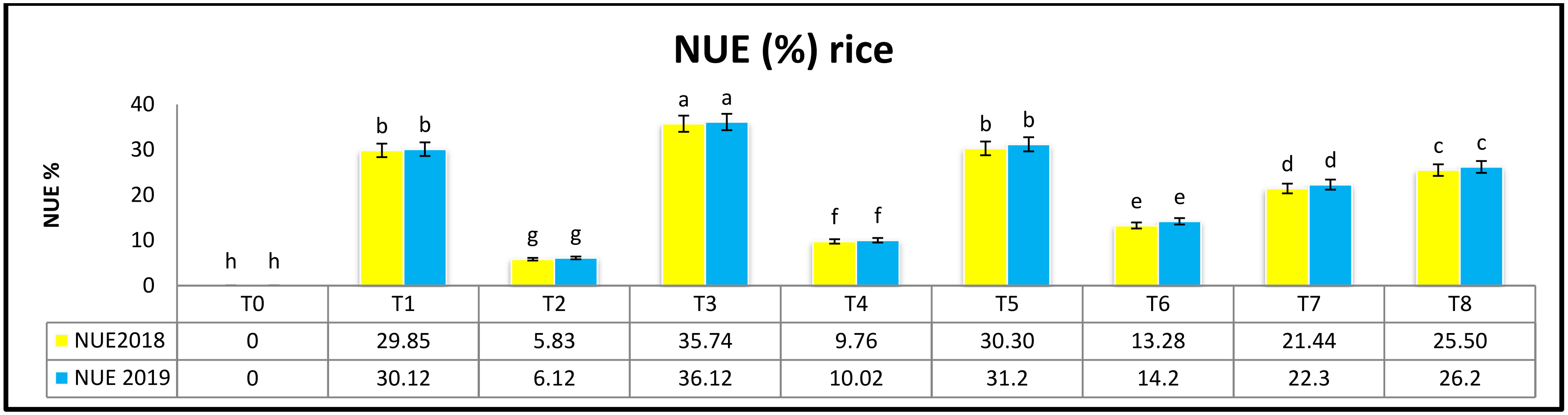
4.3 Effect of modified fertilizers on nutrient use efficiency (%)

4.3.1 Nitrogen use efficiency: - The response of any fertilizer to plant determines its use efficiency. The NUE of the rice crop was presented in table 4.3.1 (a). NUE of rice crop was presented in fig 4.3.1 (a) and 4.3.1 (b). The highest value of NUE (35.74%, 36.12%) was obtained in T3 (NCU + PK + S + Zn-EDTA) which was followed by T5 (30.3, 31.2%) during 2018 and 2019. The NUE of T1 and T8 (29.85, 54.25% and 51, 25.5%) recorded significantly more as compared significantly more as compared to other treatments in which anhydrous ammonia used. The lowest nitrogen use efficiency (5.83,,6.12%) recorded in T2 (AA + PK) which was followed by T4 (9.76, 10.02%) during 2018 and 2019. In case of wheat the NUE range from 0 to 35.2% during 2018-2019 and 0 to 36.5% during 2019-2020. The highest NUE (35.2,36.5%) recorded in T3 (NUC + PK + S + Zn-EDTA) followed by T5 with 31.8 and 32.5% recorded during both years. The combination of (NCU + PK) T1 also recorded more NUE (29.6%, 30.02%) over other treatments. The lowest NUE (0.75, 0.78) recorded under T2 which was followed by T4 3.00 and 3.28%. The trend of NUE in wheat crop was (T3> T5> T1> T8> T7> T6> T4> T2> T0). The data presented in fig. 4.3.1c, d.

4.3.2 Phosphorous use efficiency: - Phosphorous use efficiency was significantly affected by the modified fertilizers in rice – wheat crop. The data of PUE presented in table 4.3.1 (a) and 4.3.1 (b). The scrutiny of data presented in table indicated that in rice crop the PUE ranged from 0 to 15.24% during 2018 and 0 to 16.80% during 2019. The maximum PUE (15.24, 16.80) recorded under T3 (NCU + PK + S + Zn-EDTA) which was followed by T5 (NCU + PK + ZnSO4) with 13.26 and 14.63%. The combination of (NCU + PK) T1 and (RDF + S + Zn-EDTA) T8 also recorded significantly more (10.81, 12.65) and (10.34, 10.66) PUE over other treatments. The lowest PUE (2.52, 2.6%) recorded in T2 (AA + PK recommended which was followed by T4 (3.30, 2.21%). The data presented in fig. 4.3.1 (a) and 4.3.2 (b). The PUE of wheat crop ranged from 0 to 58.95% during 2018-2019 and 0 to 55.27% during 2019-2020. The maximum PUE (58.95, 55.25% recorded with the application of NCU + PK + S + Zn-EDTA (T3) which was immediately followed by T5 with 45.61 and 46.06%. The minimum PUE (13.57, 12.11%) recorded under T2 (AA + PK). The data of PUE of wheat presented in fig.

4.3.2 (c) and 4.3.2 (d). The maximum order of PUE in wheat crop was T3> T5> T1> T8> T7> T6> T4> T2> T0.

4.3.1 A



4.3.1 B

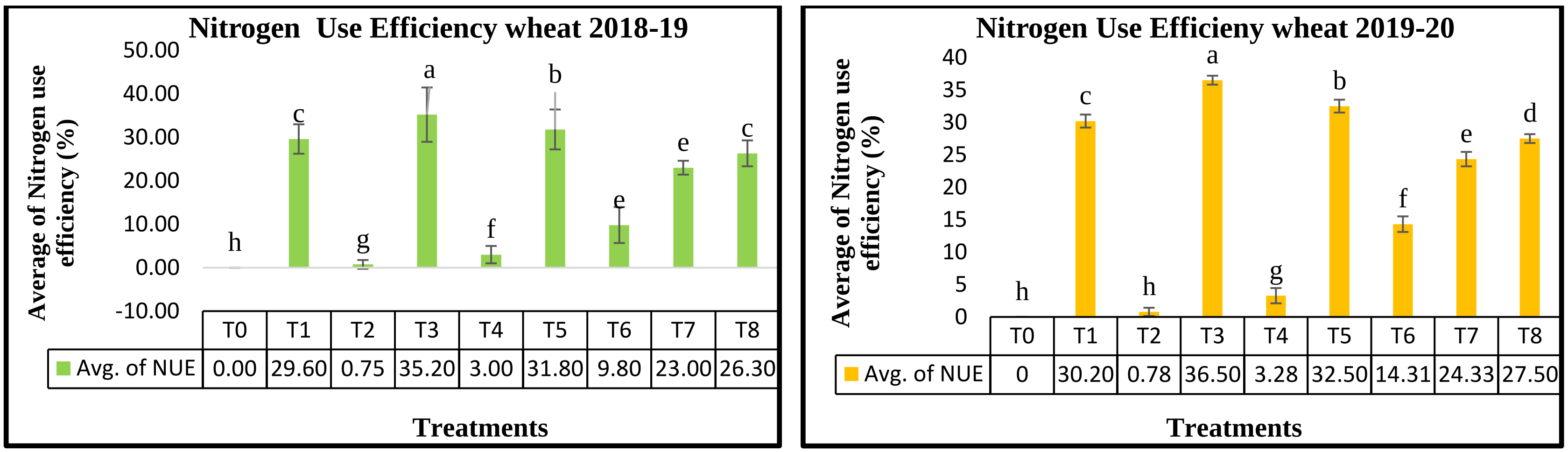


Fig.4.3.1 A&B, representing Nitrogen use efficiency(%) in rice and wheat crop during both years .Data shown as mean of S.E. Means with similar letters for each figure are not significantly different according to LSD at $p<0.05$.

4.3.2 A, B

4.3.2 C, D

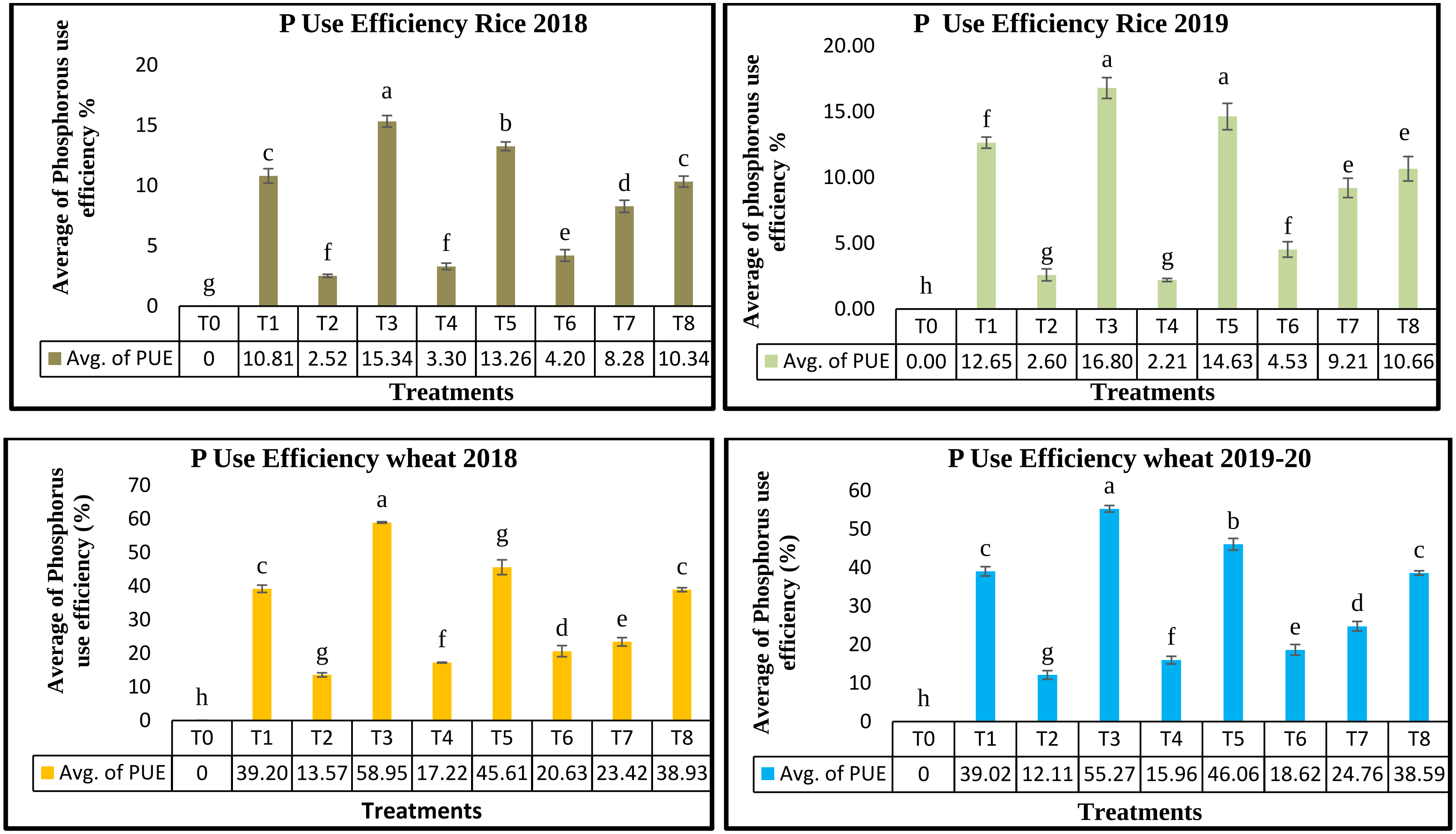


Fig.4.3.2 A&B, C&D representing Phosphorous use efficiency(%) in rice and wheat crop during both years .Data shown as mean of S.E. Means with similar letters for each figure are not significantly different according to LSD at $p<0.05$.

4.3.3 Potassium use efficiency: - The scrutiny of data presented in table 4.3.1(a) revealed that potassium use efficiency affected by use of modified fertilizers. The maximum KUE in rice crop (40.33,41.22%) recorded in T3 during 2018-2019. The second highest KUE recorded in T5 – 30.7%, 31.2% respectively during 2018 and 2019. T1 also recoded significantly more (25.83,26.5%) KUE. The lowest KUE over control recorded under T2 (6.83,7.02%). In case of wheat, the KUE ranged from 0 to 42.3% during 2018-2019 and 0 to 43.7% during 2019-2020. The highest KUE (42.3,43.7%) recorded under T3 which was followed by T5 with (37

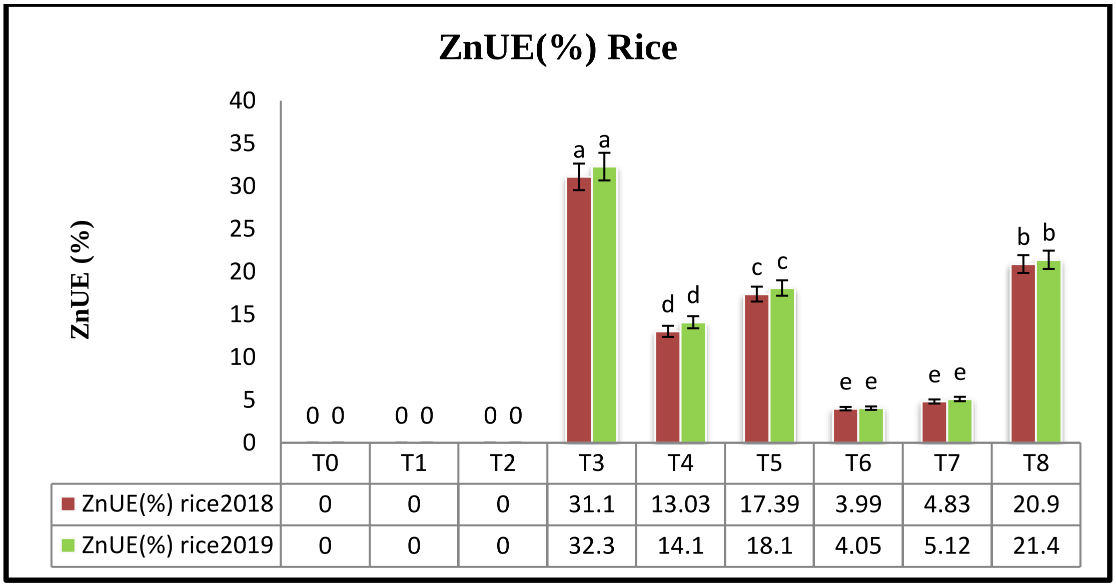
.5,40.8%) during 2018-2019 and 2019-2020. The lowest KUE (8.67, 5.50%) recorded under T2 which was followed by T4 with 13.44, 15.50%. The data presented in fig. 4.3.3 (a) and 4.3.3 (b) of rice crop and 4.3.3 (c) and 4.3.3 (d) of wheat crop. The order of KUE in wheat was T3> T5> T8> T1> T7> T6> T4> T2> T0.

4.3.4 Sulphur use efficiency: - The SUE recorded in those plots where **I** applied S over S not applied plots. The data of SUE presented in table 4.3.1 (a) and 4.3.1 (b). The SUE in case of rice crop ranged from 7.5 to 17% during 2018-2019 and 7.16 to 17.41% during 2019-2020. The maximum SUE recorded (17, 17.41%) in T3 (NCU + PK +S + Zn-EDTA) which was followed by T5 with 13.26, 16.09% during both years. The lowest SUE (7.5, 7.16%) recorded under T6 which was followed by T4 with 7.8, 7.99%). The data presented in fig. 4.3.4 (a), 4.3.4 (b). In case of wheat, SUE ranged from 7.11 to 17.48% and 1.10 to 17.72% during 2018-2019 and 2019-2020. The maximum SUE (17.48, 17.7%) recorded under T3 which was followed by T5 with 16.5, 16.63%. The minimum SUE (7.11, 7.10% recorded under T6 which was followed by T4 with 7.81, 7.29%. The date of wheat SUE depicted in fig. 4.3.4 (c) and 4.3.4 (d).

4.3.5 Zinc use efficiency: - The ZnUE recorded in those plots where **I** applied Zn over Zn not applied plots. The ZnUE in case of rice crop ranged from 4.83 to 31 % during 2018-2019 an4.05-32.3% during 2019-2020. The maximum SUE recorded (31.1,32.3%) in T3 (NCU + PK +S + Zn-EDTA) which was followed by T8 with 20.9,21.4% during both years. The lowest ZnUE 3.9,4.05%) recorded undeT6. %). The data presented in fig. 4.3.5 (a). In case of wheat, ZnUE ranged from 3.84 to 33.6% and 4.21-34.2% during 2018-2019 and 2019-2020. The maximum ZnUE (33.6,34.2%) recorded under T3 which was followed by T8 with 25.1, 26.12%.

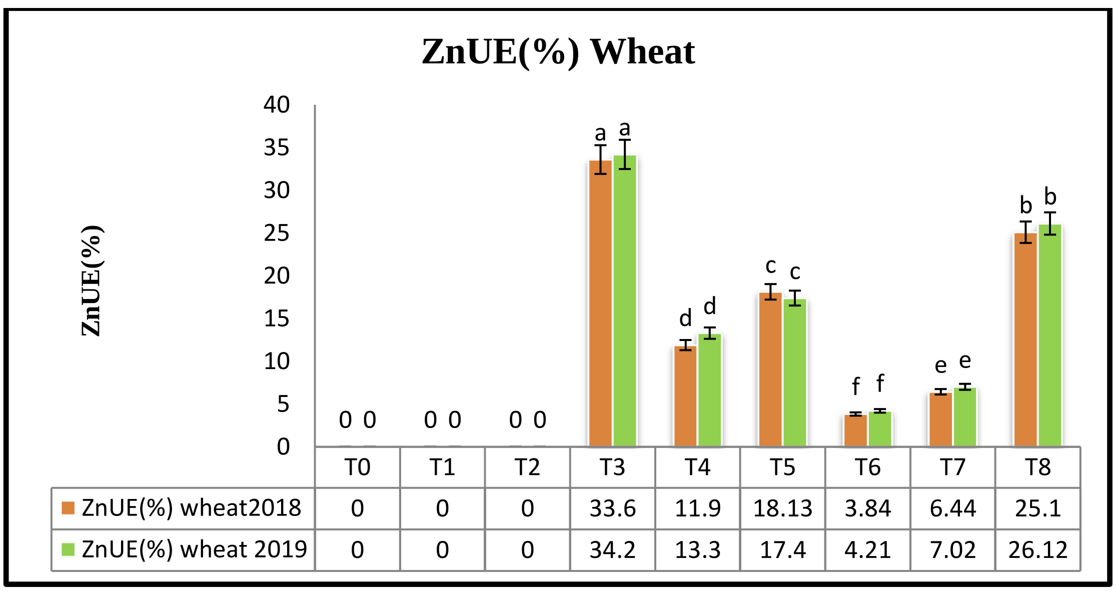
The minimum ZnUE (3.84,4.21% recorded under T6 which was followed by T4. The date of wheat SUE depicted in fig. 4.3.5 (b) .

4.3.5 a



	T0	T1	T2	T3	T4	T5	T6	T7	T8
ZnUE(%) rice2018	0	0	0	31.1	13.03	17.39	3.99	4.83	20.9
ZnUE(%) rice2019	0	0	0	32.3	14.1	18.1	4.05	5.12	21.4

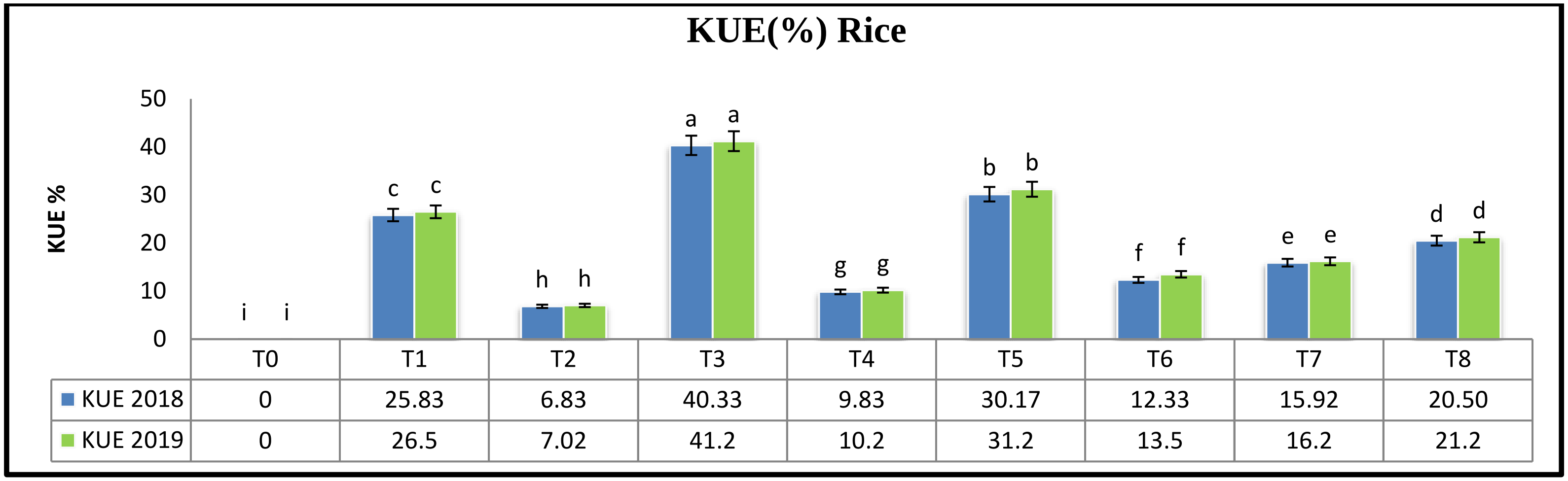
4.3.5 b



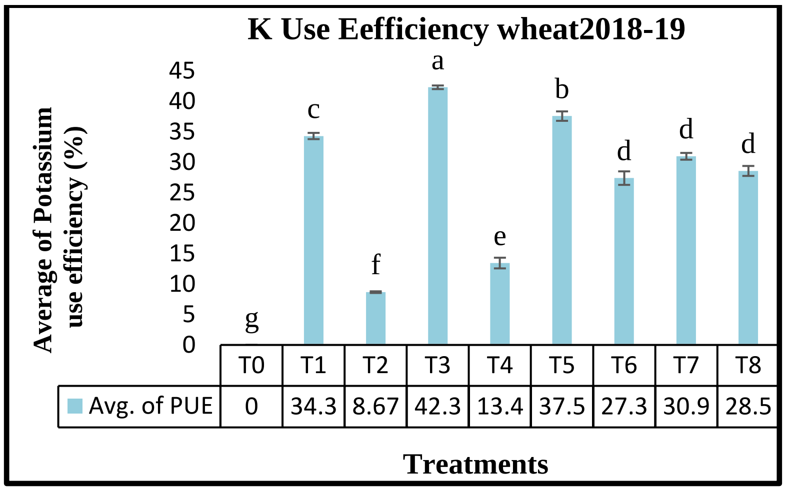
	T0	T1	T2	T3	T4	T5	T6	T7	T8
ZnUE(%) wheat2018	0	0	0	33.6	11.9	18.13	3.84	6.44	25.1
ZnUE(%) wheat 2019	0	0	0	34.2	13.3	17.4	4.21	7.02	26.12

Fig.4.3.5 A&B representingZinc use efficiency(%) in rice and wheat crop during both years. Data shown as mean of S.E. Means with similar letters for each figure are not significantly different according to LSD at $p<0.05$.

4.3.3 A



4.3.4b



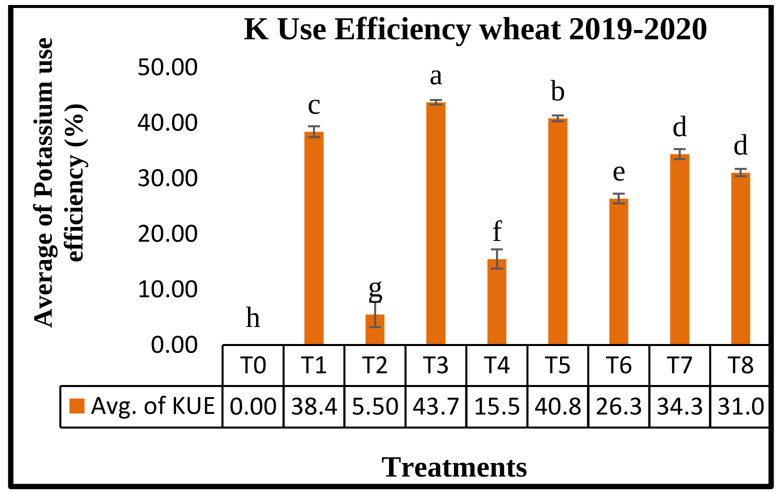


Fig.4.3.4 A&B representing Potassium use efficiency(%) in rice and wheat crop during both years .Data shown as mean of S.E. Means with similar letters for each figure are not significantly different according to LSD at $p<0.05$.

4.3.5 A, B

4.3.5 C, d

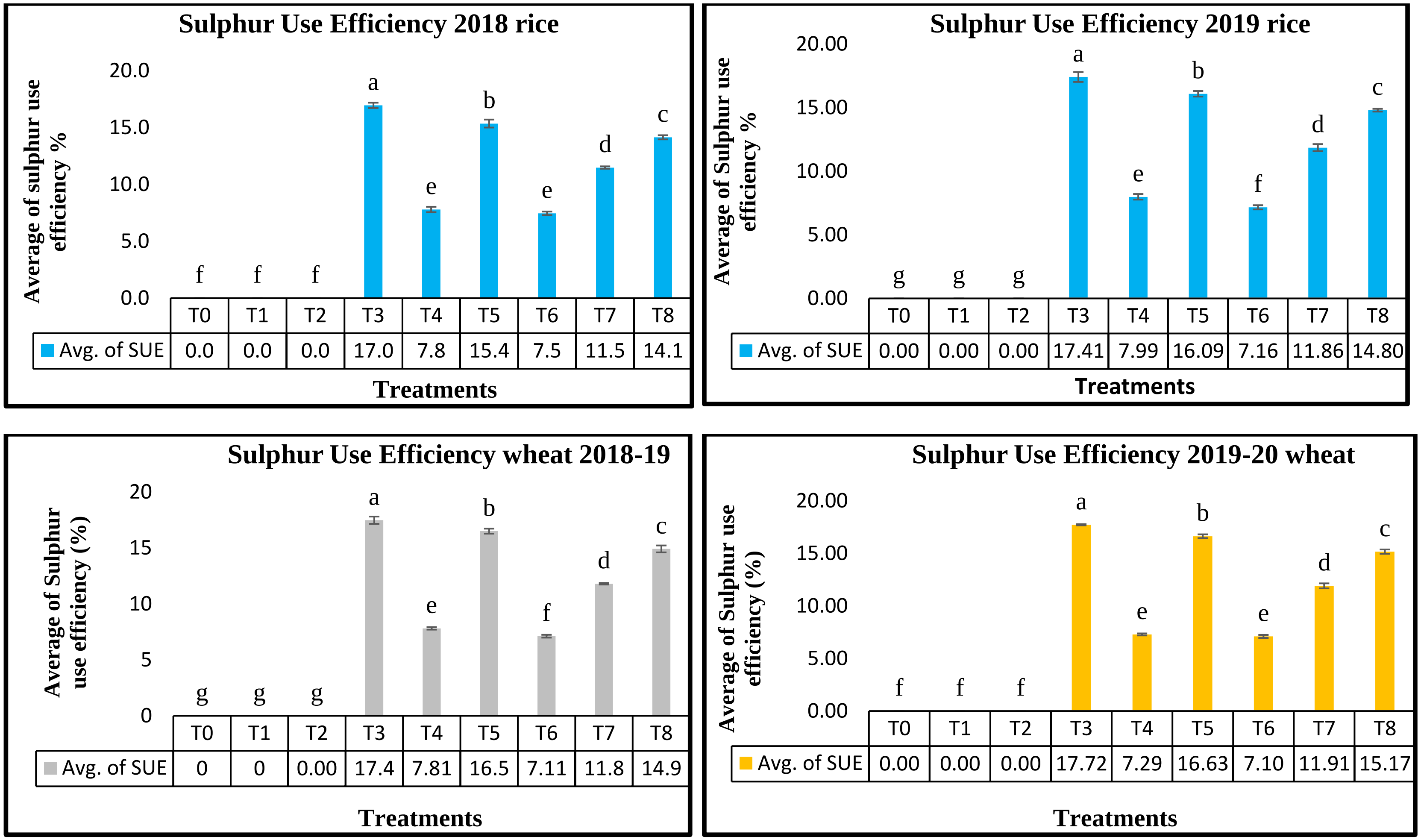


Fig.4.3.4 A&B, C&D representing Sulphur use efficiency(%) in rice and wheat crop during both years .Data shown as mean of S.E. Means with similar letters for each figure are not significantly different according to LSD at $p<0.05$

Table 4.3.4(a) Nutrient use efficiency (NUE%, PUE%, KUE %) of rice crop during 2018-2019(mean ± S.E).

Treatments	2018					2019				
	NUE (%)	**PUE (%)**	**KUE (%)**	**SUE (%)**	**ZnUE (%)**	**NUE (%)**	**PUE (%)**	**KUE (%)**	**SUE (%)**	**ZnUE (%)**
T0- Control (RDF)	0.00±0.00d	0±0g	0.0±0.0i	0.0±0.0f	0.0±0.0	0.00±0.00i	0.00±0.00h	0.00±0.00h	0.00±0.00g	0.00±0.00
T1 - Neem coated urea +PK recommended	29.85±0.74ab	10.81±0.60c	25.83±1.79c	0.0±0.0f	0.0±0.0	30.12±1.55c	12.65±0.42c	26.5±1.11c	0.00±0.00g	0.00±0.00
T2 - Anhydrous ammonia+ PK recommended	5.83±1.05de	2.52±0.13f	6.83±0.94h	0.0±0.0f	0.0±0.0	6.12±2.14h	2.6±0.56g	7.02±2.61g	0.00±0.00g	0.00±0.00
T3 - Neem coated urea+ PK+S+ Zn-EDTA	35.74±2.20a	15.34±0.48a	40.33±0.50a	17.0±0.23a	31.1±0.23a	36.12±1.78a	16.80±0.79a	41.2±1.32a	17.41±0.39a	32.3±0.39a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	9.76±2.57bc	3.30±0.27f	9.83±1.68g	7.8±0.24e	13.03±0.24d	10.0±3.27g	2.21±0.12g	10.2±3.14g	7.99±0.22e	14.1±0.22d
T5- Neem coated urea + PK + $ZnSO_4$	30.3±2.40ab	13.26±0.36b	30.17±1.34b	15.4±0.35b	17.39±0.35c	31.2±1.41b	14.63±1.00a	31.2±2.83b	16.09±0.22b	18.1±0.22c
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	13.28±1.64bc	4.20±0.48e	12.33±1.33f	7.5±0.15e	3.99±0.15e	14.2±1.76f	4.53±0.59f	13.5±3.00f	7.16±0.17f	4.05±0.17e
T7 - RDF + $ZnSO_4$	21.44±0.87ab	8.28±0.50d	15.9±0.33e	11.5±0.10d	4.83±0.10e	22.3±1.07e	9.21±0.73e	16.2±0.45e	11.86±0.28d	5.12±0.28e
T8 - RDF+ S+ Zn-EDTA	25.5±1.01bc	10.34±0.45c	20.5±2.37d	14.1±0.18c	20.9±0.18b	26.2±1.82d	10.66±0.93d	21.2±2.43d	14.80±0.11c	21.4±0.11b

Table 4.3.4(b) Nutrient use efficiency (NUE%, PUE%, KUE %) in wheat crop during 2018-19 (mean ± S.E)

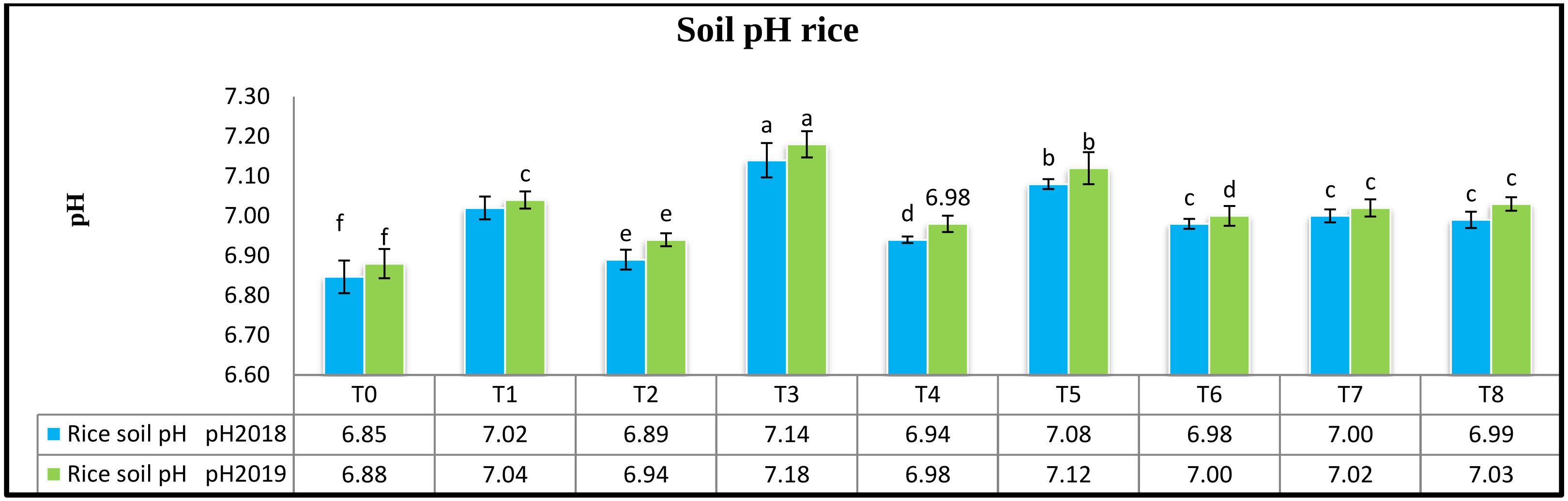
Treatments	2018				2019			
	NUE (%)	**PUE (%)**	**KUE (%)**	**ZnUE (%)**	**NUE (%)**	**PUE (%)**	**KUE (%)**	**ZnUE (%)**
T0- Control (RDF)	0.00±0.00h	0±0h	0±0h	0.0±0.0	0±0.00h	0±0h	0.00±0.00h	0.00±0.00
T1 - Neem coated urea + PK recommended	29.6±2.53c	39.20±1.10c	34.3±1.23c	0.0±0.0	30.2±1.00c	39.02±1.21c	38.4±1.02c	0.00±0.00
T2 - Anhydrous ammonia + PK recommended	0.75±0.12g	13.57±0.62g	8.67±0.14g	0.0±0.0	0.78±0.64h	12.11±1.12g	5.50±2.27g	0.00±0.00
T3 - Neem coated urea + PK + S + Zn-EDTA	35.2±0.47a	58.95±0.21a	42.39±0.42a	33.6.1±0.23a	36.5±0.69a	55.27±0.86a	43.7±0.70a	34.2±0.39a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	3.00±1.20f	17.22±0.12f	13.44±0.87f	11.9±0.24d	3.28±1.17g	15.96±1.00f	15.50±1.74f	13.3±0.22d
T5- Neem coated urea + PK + $ZnSO_4$	31.8±1.51b	45.61±2.20b	37.5±0.89b	18.13±0.35c	32.5±1.00b	46.06±1.52b	40.8±1.58b	17.4±0.22c
T6- Anhydrous ammonia + PK + $ZnSO_4$	9.8±1.63e	20.63±1.66e	27.39±1.11e	3.84±0.15e	14.31±1.20f	18.62±1.39e	26.39±0.87e	4.20±0.17e
T7 - RDF + $ZnSO_4$	23.00±0.54d	23.42±1.25d	30..97±2.29d	6.44±0.10e	24.33±1.11e	24.76±1.25d	34.39±0.91d	7.02±0.28e
T8 – RDF + S + Zn-EDTA	26.3±1.30c	38.93±0.59c	28.50±0.62c	25.1±0.18b	27.5±0.68d	38.59±0.57c	31±1.23c	26.12±0.11b

4.4 Effect of modified fertilizer on soil physiochemical properties

4.4.1 pH: - The data pertaining to pH of soil presented in table 4.4.1 (a) and 4.4.1 (b). The study on soil pH revealed that soil pH was significantly among all treatments. Highest pH was found in T3 (7.14) followed by T5 (7.08). The lowest pH 6.85 was found inT0 during 2018 rice crop. In following season wheat crop, the highest pH (7.15) recorded in T3 which was followed by T5 with 7.10 pH value. Treatments T1 and T8 also recorded more pH (7.02, 6.99) over other treatments. The lowest pH recorded (6.87) under T0 which was followed by T2 with 6.92 pH. During 2019 rice crop maximum pH (7.18) recorded in T3 followed by T5 (7.15) .The lowest pH (6.88) recorded in T0. In consecutive wheat crop, maximum pH (7.21) recorded in T3 which was following by T5 with 7.15 pH. The lowest pH (6.92) recorded in T0. The data of rice and wheat pH depicted in fig. 4.4.1 (a) and 4.4.1 (b).

4.4.2 EC: - The total soluble salt content expressed as electrical conductivity (dSm^{-1}). The EC values were expressed in table 4.4.1 (a) and 4.4.1 (b). The higher EC (0.42 dSm^{-1}) recorded in T3 followed by T5, T8 with 0.36 dSm^{-1} EC. The minimum EC 0.20 dSm^{-1} recorded under T0, T2.In succeeding wheat crop, significantly highest EC 0.40 dSm^{-1} recorded due to T3 which was followed by T5 with 0.36 dSm^{-1} EC which was at par with T8 having 0.35 dSm^{-1} EC. The lowest EC recorded (0.22 dSm^{-1}) in T0, T4 which was at par with T1, T2, having EC 0.24, 0.25, 0.25 dSm^{-1} respectively. In 2019 rice crop significantly highest EC (0.40 dSm^{-1}) recorded in T3 which was at par with T5 with 0.37 dSm^{-1}. Which was followed by T8 with 0.32 dSm^{-1}. The lowest EC (0.19) recorded in T2, T4. In consecutive wheat crop of 2019, the highest EC (0.43 dSm^{-1}) recorded in T3 which was at par with T5 with 0.41 dSm^{-1} EC. The lowest EC recorded in T2 (0.23 dSm^{-1}). The data of rice wheat EC depicted in fig. 4.4.2 (a) and 4.4.2 (b).

4.4.1 A, B



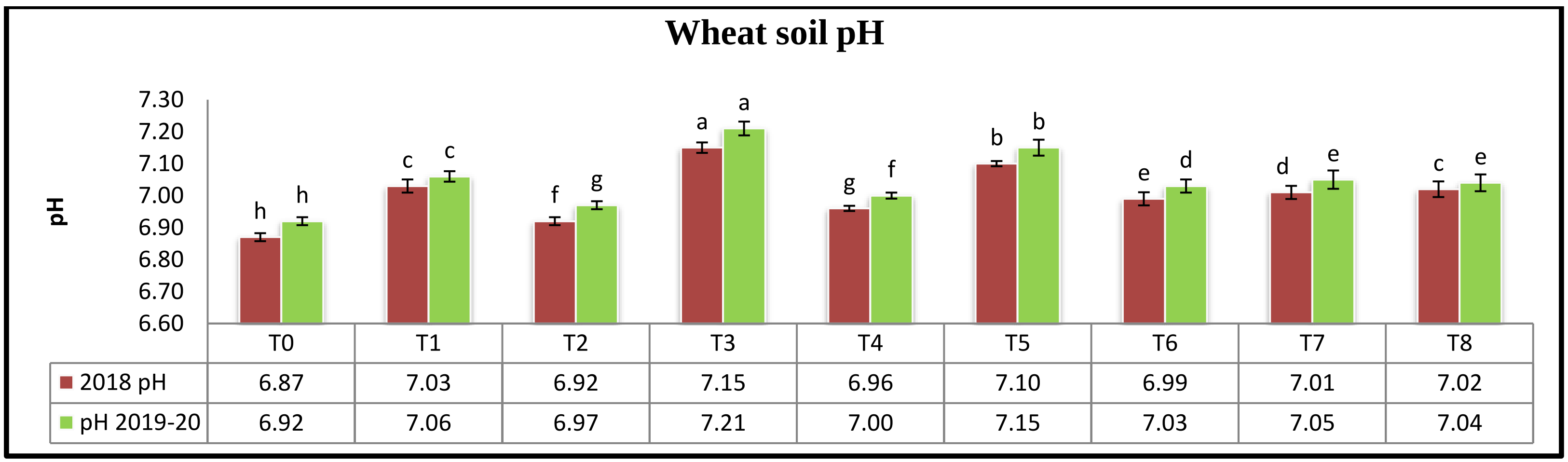
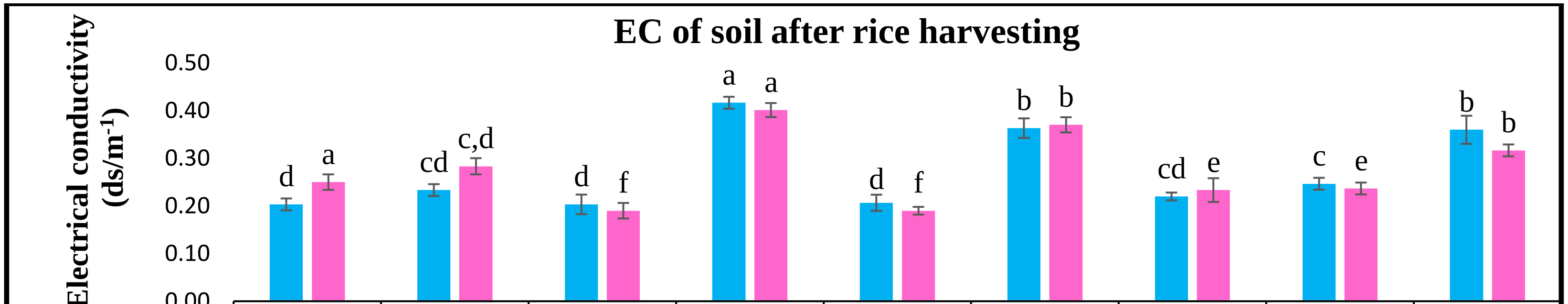
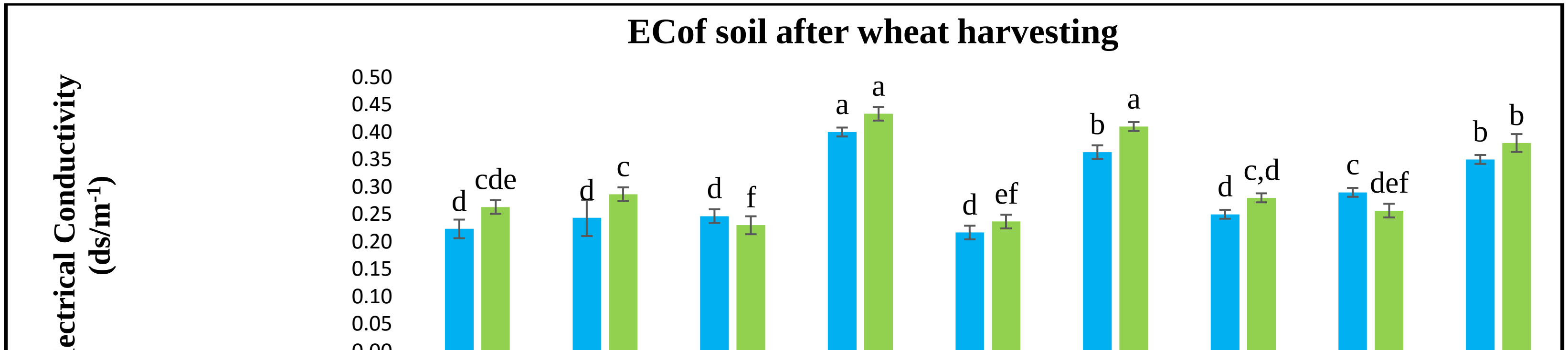


FIG 4.4.1(A, B) representing effect of modified fertilizers on pH (mean± S.E) of soil after harvesting of rice –wheat crop during 2018- 2019 &2019-2020.

4.4.2 A, B



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 2018 EC	0.20	0.23	0.20	0.42	0.21	0.36	0.22	0.25	0.36
Avg. of 2019 EC	0.25	0.28	0.19	0.40	0.19	0.37	0.23	0.24	0.32



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 2019 EC	0.22	0.24	0.25	0.40	0.22	0.36	0.25	0.29	0.35
Avg. of 2020 EC	0.26	0.29	0.23	0.43	0.24	0.41	0.28	0.26	0.38

Fig 4.4.2 (A,B) representing the impact of modified fertilizers on EC(dSm^{-1}) of soil after harvesting of rice- wheat crop of 2018-19&2019-2020. Different letters above the error bars indicate treatments are significantly different according to DMRT ($p < 0.05$)

Table 4.4.1 (a) Effect of modified fertilizers on pH and EC (mean ± S.E) of soil after harvesting of rice crop during 2018-2019.

Treatments	2018			2019		
	pH	**EC dSm^{-1}**	**OC (%)**	**pH**	**EC dSm^{-1}**	**OC (%)**
T0- Control (RDF)	6.85±0.01f	0.20±0.01d	0.40±0.01e	6.88±0.02f	0.25±0.02a	0.44±0.01g
T1 - Neem coated urea +PK recommended	7.02±0.02c	0.23±0.01cd	0.49±0.01b	7.04±0.10c	0.28±0.02cd	0.53±0.01c
T2 - Anhydrous ammonia+ PK recommended	6.89±0.02e	0.20±0.02d	0.42±0.01d	6.94±0.02e	0.19±0.02f	0.46±0.02f
T3 - Neem coated urea+ PK+S+ Zn-EDTA	7.14±0.02a	0.42±0.01a	0.54±0.01a	7.18±0.02a	0.40±0.01a	0.59±0.02a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	6.94±0.01d	0.21±0.02d	0.43±0.02d	6.98±0.02d	0.19±0.01f	0.48±0.01e
T5 Neem coated urea +PK+$ZnSO_4$	7.14±0.02b	0.36±0.02b	0.51±0.01b	7.12±0.03b	0.37±0.02b	0.56±0.01b
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	6.94±0.02c	0.22±0.01cd	0.43±0.01d	7.00±0.0d	0.23±0.02e	0.48±0.01e
T7 - RDF + $ZnSO_4$	7.08±0.02c	0.25±0.01c	0.47±0.01c	7.02±0.01c	0.24±0.01e	0.50±0.01d
T8 - RDF+ S+ Zn-EDTA	6.98±0.02c	0.36±0.03b	0.45±0.01d	7.03±0.01c	0.32±0.01b	0.51±0.01d

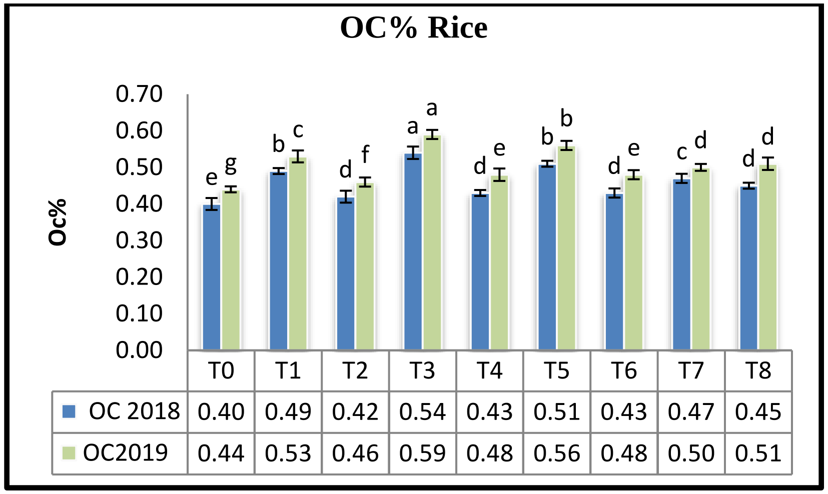
Table 4.4.1 (b) Effect of modified fertilizers on pH and EC (mean ± S.E) of soil after harvesting of wheat crop during 2018-2019&2019-2020.

Treatments	**2018**			**2019**		
	pH	**EC dSm^{-1}**	**OC (%)**	**pH**	**EC dSm^{-1}**	**OC (%)**
T0- Control (RDF)	6.87±0.02h	0.22±0.02d	0.42±0.01f	6.92±0.01h	0.26±0.01cde	0.46±0.01f
T1- Neem coated urea + PK recommended	7.03±0.02c	0.24±0.03d	0.51±0.01c	7.06±0.02c	0.29±0.01c	0.53±0.01c
T2- Anhydrous ammonia + PK recommended	6.92±0.01f	0.25±0.01d	0.44±0.01e	6.97±0.02g	0.23±0.02f	0.48±0.02e
T3- Neem coated urea + PK + S + Zn-EDTA	7.15±0.02a	0.40±0.01a	0.57±0.04a	7.21±0.01a	0.43±0.01a	0.6±0.16a
T4- Anhydrous ammonia + PK + S + Zn-EDTA	6.96±0.02g	0.22±0.01d	0.45±0.01e	7.00±0.02f	0.24±0.01ef	0.50±0.01d
T5- Neem coated urea + PK + $ZnSO_4$	7.10±0.03b	0.36±0.01b	0.54±0.02b	7.15±0.01b	0.41±0.01a	0.58±0.01b
T6- Anhydrous ammonia + PK + $ZnSO_4$	6.99±0.01e	0.25±0.01d	0.46±0.02e	7.03±0.02d	0.28±0.01cd	0.49±0.01e
T7- RDF + $ZnSO_4$	7.01±0.04d	0.29±0.01c	0.49±0.02d	7.05±0.03e	0.26±0.01def	0.51±0.01d
T8- RDF+ S+ Zn-EDTA	7.02±0.04c	0.35±0.01b	0.48±0.01d	7.04±0.02e	0.38±0.02b	0.52±0.02d

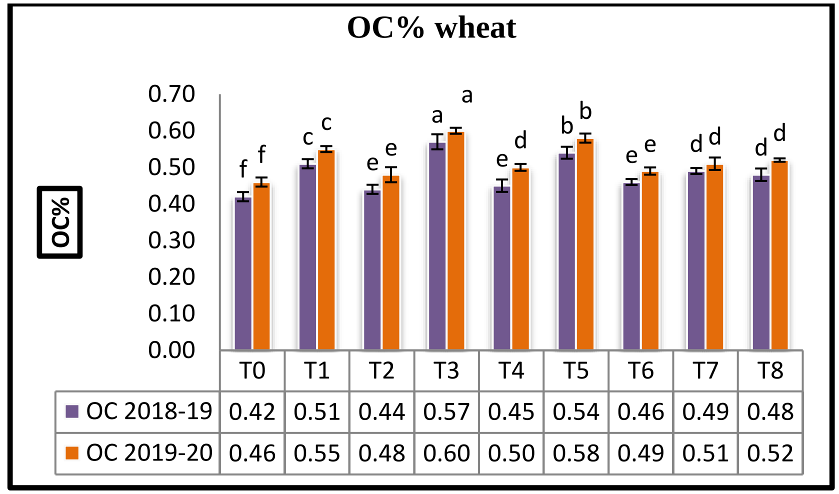
4.4.3 Organic carbon (%): - Soil organic carbon (%) data depicted in table indicated that organic carbon (%) was significantly affected by modified fertilizers. In case of rice crop, maximum organic (0.54, 0.59%) recorded with application of NCU + PK + S + Zn-EDTA (T3) during 2018-2019. The second highest organic carbon (%) – 0.51, 0.56 found in T5 (NCU + PK + $ZnSO_4$) which was followed by T1 with 0.49, 0.53% O.C. The minimum OC% (0.40, 0.44%) recorded under T0 which was followed by T2 with 0.42, 0.46% respectively during both years. The maximum order of O.C% in rice crop was T3> T5> T8> T1> T7> T6> T4> T2> T0 depicted in fig 4.4.3(a). In case of wheat crop the maximum O.C (0.57,0.60%) recorded with the application of NCU + PK + S +Zn-EDTA (T3) which was followed by T5 with 0.54,0.58% O.C and again followed by T1 with 0.51, 0.55%. The lowest O.C% (0.42, 0.46) recorded under T0 which was followed by T2 with 0.44, 0.48% O.C. The order of O.C in wheat was T3> T5> T8> T1> T7> T6> T4> T2> T0 as depicted in fig. 4.4.3(b).

4.4.4 Available N: - The soil available N content in soil was significantly influenced by the application of modified fertilizers (Table 4.4.4 (a) and 4.4.4 (b). It is observed from table 4.4.4 (a) that available N in soil after harvest of 2018 and 2019 rice, was found significantly higher in treatment T3(24.63, 255 kg ha^{-1}) followed by T5(227.62, 252 kg ha^{-1}). During both years the minimum available N was found under T2 (167. 10, 172 kg ha^{-1}) .The order of available N in soil- T3>, T5> T8> T1> T7> T0> T4> T6> T2. In case of wheat, the available N in soil significantly affected by various combination of modified fertilizers during both years. The significantly maximum available N (266.6, 276 $Kgha^{-1}$) recorded in T3 followed by T5 with 260, 270 $kgha^{-1}$. The treatment T8 and T1 also recorded significant more (247, 250), (245.83, 246) N Kg ha^{-1} in soil during 2018-2019 and 2019-2020. The lowest available N (176.5, 183.67 N Kg ha^{-1}) recorded under T2 which was followed by T4 (199, 204 Kg ha^{-1}) during both years. The data of available N in rice – wheat presented in fig 4.4.4 (a) and 4.4.4 (b).

4.4.3 A, B

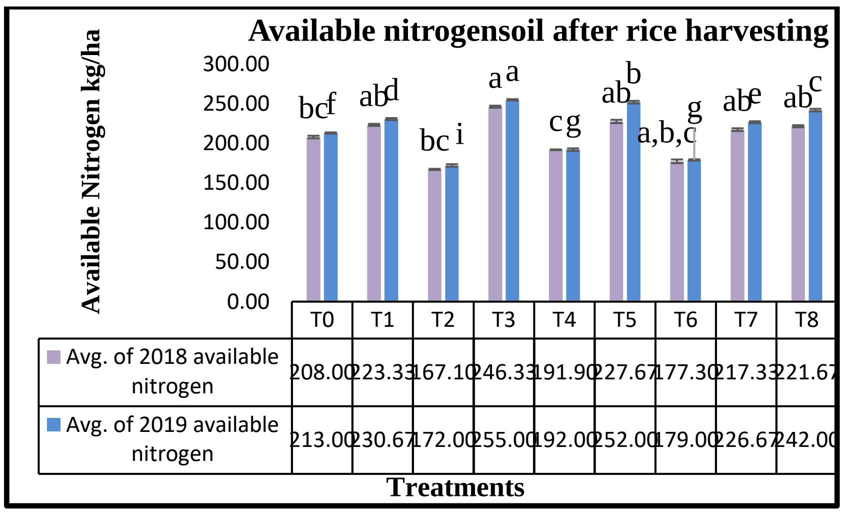


	T0	T1	T2	T3	T4	T5	T6	T7	T8
OC 2018	0.40	0.49	0.42	0.54	0.43	0.51	0.43	0.47	0.45
OC2019	0.44	0.53	0.46	0.59	0.48	0.56	0.48	0.50	0.51

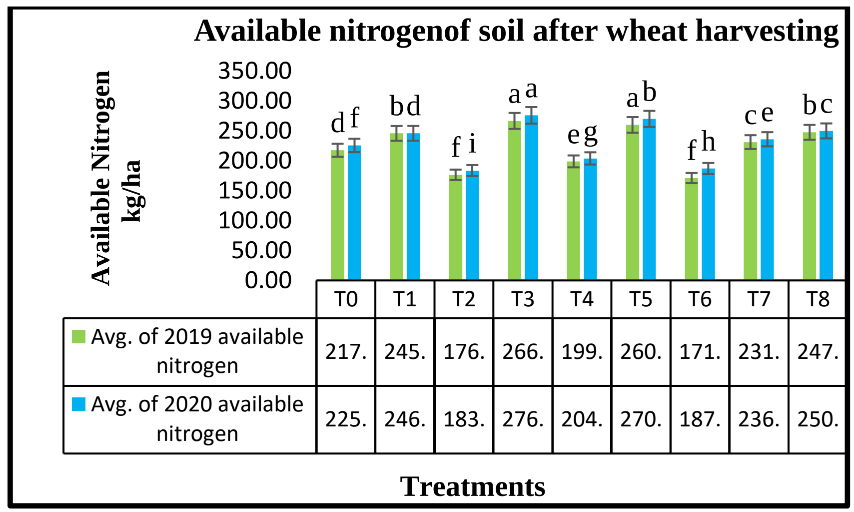


	T0	T1	T2	T3	T4	T5	T6	T7	T8
OC 2018-19	0.42	0.51	0.44	0.57	0.45	0.54	0.46	0.49	0.48
OC 2019-20	0.46	0.55	0.48	0.60	0.50	0.58	0.49	0.51	0.52

4.4.4 A, B



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 2018 available nitrogen	208.00	223.33	167.10	246.33	191.90	227.67	177.30	217.33	221.67
Avg. of 2019 available nitrogen	213.00	230.67	172.00	255.00	192.00	252.00	179.00	226.67	242.00



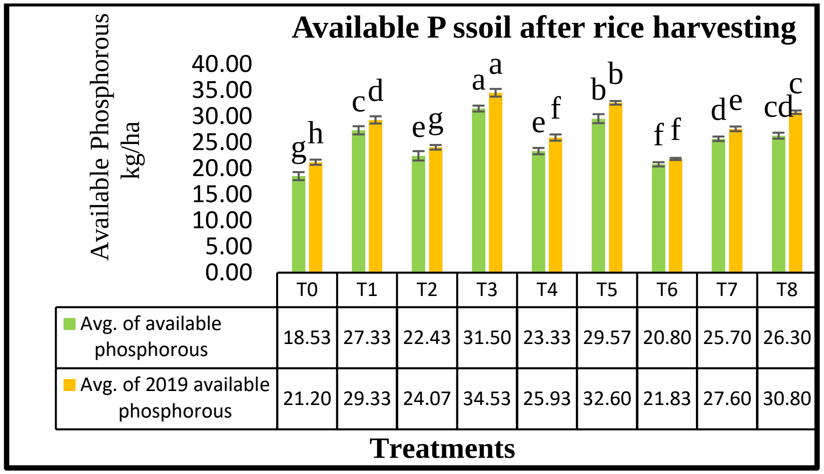
	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 2019 available nitrogen	217.	245.	176.	266.	199.	260.	171.	231.	247.
Avg. of 2020 available nitrogen	225.	246.	183.	276.	204.	270.	187.	236.	250.

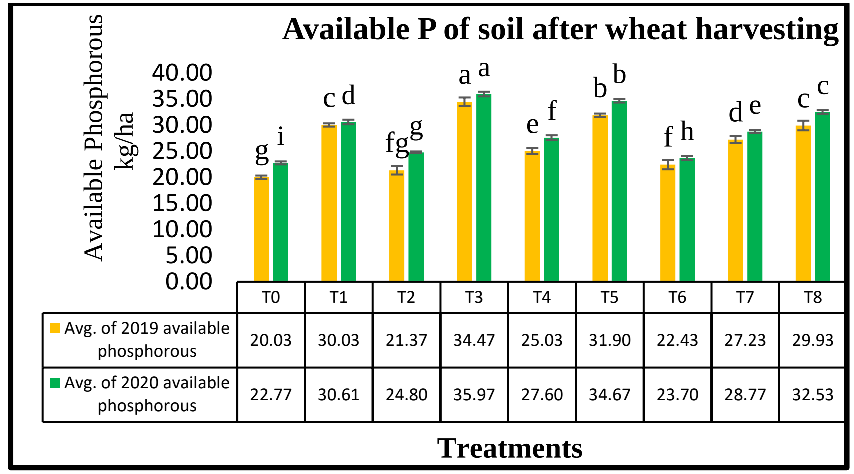
Fig. 4.4.3 (A,B) representing Organic carbon(%) and FIG. 4.4.4(A, B) depicting soil available Nitrogen (Kgha-1) after the application of modified fertilizers after the harvesting of rice- wheat crop during 2018-2019& 2019-2020. Common letters indicate that means are not significantly different according to DMRT ($p<0.05$).

4.4.5 Available Phosphorous Kg ha^{-1}: - Significant differences in changes of available P were found among treatments during 2018-2019. The date of available P in rice – wheat presented in fig. 4.4.4 (a) and 4.4.4 (b). The available P content was significantly affected by various combinations of modified fertilizers. It is revealed from the table 4.4.4 (a) that available P in soil after harvest of rice was found significantly higher in T3(31.5, 34.53 Kg ha^{-1})followed by T5 –(29.57, 32.6 Kg ha^{-1}) [1]. The lowest available P (18.53, 21.2 Kg ha^{-1}) found under T0 which was followed by T2 (22.43, 24.07 Kg ha^{-1}). The date of available P was depicted in fig. 4.4.5 (a). In case of wheat crop during both years the application of NCU + PK + S + Zn-EDTA (T3) significantly increased the availability of P (34.47, 35.97 Kg ha^{-1}). The second highest available P (31.9, 34.67 Kg ha^{-1}) recorded in T5 – NCU + PK + ZnSO4 which was at par with T1 with 30.03, 30.6 Kg ha^{-1} P. The lowest P (20.03, 22.77 Kg ha^{-1}) recorded under T0. The data of availability of P was depicted in fig 4.4.5(b). The trend followed in available P in wheat T3>T5>T8>T1>T7>T0>T6>T4 >T2.

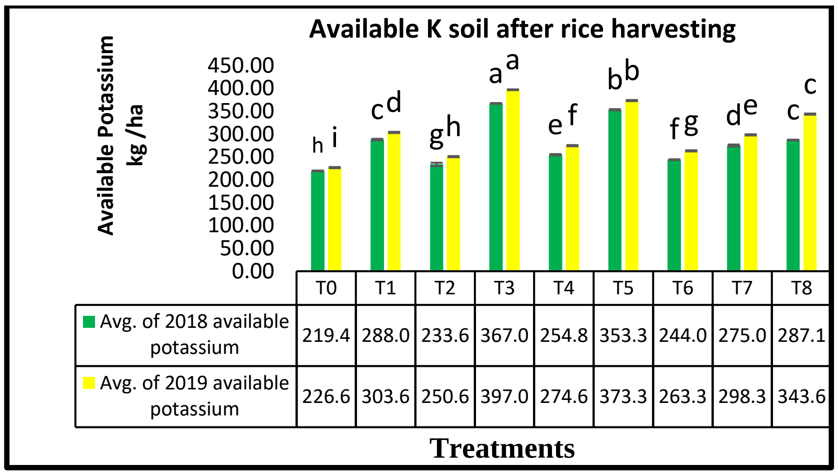
4.4.6 Available Potassium (Kg ha^{-1}): - Available K in soil was significantly different from each other during both years (Table 4.4.4(a, b), Fig. 4.1.6(a) and 4.4.6(b). After harvesting rice in 2018, the highest available K (367 kg ha^{-1}) was found in T3 .The second highest available K (355.3) was found was found in T5 .The lowest available K was recorded in T0 (control)-287kg ha^{-1}.The other treatments were statistically comparable with control. After succeeding wheat crop, highest available K was recorded in T3 (399.43kg ha^{-1}) followed by T5 (377.3 kg ha^{-1}). The lowest available K (224kgha$^{-1)}$ was recorded in T0. All the treatments were significantly comparable to control. In the next year again T3 (397 kg ha^{-1}) recorded highest available K. The second highest available K was found in T7 (373.3kg ha^{-1}) .The lowest potassium was recorded in T0 (226 kgha^{-1}).The order of maximum available K was T3>T5>T8>T1>T7>T6>T4>T2>T0. After the consecutive wheat crop control recorded lowest available K (227 Kgha^{-1}) and maximum available K (407kg ha^{-1}) recorded in T3followed by T5. All other treatments gave more available K as compared to control. The order of highest available K in soil after wheat harvest was - T3>T5>T8>T1>T7>T6>T4>T2>T0. The data of available K depicted in fig 4.4.6 (b)

4.4.5 A, B





4.4.6A, B



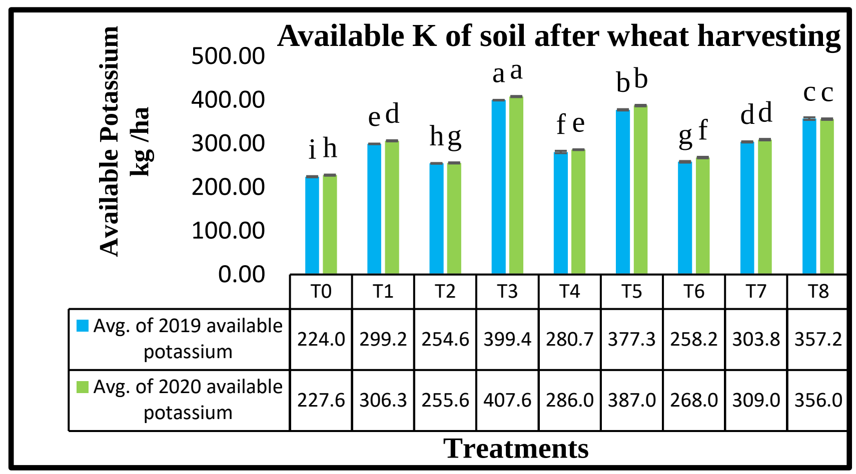


Fig 4.4.5(A, B) depicting available phosphorous and Fig. 4.1.6 (a, b) depicting soil available potassium (Kgha-1) after the application of modified fertilizers after the harvesting of rice- wheat crop during 2018-2019& 2019-2020. Different letters indicate that means are significantly different according to DMRT ($p<0.05$).

Table 4.4.4(a) Effect of modified fertilizers on soil available N, P and K (kg ha_{-1}) (mean± S.E) after harvesting of two seasons of rice crop 2018-19.

Treatments	**2018**			**2019**		
	Available N kgha^{-1}	**Available P kgha^{-1}**	**Available K kgha^{-1}**	**Available N kgha^{-1}**	**Available P kgha^{-1}**	**Available K kgha^{-1}**
T0- Control (RDF)	208.00±1.63ab	18.53±0.77g	219.40±0.83h	213.00±0.82f	21.20±0.50h	226.67±1.25i
T1 - Neem coated urea +PK recommended	223.33±1.25ab	27.33±0.78c	288.00±1.63c	230.67±1.25d	29.33±0.69d	303.67±1.25d
T2 - Anhydrous ammonia+ PK recommended	167.10±0.70bc	22.43±0.90e	233.63±3.64g	172.00±1.63i	24.07±0.45g	250.67±1.25h
T3 - Neem coated urea+ PK+S+ Zn-EDTA	246.33±1.25a	31.50±0.57a	367.00±0.82a	255.00±0.82a	34.53±0.74a	397.00±0.82a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	191.90±0.40c	23.33±0.61e	254.87±1.38e	192.00±1.63g	25.93±0.60f	274.67±1.25f
T5 Neem coated urea +PK+$ZnSO_4$	227.67±2.05ab	29.57±0.86b	353.33±1.25b	252.00±1.63b	32.60±0.36b	373.33±1.25b
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	177.30±2.33abc	20.80±0.41f	244.00±0.82f	179.00±0.82g	21.83±0.21g	263.33±1.25g
T7 - RDF + $ZnSO_4$	217.33±1.70ab	25.70±0.43d	275.00±2.16d	226.67±1.25e	27.60±0.45e	298.33±1.25e
T8 - RDF+ S+ Zn-EDTA	221.67±1.25ab	26.30±0.57cd	287.10±0.70c	242.00±1.63c	30.80±0.33c	343.67±1.25c

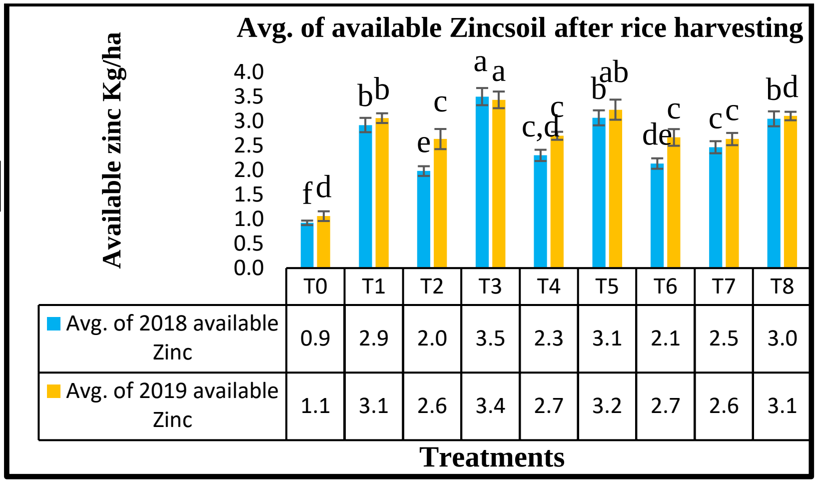
Table 4.4.4(b) Effect of modified fertilizers on soil available N, P and K (kg ha^{-1}) (mean± S.E) after harvesting of wheat crop during 2018-2019 and 2019-2020.

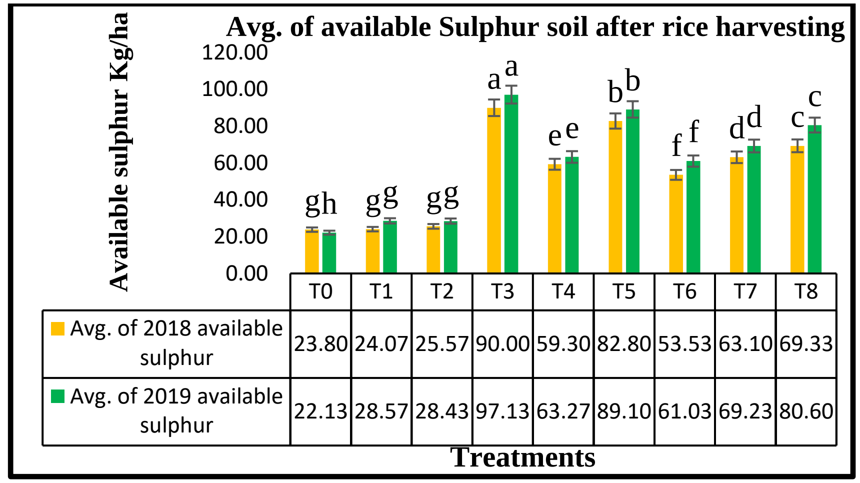
Treatments	**2018**			**2019**		
	Available N kgha^{-1}	**Available P kgha^{-1}**	**Available K kgha^{-1}**	**Available N kgha^{-1}**	**Available P kgha^{-1}**	**Available K kgha^{-1}**
T0- Control (RDF)	217.67±1.25d	20.03±0.31g	224.07±1.28i	225.67±1.25f	22.77±0.29i	227.67±1.25h
T1 - Neem coated urea + PK recommended	245.83±1.28b	30.03±0.31c	299.27±0.68e	246.000.82d	30.61±0.45d	306.33±1.25d
T2 - Anhydrous ammonia + PK recommended	176.50±1.15f	21.37±0.82fg	254.60±0.82h	183.67±1.25i	24.80±0.16g	255.67±1.25g
T3 - Neem coated urea + PK + S + Zn-EDTA	266.67±1.70a	34.47±0.84a	399.43±0.65a	276.00±1.63a	35.97±0.45a	407.67±1.25a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	199.00±0.82e	25.03±0.60e	280.77±2.63f	204.00±1.63g	27.60±0.45f	286.00±0.82e
T5- Neem coated urea + PK + $ZnSO_4$	260.00±1.63a	31.90±0.33b	377.33±1.47b	270.00±1.63b	34.67±0.33b	387.00±1.63b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	171.10±1.493f	22.43±0.90f	258.20±1.76g	187.00±1.63h	23.70±0.37h	268.00±1.63f
T7 - RDF + $ZnSO_4$	231.20±0.82c	27.23±0.68d	303.80±1.30d	236.00±1.63e	28.77±0.29e	309.00±1.63d
T8 - RDF+ S+ Zn-EDTA	247.63±2.62b	29.93±0.93c	357.20±2.94c	250.00±1.63c	32.53±0.34c	356.00±1.63c

4.4.7 Available Sulphur Kg ha^{-1}: - The date of available Sulphur presented in table 4.4.7 (a) and 4.4.7 (b). The scrutiny of date in table 4.4.7 (a) indicated that, the available Sulphur in soil after harvesting was significantly affected. The significantly highest available sulphur (**90**, 97.13 Kg ha^{-1}) recorded under T3 followed by T5 with 82.8, 89.10 Kg ha^{-1} sulphur during 2018 and 2019 rice crop. The minimum available Sulphur (23.8, 22.13 Kg ha^{-1}) observed under T0 which was at par with T1, T2 (24.07, 25.57 Kg ha^{-1}) during 2018 and followed by T1 and T2 during 2019 (28.57, 28.43 Kg ha^{-1}) .The data of available Sulphur in rice presented in fig 4.4.7 (a). In case of wheat crop the highest available Sulphur (95.50, 101.7 Kg ha^{-1})in T3 during 2018-2019 and 2019-2020. Second highest availability of sulphur (91.37, 96.43 Kg ha^{-1}) recorded in T5 which was followed by T8 (76.47, 85.17 Kg ha^{-1} S) during 2018-2019, 2019-2020. The lowest available sulphur in soil (25.63, 25.57 Kg ha^{-1}) recorded in T0 which was at par with T1, T2 (26.07, 26.63 Kg ha^{-1}) during first years and followed by T1, T2 (26.6, 27.37 Kg ha^{-1}) during 2019-2020. The data presented in fig. 4.4.7 (b).

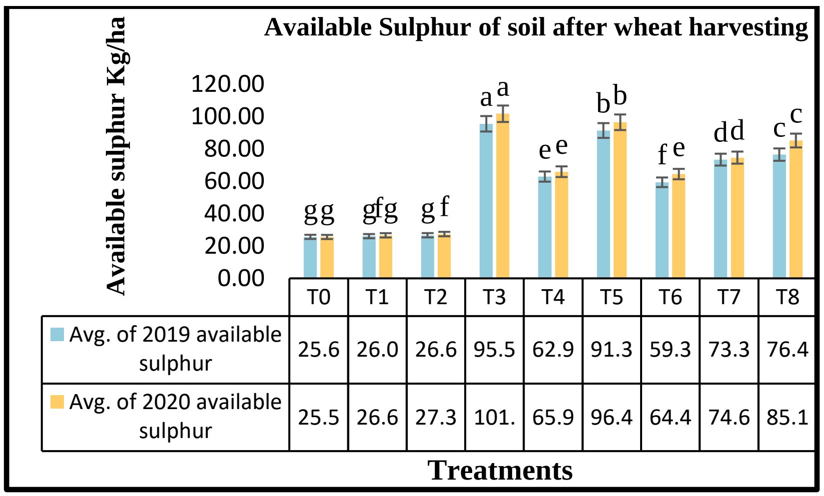
4.4.8 Available Zinc (mg): - The data on the effect of modified fertilizers with sulphur and zinc on straw of DTPA- extractable zinc at time of harvest present in table 4.4.7 (a) and 4.4.7 (b). In case of rice crop, higher DTPA extractable (3.5, 3.4) zinc recorded in T3- NCU + PK + S + Zn-EDTA followed by T5 and T8 .These treatments were non-significantly among themselves. The lowest available Zn (0.9, 1.1 mg Kg^{-1}) recorded by T2 (2.0, 2.6 mg kg^{-1}). The data presented in fig. 4.4.8 (a). In case of wheat crop maximum DTPA extractable Zn (3.8, 4 mg Kg^{-1}). All treatments were statistically significant among themselves. The lowest DTPA extractable zinc (1.3, 1.5 mg Kg^{-1}) recorded under T0 which was followed by T2 and T4 (2.5, 2.7 mg Kg^{-1} and 2.4, 2.8 mg Kg^{-1}) during both years. The data of available zinc after wheat harvesting zinc after wheat harvesting presented in fig..4.4.8 (b).

4.4.7 A, B





4.4.8 A, B



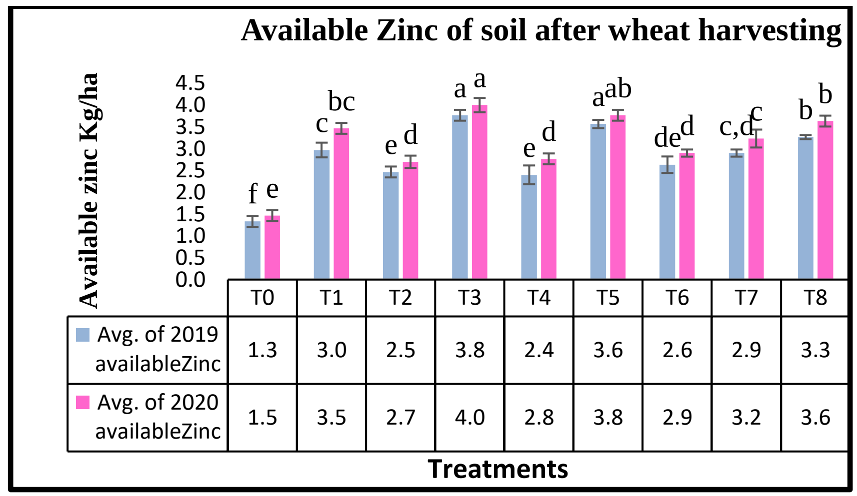


FIG. 4.4.7 (a,b) depicting soil available sulphur (Kgha-1) & 4.4.8 (A,B) representing available zinc after the application of modified fertilizers after the harvesting of rice-wheat crop during 2018-2019& 2019-2020. Different letters indicate that means are significantly different according to DMRT ($p<0.05$)

Table 4.4.7 (a) Effect of modified fertilizers on soil available S and Zn (kg ha^{-1}) (mean± S.E) after harvesting of two seasons of rice

Table 4.4.7 (b) Effect of modified fertilizers on soil available S and Zn (kg ha^{-1}) (mean± S.E) after harvesting of two seasons of wheat crop

Treatments	**2018**		**2019**	
	Available S	**Available Zn**	**Available S**	**Available Zn**
T0- Control (RDF)	23.80±1.12g	0.9±0.0f	22.13±1.60h	1.1±0.1d
T1 - Neem coated urea +PK recommended	24.07±1.28g	2.9±0.0b	28.57±0.82g	3.1±0.1b
T2 - Anhydrous ammonia+ PK recommended	25.57±0.77g	2.0±0.0e	28.43±0.78g	2.6±0.2c
T3 - Neem coated urea+ PK+S+ Zn-EDTA	90.00±1.63a	3.5±0.2a	97.13±0.69a	3.4±0.2a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	59.30±0.96e	2.3±0.1cd	63.27±0.70e	2.7±0.1c
T5 - Neem coated urea +PK+$ZnSO_4$	82.80±2.27b	3.1±0.1b	89.10±1.53b	3.2±0.2ab
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	53.53±0.88f	2.1±0.1de	61.03±0.46f	2.7±0.2c
T7 - RDF + $ZnSO_4$	63.10±1.50d	2.5±0.0c	69.23±0.66d	2.6±0.1c
T8 - RDF+ S+ Zn-EDTA	69.33±0.69c	3.0±0.1b	80.60±0.49c	3.1±0.1d

Treatments	2018		2019	
	Available S	**Available Zn**	**Available S**	**Available Zn**
T0- Control (RDF)	25.63±0.47g	1.3±0.1f	25.57±0.52g	1.5±0.1e
T1 - Neem coated urea + PK recommended	26.07±0.33g	3.0±0.2c	26.60±0.96fg	3.5±0.1bc
T2 - Anhydrous ammonia + PK recommended	26.63±0.47g	2.5±0.1e	27.37±0.79f	2.7±0.1d
T3 - Neem coated urea + PK + S + Zn-EDTA	95.50±2.57a	3.8±0.1a	101.70±0.43a	4.0±0.2a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	62.90±1.20e	2.4±0.2e	65.90±0.41e	2.8±0.1d
T5- Neem coated urea + PK + $ZnSO_4$	91.37±0.98b	3.6±0.1a	96.43±1.01b	3.8±0.1ab
T6 - Anhydrous ammonia + PK+ $ZnSO_4$	59.37±0.79f	2.6±0.2de	64.43±0.71e	2.9±0.d
T7 - RDF + $ZnSO_4$	73.37±0.95d	2.9±0.1cd	74.60±0.41d	3.2±0.2c
T8 - RDF+ S+ Zn-EDTA	76.47±1.92c	3.3±0.0b	85.17±0.82c	3.6±0.1b

4.5 Effect of modified fertilizers on soil biological indicators: -

4.5.1 Urease enzymes (mg urea g^{-1} soil $^{-1}$24 h^{-1}): - Urease enzyme is one of the major soil enzymes which is influenced by the fate and performance of urea fertilizer. The urease activity recorded in rice – wheat crop at heading stage from 0-15 cm and 15-30 cm soil surface. The periodical soil urease enzymes activity influenced by various treatments presented in table is reported in table 4.5.1 (a) and 4.5.1 (b). In case of rice crop, the application of neem coated urea + PK + S + Zn-EDTA-T3 was found significantly affected soil urease activity at heading stage at surface as well as sub surface. The highest urease activity (7.65, 5.57 mg urea g^{-1} soil $24h^{-1}$) at 0-15 cm and 15-30 cm recorded under T3 in rice during both years. The second highest urease activity (6.32, 4.85 mg) in soil recorded in T5 which was followed by T8 (6.134.82 mg) respectively at surface (0-15 cm) and sub-surface soil (15-30 cm). The lowest urease activity (3.63, 2.43 mg) recorded in T0 in 0-15 cm, 15-30 cm surface followed by T2 (4.15, 2.24 mg). The data depicted in fig. 4.5.1(a). In case of wheat crop, significantly variation recorded in urease activity among treatments NCU + PK + S + Zn-EDTA (T3) recorded significantly more (8.54, 6.40 mg) urease activity in soil at 0-15 and 15-30 cm. This treatment was immediately followed by T5 with (6.69, 5.41 mg) and T8 with 6.69, 5.19 mg urease activity in soil at surface and subsurface soil. The lowest urease activity (3.63, 2.40 mg) recorded in control (T0) which was followed by T2 (4.69, 2.69 mg) urease activity. The data of urease activity depicted in fig. 4.5.1 (b). The order of urease activity in wheat was T3>T5>T8>T1>T7>T6>T4>T2>T0.

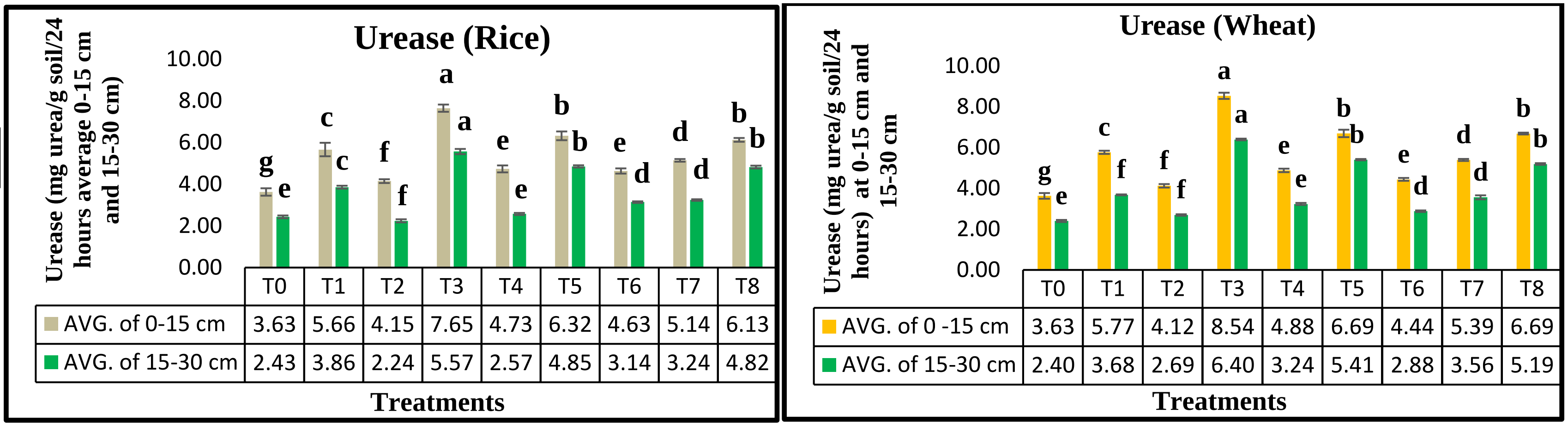
4.5.2 Dehydrogenase (µg TPF g^{-1} soil $24h^{-1}$): - Dehydrogenase enzymes activity in soil is one of the important characteristics of soil quality. The activity of dehydrogenase decided the availability of nitrogen and microbial population. The dehydrogenase activity in soil was measured at heading stage from surface and subsurface soil. The use of modified fertilizer significantly influenced the soil dehydrogenase enzymes activity. In rice crop, the maximum dehydrogenase activity 346.8, 151.5 mg recorded in T3 at 0-15 cm, 15-30 cm. The maximum dehydrogenase observed in surface soil as compared to subsurface soil. The second highest (310.4, 116.6 µg) dehydrogenase activity in surface and sub- surface soil recorded with T5 which was followed by T8 with 290.1, 114.8 mg dehydrogenase enzyme activity in 0-15 cm and 15-30 cm. The lowest activity (110.3, 71.4 µg) observed in T0. The data presented in fig.

4.5.2(a). In wheat crop, the maximum dehydrogenase activity (365.4, 154.1 µg) recorded in T3 at 15 and 15-30 cm soil surface. This treatment was followed by T5 at surface and sub- surface soil with 325.3, 152.3 µg dehydrogenase activities. T8 and T1 also resulted more (292.2, 118.4 mg and 269.7, 110.2 mg) activities over other treatments. The lowest activity of dehydrogenase recorded in T0 (137.6, 80.6 µg) at 0-15, 15-30 cm surface. The data was presented in fig. 4.5.2 (b). The order of dehydrogenase activity in wheat was T3>T5>T8>T1>T7>T6>T4>T2>T0.

4.53 Aryl sulfatase: - Aryl sulfatase enzyme is the enzyme which influenced by sulphur fertilization. Aryl sulfatase activity combinations of modifies fertilizers. In wheat crop, the maximum aryl sulfatase (59.3, 30.9 µg) recorded under T3 at 0-15 and 15-30 cm depth. The enzymatic activities decreased with depth. The second highest activity of aryl sulfatase (55.9, 25.1 µg) recorded under T5 which was followed by T8 with 52, 23 µg) at 0-15 cm and 15-30 cm soil surface. The minimum activity of aryl sulfatase (14.4, 4.3 µg) recorded under T0 which was followed by T2 (34.8, 12.1 µg) at 0-15 cm and 15-30 cm soil surface. The data presented in fig. 4.5.3 (b). The application of NCU + PK + S + Zn-EDTA (T3) in rice recorded maximum activity of aryl sulfatase at surface and sub- surface soil (66.23, 32.3 µg) which was immediately followed by T5 (62, 26.87 µg). The next highest (54.63, 25.5 µg) recorded in T8. The lowest activity recorded in T0 (12.43, 2.53 µg) at 0-15 cm and 15-30 cm soil surface. The data presented in fig. 4.5.3 (a).

4.5.4 Nitrate reductase (NR-mg g^{-1} soil hr^{-1}): - Nitrate reductase activity is the enzyme which influenced the nitrogen fractions in soil. The nitrate reductase activities significantly different from each other. In rice crop, the application of NCU + PK + S + Zn-EDTA (T3) recorded maximum (3.24, 1.92 mg) nitrate reductase activity. The second highest activity (2.96, 1.70 mg) recorded in T5 which was followed by T1 (2.72, 1.37 mg). The lowest activity (1.14, 0.49 mg) recorded under T0 in surface and sub- surface soil. The data presented in fig. 4.5.4 (a) of nitrate reductase in rice. In case of wheat crop, nitrate reductase activity recorded maximum (2.23, 1.67 mg) under T3 followed by T5 (2.09, 1.38 mg) at surface and subsurface soil. T1 and T8 also recorded more activities (1.95, 1.24 mg and1.55, 0.88 mg) over other treatments. The lowest activities (0.95, 0.54 mg) recorded under T2 followed by T0 (1, 0.31 mg) at 0-15 and 15-30 cm soil surface. The data of nitrate reductase in wheat presented in fig. 4.5.4(b).

4.5.1 A, B



4.5.2 A, B

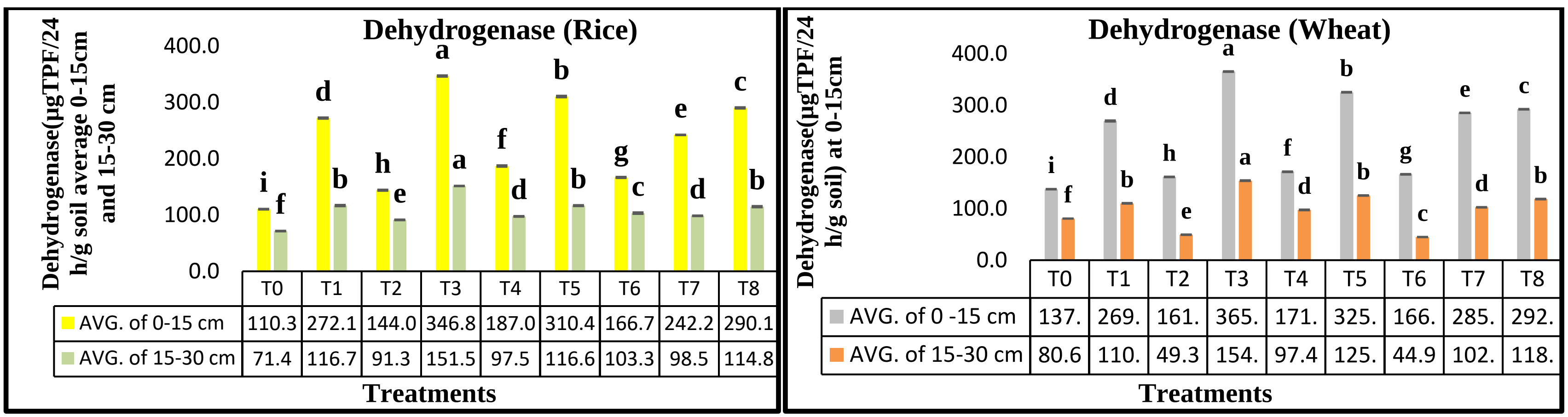
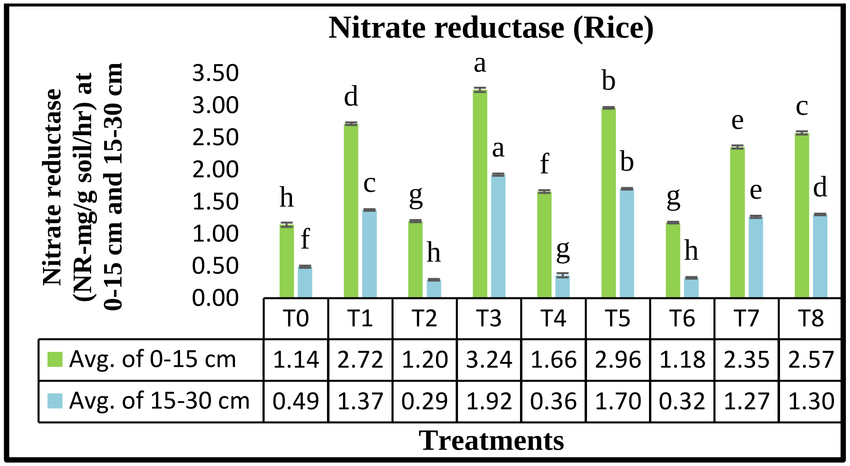
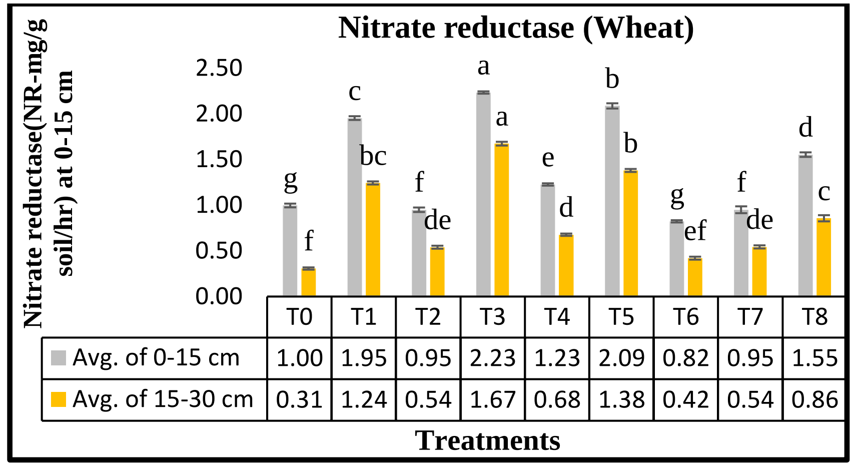


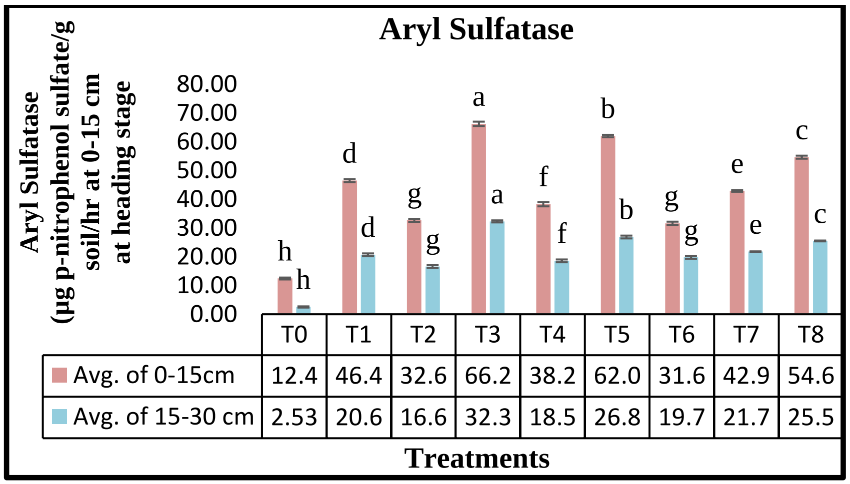
Fig. 4.5..1(A,B)& 4.5.2(A,B) : Impact of modified fertilizers on urease(mg urea g^{-1} soil $24h^{-1}$) and dehydrogenase (µg TPF/ hr/g soil) at different depths in rice- wheat cropping system during 2018-2019& 2019-2020.Different letters represent treatments are significant from each other.

4.5.3 A, B





4.5.4 A. B



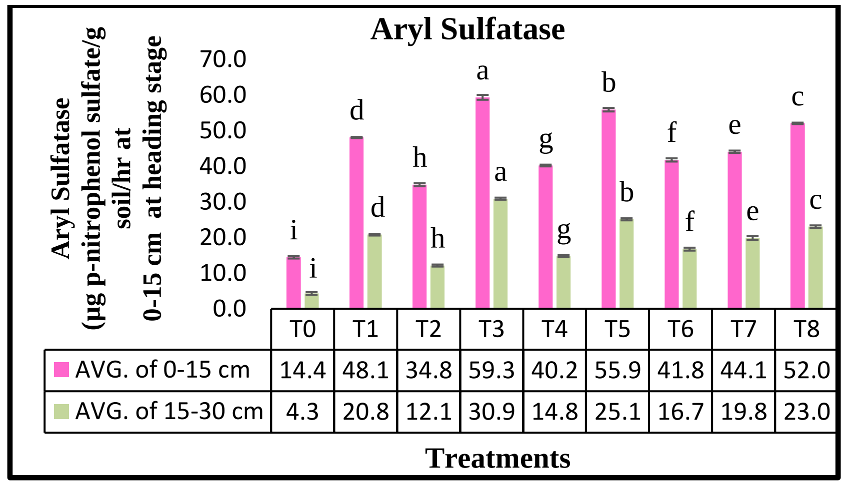


Fig. 4.5.3 (A, B) & Fig. 4.5.4(A,B) indicating nitrate reductase activities and aryl sulfatase activities in rice- wheat crop at heading stage from different depths during 2018-2019& 2019-2020. Different symbols above the standard bars indicate the treatments are statistically different from each other according to DMRT (p<0.05).

Table 4.5.1(a) Impact of modified fertilizers on urease, dehydrogenase and aryl sulfatase activities (mean± S.E) in rice crop at heading stage.

Treatments	Urease (mg urea g^{-1} soil 24 hours-^{1})		Dehydrogenase (µg TPF 24 h-^{1}g soil^{-1})		Aryl sulfatase (µg p-nitro phenol sulfate g^{-1} soil hr^{-1})	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**	**0-15cm**	**15-30cm**
T0- Control (RDF)	3.63±0.18g	2.43±0.066e	110.3±0.86i	71.4±0.78f	12.43±0.33h	2.53±0.21h
T1 - Neem coated urea +PK recommended	5.66±0.32c	3.86±0.070c	272.1±1.36d	116.7±1.38b	46.47±0.52d	20.67±0.50d
T2 - Anhydrous ammonia+ PK recommended	4.15±0.09f	2.24±0.074f	144.0±1.20h	91.3±0.86e	32.67±0.52g	16.60±0.45g
T3 - Neem coated urea+ PK+S+ Zn-EDTA	7.65±0.17a	5.57±0.125a	346.8±1.40a	151.5±0.61a	66.23±0.76a	32.30±0.36a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	4.73±0.17e	2.57±0.049e	187.0±1.52f	97.5±0.88d	38.27±0.74f	18.57±0.49f
T5- Neem coated urea + PK + $ZnSO_4$	6.32±0.21b	4.85±0.054b	310.4±1.60b	116.6±1.11b	62.00±0.41b	26.87±0.50b
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	4.63±0.12e	3.14±0.037d	166.7±1.29g	103.3±1.59c	31.63±0.58g	19.77±0.45g
T7 - RDF + $ZnSO_4$	5.14±0.06d	3.24±0.037d	242.2±0.71e	98.5±0.82d	42.90±0.29e	21.77±0.11e
T8 - RDF+ S+ Zn-EDTA	6.13±0.09b	4.82±0.066b	290.1±1.39c	114.8±1.35b	54.63±0.53c	25.50±.15c

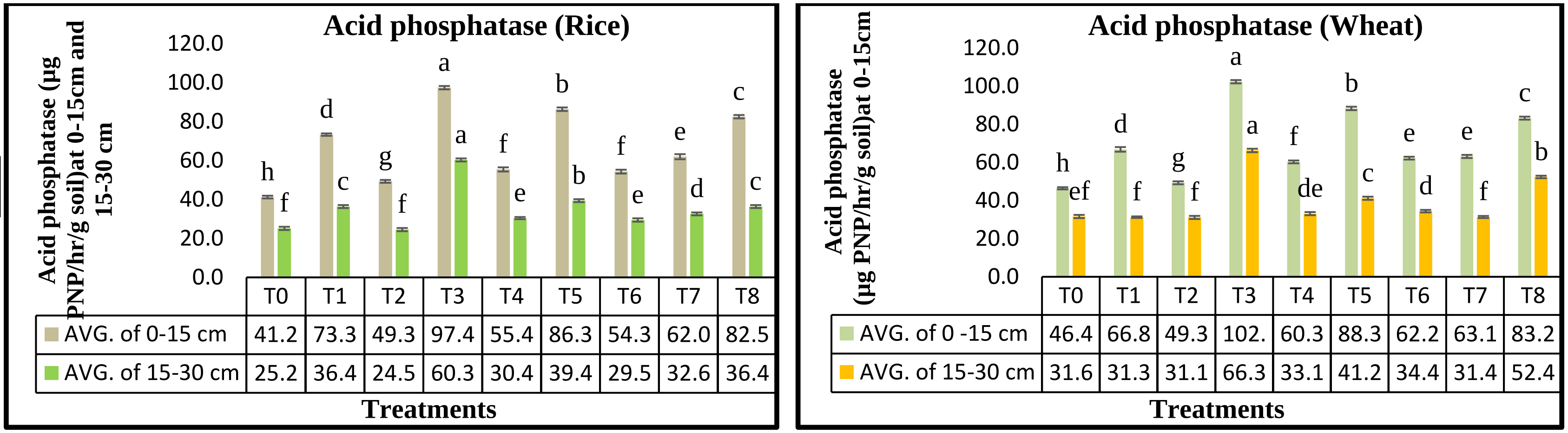
Table 4.5.1(b) Impact of modified fertilizers on Urease, dehydrogenase and aryl sulfatase (mean± S.E) at different depths in wheat crop at heading stage.

Treatments	Urease (mg urea g^{-1} soil24 hours-^{1})		Dehydrogenase (µg TPF24 h-^{1}g soil^{-1})		Aryl sulfatase (µg p-nitro phenol sulfateg^{-1} soil hr^{-1})	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**	**0-15cm**	**15-30cm**
T0- Control (RDF)	3.63±0.140g	2.40±0.05e	137.6±0.70i	80.6±0.43f	14.4±0.3i	4.3±0.4i
T1 - Neem coated urea + PK recommended	5.77±0.078c	3.68±0.02c	269.7±1.35d	110.2±0.86b	48.1±0.2d	20.8±0.2d
T2 - Anhydrous ammonia + PK recommended	4.12±0.086f	2.69±0.04f	161.3±0.78h	49.3±0.69e	34.8±0.4h	12.1±0.3h
T3 - Neem coated urea + PK + S + Zn-EDTA	8.54±0.152a	6.40±0.04a	365.4±0.86a	154.1±0.99a	59.3±0.7a	30.9±0.3a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	4.88±0.086e	3.24±0.05e	171.3±0.88f	97.4±0.98d	40.2±0.2g	14.8±0.3g
T5- Neem coated urea + PK + $ZnSO_4$	6.69±0.183b	5.41±0.03b	325.3±0.85b	125.3±0.71b	55.9±0.5b	25.1±0.3b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	4.44±0.070e	2.88±0.04d	166.4±0.87g	44.9±0.54c	41.8±0.4f	16.7±0.4f
T7 - RDF + $ZnSO_4$	5.39±0.050d	3.56±0.10d	285.4±0.67e	102.4±0.70d	44.1±0.3e	19.8±0.5e
T8 - RDF+ S+ Zn-EDTA	6.69±0.045b	5.19±0.04b	292.4±0.82c	118.4±0.84b	52.0±0.2c	23.0±0.4c

4.5.5 Acid phosphatase (µg PNP hr^{-1} g^{-1} soil): - Acid phosphatase activity also influenced by various treatments which are depicted in table 4.5.5 (a) and 4.5.5 (b). In rice crop, the maximum (97.4, 60.3 µg) acid phosphatase activity recorded at surface and sub- surface soil with the application of NCU + PK + S + Zn-EDTA (T3) which was immediately followed by T5 with 86.3, 39.4 µg activity. The lowest activity of acid phosphatase (41.2, 25.2 µg) recorded in T0 which was followed by T2 with 49.3, 24.5 µg activities. In wheat crop, maximum acid phosphatase activities (102.3, 66.3 µg) recorded under T3 which was followed by T5 with 88.3, 41.2 µg activity and again followed by T8 with 83.2, 52.4 µg. The lowest activities (46.4, 31.2 µg) recorded in T0. The data of rice and wheat soil acid phosphatase activity depicted in fig. 4.5.5 (a) and 4.5.5 (b). The order of acid phosphatase activity in rice- wheat was T3>T5>T8>T1>T7>T6>T4>T2>T0. All the treatments were significantly superior over control.

4.5.6 Alkaline Phosphatase (mg NH_4^+ g^{-1} soil hr^{-1}): - Alkaline phosphatase activities also influenced by modified fertilizers. The data presented in table 4.5.4 (a) and 4.5.4 (b). All treatments were significantly different from each other. In rice crop, the maximum alkaline phosphatase (121.3, 51.3 mg) recorded under T3 which was immediately followed by T5 (108.5, 42.8 mg) and T8 (97.4, 41.8 mg) at surface and surface soil. The lowest activity (45.5, 20.3 mg) of alkaline phosphatase observed underT0. The data of alkaline phosphatase activity in rice soil depicted in fig 4.5.6 (a). In wheat crop, the maximum alkaline phosphatase activity (125.4, 88.4 mg) recorded in T3 followed by 105.4, 75.2 mg in T5. All the other treatments were significantly better than control. The lowest activity (41.6, 20.3 mg) recorded under T0 which was followed by T2 (61.4, 42.1 mg) at surface and sub-surface soil. The data of alkaline phosphatase presented in fig. 4.5.6 (b).

4.5.5 A, B



4.5.6 A, B

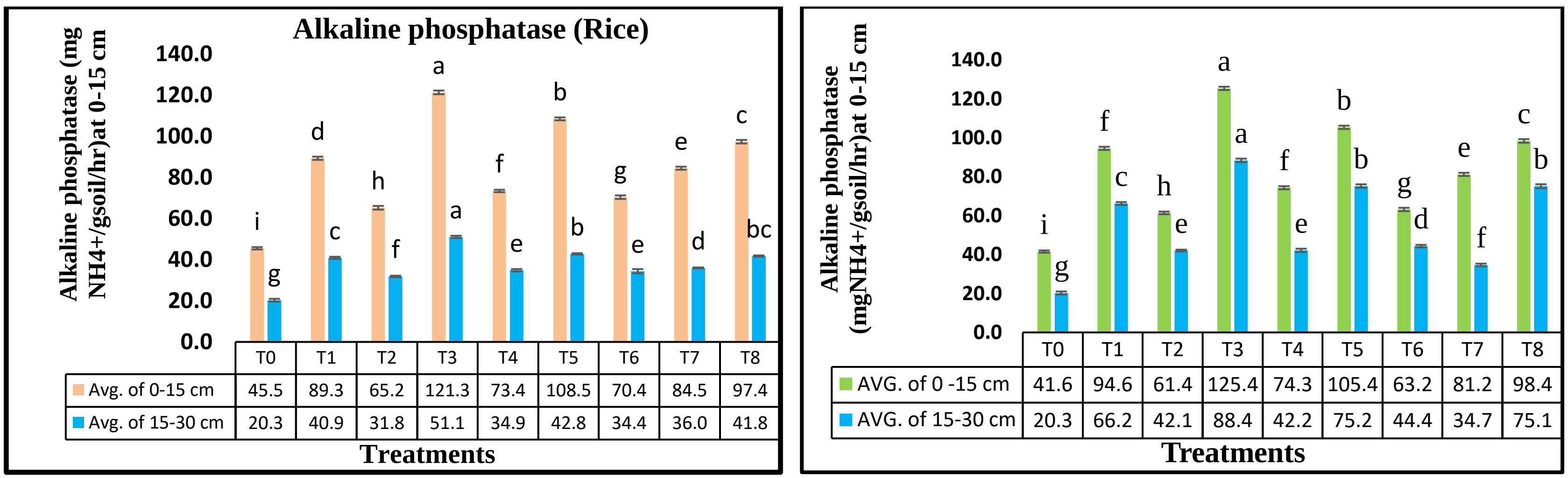


Fig. 4.5.5, 4.5.6(A,B) indicating acid and alkaline phosphatase activities in rice wheat crop at heading stage from different depths during 2018- 2019& 2019-2020. Different symbols above the standard bars indicate the treatments are statistically different from each other according to DMRT ($p<0.05$)

Table 4.5.4(a) Impact of modified fertilizers on acid phosphatase, alkaline phosphatase activity and nitrate reductase activity at different depths from rice crop at heading stage during 2018-2019

Treatments	Acid phosphatase (µg PNPhr^{-1}g^{-1}soil)		Alkaline phosphatase (mgNH4^{+} g^{-1} soil hr^{-1})		Nitrate reductase (NR-mg g^{-1} soil hr^{-1})	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**	**0-15cm**	**15-30cm**
T0- Control (RDF)	41.2±0.69h	25.2±0.82f	45.5±0.57i	20.3±0.67g	1.14±0.03h	0.49±0.02f
T1 - Neem coated urea + PK recommended	73.3±0.62d	36.4±0.76c	89.3±0.78d	40.9±0.50c	2.72±0.02d	1.37±0.01c
T2 - Anhydrous ammonia + PK recommended	49.3±0.73g	24.5±0.82f	65.2±0.90h	31.8±0.37f	1.20±0.02g	0.29±0.01h
T3 - Neem coated urea+ PK + S + Zn-EDTA	97.4±0.87a	60.3±0.78a	121.3±0.90a	51.1±0.54a	3.24±0.03a	1.92±0.02a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	55.4±1.07f	30.4±0.56e	73.4±0.59f	34.9±0.57de	1.66±0.02f	0.36±0.03g
T5- Neem coated urea + PK + $ZnSO_4$	86.3±0.90b	39.4±0.75b	108.5±0.71b	42.8±0.33b	2.96±0.01b	1.70±0.01b
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	54.3±0.99f	29.5±0.86e	70.4±0.87g	34.4±1.02e	1.18±0.01g	0.32±0.01h
T7 - RDF + $ZnSO_4$	62.0±1.31e	32.6±0.75d	84.5±0.74e	36.0±0.22d	2.35±0.02e	1.27±0.02e
T8 - RDF+ S+ Zn-EDTA	82.5±0.86c	36.4±0.76c	97.4±0.87c	41.8±0.29bc	2.57±0.02c	1.30±0.01d

Table 4.5.4(b) Impact of modified fertilizers on acid phosphatase, alkaline phosphatase activity and nitrate reductase activity at different depths from wheat crop at heading stage during 2018-2019

Treatments	Acid phosphatase (μg PNP $hr^{-1} g^{-1}$ soil)		Alkaline phosphatase (mg NH_4^+ g^{-1} soil hr^{-1})		Nitrate reductase (NR-mg g^{-1} soil hr^{-1})	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**	**0-15cm**	**15-30cm**
T0- Control (RDF)	46.4±0.57h	31.6±0.84ef	41.6±0.59i	20.3±0.78g	1.00±.02g	0.31±0.01f
T1 - Neem coated urea + PK recommended	66.8±1.21d	31.3±0.41f	94.6±0.82f	66.2±0.74c	1.95±0.02c	1.24±0.02bc
T2 - Anhydrous ammonia + PK recommended	49.3±0.78g	31.1±0.82f	61.4±0.67h	42.1±0.43e	0.95±0.02f	0.54±0.02de
T3 - Neem coated urea + PK + S + Zn-EDTA	102.3±0.86a	66.3±0.90a	125.4±0.86a	88.4±0.90a	2.23±0.01a	1.67±0.02a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	60.3±0.74f	33.1±0.82de	74.3±0.79f	42.2±0.86e	1.23±0.01e	0.68±0.01d
T5- Neem coated urea + PK + $ZnSO_4$	88.3±0.90b	41.2±0.82c	105.4±0.85b	75.2±0.87b	2.09±0.03b	1.38±0.02b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	62.2±0.74e	34.4±0.65d	63.2±0.8g	44.4±0.62d	0.82±0.01g	0.42±0.02ef
T7 - RDF + $ZnSO_4$	63.1±0.82e	31.4±0.54f	81.2±0.82e	34.7±0.68f	0.95±0.04f	0.54±0.02de
T8 – RDF + S + Zn-EDTA	83.2±0.79c	52.4±0.65b	98.4±0.91c	75.1±1.04b	1.55±0.02d	0.86±0.03c

4.6 Economics: - The economics of treatments comprised with cost of cultivation, gross return, net returns, and B: C ratio presented in table 4.6 (a) and table 4.6 (b).

4.6.1 Cost of cultivation: - In case of rice Rs. 34,972 ha^{-1} was common cost of cultivation for all treatments. In case of wheat Rs. 26291 ha^{-1} was common cost of cultivation. Cost of cultivation different due to different fertilizers sources. Among the nine treatments lowest expenditure Rs. 38769 was exhibited under control (T0) as compare to other treatments, on the other hand, the maximum expenditure Rs. 48115 ha^{-1} exhibited under T3 (NCU + PK + S + Zn-EDTA) in rice crop. In wheat crop Rs. 31246 has lowest expenditure recorded in T0 and maximum (35891) recorded in T3 among all treatments.

4.6.2 Gross return: - Among the different treatments in rice crop, NCU + PK + S + Zn-EDTA (T3) recorded maximum gross return (Rs. 191230.6 ha^{-1}) followed by NCU + PK + $ZnSO_4$ with Rs. 180072.3 ha^{-1}. Lowest gross return recorded in T0 (136840.3 ha^{-1}) followed by T2 (Rs. 13747.2 ha^{-1}). In wheat crop, the maximum gross return of (Rs 106852.0 ha^{-1}) recorded with T3 (NCU + PK + S + Zn-EDTA) followed by T5 with Rs. 102752 ha^{-1}. The minimum gross return recorded with T2 (Rs. 90893.17 ha^{-1}) followed by T4 (90564.8 ha^{-1}).

4.6.3 Net returns: - In rice crop, among all treatments the application of NCU + S + PK + Zn-EDTA recorded highest net returns (Rs. 143115.0 ha^{-1}) followed by T5 with Rs. 134910.0 ha^{-1}. The lowest monetary returns (92814.67) recorded with T4 followed by T2 with Rs. 96703 ha^{-1}. In wheat crop, the highest net returns 70960 ha^{-1} recorded under T3 which was followed by T5 with Rs. 70511 ha^{-1}. The lowest net monetary returns recorded in T4 (Rs. 54813 ha^{-1}) followed by T2 (Rs. 59492.17 ha^{-1}).

4.6.4 B: C ratio: - The highest (2.987) benefit cost ratio was recorded with NCU + PK + $ZnSO_4$ (T5) followed by T3 (2.974) and T1 (NCU + PK) with 2.912 B:C ratio (1.9) was recorded in T5. In wheat crop, the maximum B:C ratio (2.19) recorded in T5 (NCU + PK + $ZnSO_4$) followed by T3 (NCU + PK + Zn-EDTA + S) with 2.08 ratio. The lowest B:C ratio recorded (1.53) in T4. The highest B:C ratio recorded in T5 as compared to T3 because in T5 we used $ZnSO_4$ for both sources of Zn and S. which is a cheap in cost over Zn-EDTA and elemental S. So, due to use of Zn-EDTA which is a costly chelate and element sulphur. The cost of cultivation increases as compared to T5. So, that’s why B: C ratio is more in T5 as compare to T3. In case of lowest B:C ratio, recorded in T4, due to cost of Anhydrous ammonia + Zn-EDTA + S + PK. So, cost of cultivation more as compared to other but net returns less.

Table 4.6 (a) Avg. cost of cultivation, gross returns, net returns and B: C ratio of rice crop.

Treatments	Cost of cultivation (Rs.ha^{-1})	Gross return (Rs. ha^{-1})	Net returns Rs. ha^{-1})	B:C ratio
T0- Control (RDF)	38769	136840.3	98071.33	2.530
T1 - Neem coated urea +PK recommended	39765	155560.3	115795.3	2.912
T2 - Anhydrous ammonia+ PK recommended	40769	137472	96703	2.372
T3 - Neem coated urea+ PK+S+ Zn-EDTA	48115	191230.6	143115.6	2.974
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	47118	139932.7	92814.67	1.970
T5 - Neem coated urea +PK+$ZnSO_4$	45162	180072.3	134910.3	2.987
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	44469	144909.3	100440.3	2.259
T7 - RDF + $ZnSO_4$	44122	150213	106091	2.404
T8 - RDF+ S+ Zn-EDTA	46449	170230.2	123781.2	2.665

Table 4.6 (b) Avg. Cost of cultivation, gross returns, net returns and B: C ratio of wheat crop.

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T0- Control (RDF)	31246	93355.00	62109.00	1.90
T1 - Neem coated urea +PK recommended	31541	97525.53	65984.53	1.98
T2 - Anhydrous ammonia+ PK recommended	31401	90893.17	59492.17	1.89
T3 - Neem coated urea+ PK+S+ Zn-EDTA	35891	106851.00	70960.00	2.08
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	35751	90564.87	54813.87	1.53
T5 - Neem coated urea +PK+$ZnSO_4$	32241	102752.00	70511.00	2.19
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	32101	93160.83	61059.83	1.90
T7 - RDF + $ZnSO_4$	31941	96614.03	64673.03	1.80
T8 - RDF+ S+ Zn-EDTA	35591	100439.10	64848.10	1.82

4.7 Result of Pot experiment

A pot experiment was conducted to evaluate the effects of modified fertilizers on growth, yield and leached nutrients of rice – wheat cropping system during 2018-2019 and 2019-2020 Kharif - Rabi seasons. In containerized plant production, fertilizer nutrients are commonly lost from the substrate by leaching and the type of fertilizer has been demonstrated to significantly affect the nutrient leaching. Most of the leaching experiment has demonstrated on N leaching because of its high use mobile nature in soil and organic substrates. P leaching is also of major concern due to its surface water contamination potential. These nutrients have been shown to leach at concentration above the recommended level. With this objective to record the leaching of nutrients a pot experiment was conducted. The result of pot experiment was explained under following headings: -

4.7.1 Crop growth parameters

4.7.2 Yield attributing parameters

4.7.3 Nutrient uptake

4.7.4 Nutrient use efficiency

4.7.5 Leached nutrients

4.7.6 Soil nutrient status

4.7.1 Crop growth parameters: - The application of modified fertilizers to rice – wheat crop affects the growth parameter which was discussed in this chapter. The main parameters plant height, tillers, fresh weight, dry weight, chlorophyll content, leaf area, CGR, RGR, NAR and flag leaf discussed and presented in tables and figures under this heading.

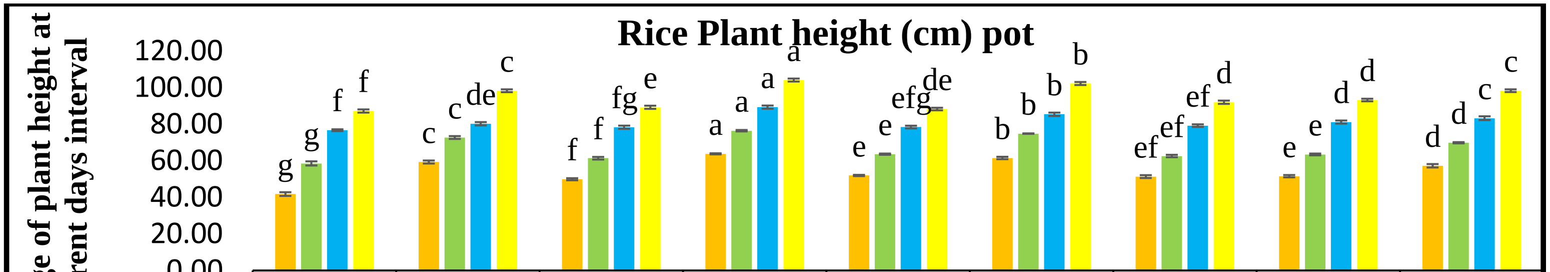
4.7.1.1 Plant height: - The plant height was recorded at different intervals was presented in table 4.7.1.1 and fig 4.7.1.1 (A), 4.7.1.1 (B). The data depicted in the table indicated that different treatments respond differently to plant height. All the treatments were significantly different from each other. The average value of both year rice and wheat crop presented. In rice crop plant height recorded at 20, 40, 60 and 80 DAT. The plant height ranged from 41.8 to

104.17 cm. The maximum plant height at all intervals (63.8, 76.47, 89.13 and 104.17 cm) recorded under T_3 (NCU + PK + S + Zn-EDTA). The second highest plant height recorded (61.53, 74.87, 85.43, 102.27 cm) with the application of NCU + PK + Zn-SO_4 (T_5) which was immediately followed by T_1 (NCU + PK) with plant height 59.33, 72.73, 80.27, 98.3 cm. The minimum plant height (41.8, 58.57, 76.77, 87.23 cm) recovered under T_0 (control) which was followed by T_2 (AA + PK) having 49.9, 61.4, 78.37 and 89.27 cm respectively at all intervals. In case of wheat crop, plant height recorded at 30, 60, 90 and 120 DAS. There was significant variation observed among treatments. The data of plant height depicted in Table 4.7.1(a) and fig. 4.7.1 (b). The scrutiny of data presented in table indicated that in wheat pot crop plant height ranged from 31.73 cm to 76.9 cm. the maximum plant height (37.8, 51.63, 70.57, 76.9 cm) recorded under T_3 (NCU + PK + S + Zn-EDTA) which was immediately followed by T_5 with 36.17, 51.3, 68.53 and 752 cm plant height at 30, 60, 90 and 120 DAS. This treatment was followed by T_8 and T_1 (35.5, 49.03, 68.40, 74.43 and 32.97, 47.33, 67.3, 73.93 cm). The lowest plant height (31.53, 45.63, 60.23, 65.47 cm) at 30, 60, 90 and 120 DAS recorded under T_0 which was followed by T_2 (32.97, 47.33, 67.33, 73.93 cm). The order of plant height was $T_3 > T_5 > T_8 > T_1 > T_7 > T_6 > T_4 > T_2 > T_0$.

4.7.1.2 Total tillers and productive tillers: - The data of total tillers and productive tillers presented in table 4.7.1.2 for rice and wheat crop. In rice crop the tillers recorded at 20, 40 and 60 DAT which indicated total tillers of plant and at 80 DAT productive tillers were computed. The tiller number of plants was statistically significant among treatments. The maximum number of tillers (7.67, 10.47, 12.5) recorded with the application of NCU + PK + Zn-EDTA (T_3) at 20, 40 and 60 DAT. Out of the 12.5 – 10.8 were productive tillers. The second highest total tillers (6.43, 9.37, and 12.30) recorded under T_5 with 9.8 productive tillers. The lowest (4.37, 7.60, 9.03), (4, 7.17, 8.60) total tillers and productive tillers (6.9 and 7.33) recorded by T_2 and T0. In wheat crop the total tillers/pot recorded the total tillers ranged from 26.3 to 41. The greatest total tillers (41) recorded under T_3 which was followed by T_5 (36.3) and T_1 (36). The lowest total tillers (26.3) recorded under T_2 which was followed by T_4 (27.7) tillers. The highest effective tillers (37.3) recorded by T_3 followed by T_5 with 33 tillers. T_8 and T_1 also recorded significantly more tillers (32, 31) over other treatments. The minimum effective tillers

(23) recorded under T_2 followed by T_4 (23.3). The data of total tillers and effective tillers presented in Fig. 4.7.1.2 (a) and 4.7.1.2(b).

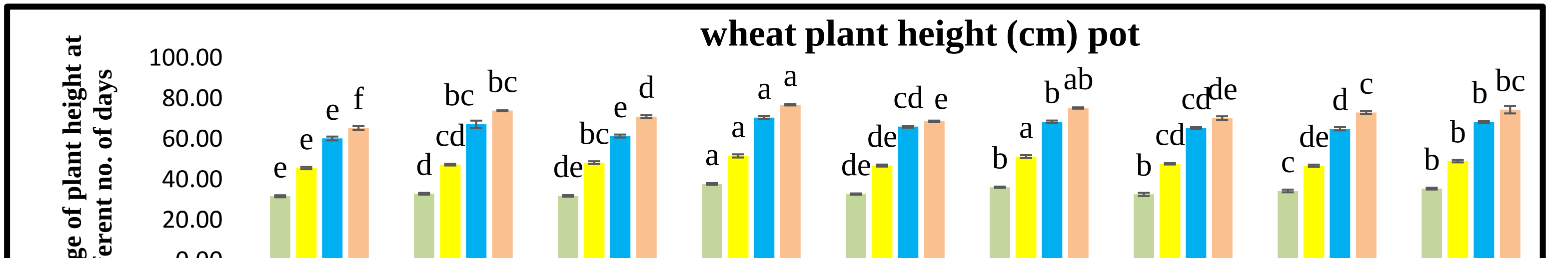
4.7.1 A



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 20 DAT	41.80	59.33	49.90	63.80	51.97	61.53	51.37	51.57	57.27
Avg. of 40 DAT	58.57	72.73	61.40	76.47	63.63	74.87	62.60	63.47	69.87
Avg. of 60 DAT	76.73	80.27	78.37	89.37	78.47	85.43	79.23	81.20	83.30
Avg. of 80 DAT	87.23	98.30	89.27	104.17	88.30	102.27	92.03	93.23	98.33

Treatments

4.7.1 B

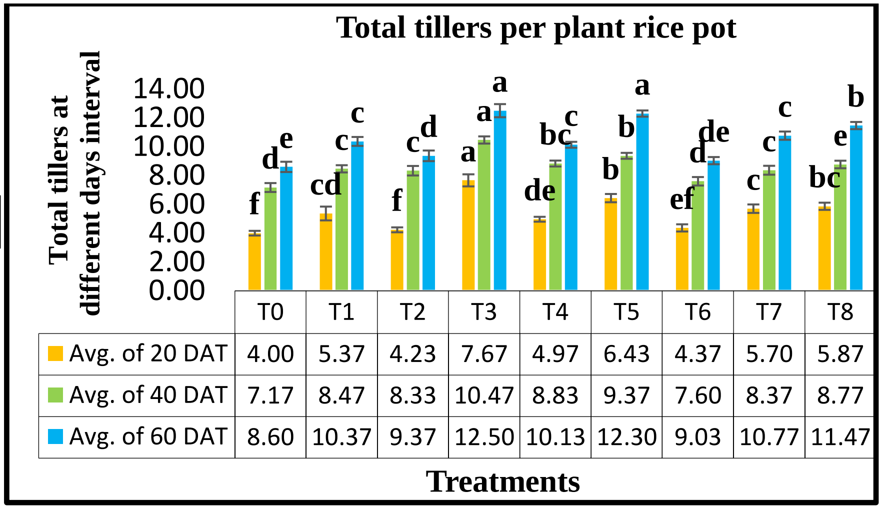


	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 30 DAS	31.73	32.97	31.90	37.80	32.80	36.17	32.63	34.33	35.50
Avg. of 60 DAS	45.63	47.33	48.30	51.63	46.87	51.30	47.73	46.80	49.03
Avg. of 90 DAS	60.23	67.30	61.43	70.57	66.05	68.53	65.47	65.03	68.40
Avg. of maturity	65.47	73.93	71.07	76.90	68.77	75.27	70.23	73.07	74.43

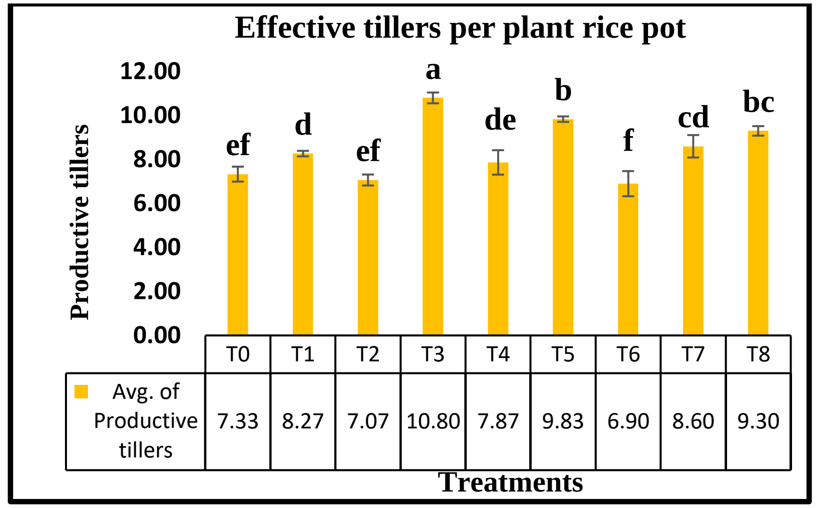
Treatments

Fig. 4.7.1A&B representing the avg. plant height (cm) at different intervals in rice and wheat crop in pot experiment. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

4.7.1.2 A, B

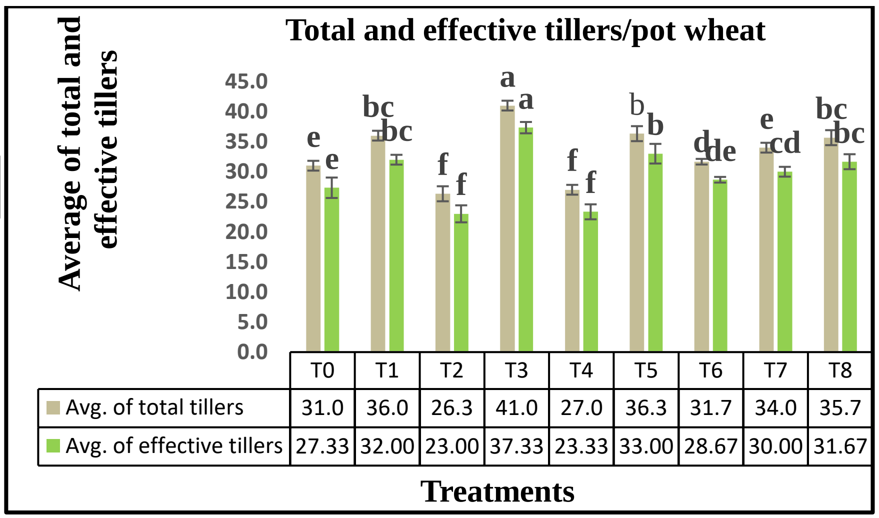


	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 20 DAT	4.00	5.37	4.23	7.67	4.97	6.43	4.37	5.70	5.87
Avg. of 40 DAT	7.17	8.47	8.33	10.47	8.83	9.37	7.60	8.37	8.77
Avg. of 60 DAT	8.60	10.37	9.37	12.50	10.13	12.30	9.03	10.77	11.47

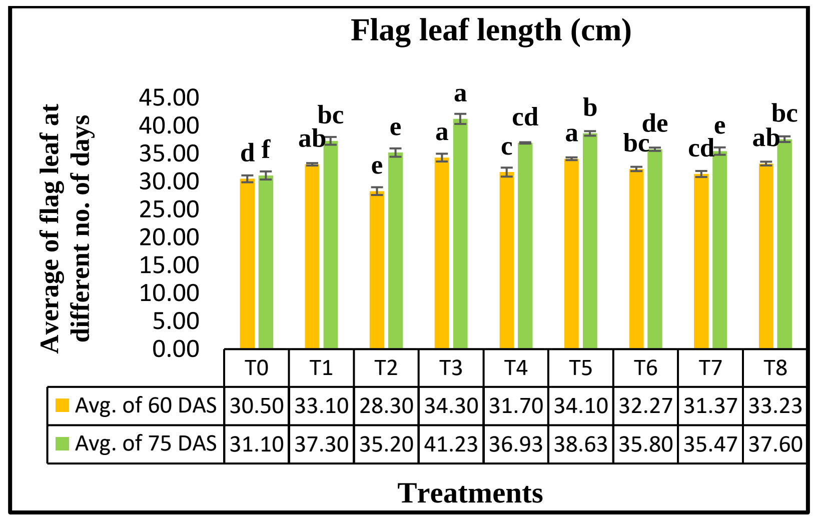


	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of Productive tillers	7.33	8.27	7.07	10.80	7.87	9.83	6.90	8.60	9.30

4.7.1.2 C, D



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of total tillers	31.0	36.0	26.3	41.0	27.0	36.3	31.7	34.0	35.7
Avg. of effective tillers	27.33	32.00	23.00	37.33	23.33	33.00	28.67	30.00	31.67



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	30.50	33.10	28.30	34.30	31.70	34.10	32.27	31.37	33.23
Avg. of 75 DAS	31.10	37.30	35.20	41.23	36.93	38.63	35.80	35.47	37.60

Fig. 4.7.1.2 A&B, C&D representing total and effective tillers in rice and wheat crop in pot experiment. Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$.

Table 4.7.1 Avg. Plant height of rice and wheat (cm) (mean± S.E) at different intervals in pot experiment influenced by modified fertilizers.

Treatments	Rice				Wheat			
	20 DAT	40 DAT	60 DAT	80 DAT	30 DAS	60 DAS	90 DAS	120 DAS
T0- Control (RDF)	41.80±1.02g	58.57±1.13g	76.73±0.48f	87.23±0.87f	31.73±0.50e	45.63±0.56e	60.23±0.94e	65.47±0.97f
T1 - Neem coated urea + PK recommended	59.33±0.82c	72.73±0.77c	80.27±0.90de	98.30±0.78c	32.97±0.42d	47.33±0.42cd	67.30±1.75bc	73.93±0.25bc
T2 - Anhydrous ammonia + PK recommended	49.90±0.57f	61.40±0.71f	78.37±0.86fg	89.27±0.87e	31.90±0.37de	48.30±0.70bc	61.43±0.74e	71.07±0.66d
T3 - Neem coated urea+ PK + S + Zn-EDTA	63.80±0.29a	76.47±0.39a	89.37±0.86a	104.17±0.82a	37.80±0.43a	51.63±0.78a	70.57±0.83a	76.90±0.37a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	51.97±0.33e	63.63±0.33e	78.47±0.74efg	88.30±0.70de	32.80±0.33de	46.87±0.49de	66.05±0.47cd	68.77±0.29e
T5- Neem coated urea + PK + $ZnSO_4$	61.53±0.40b	74.87±0.12b	85.43±0.92b	102.27±0.2b	36.17±0.33b	51.30±0.70a	68.53±0.56b	75.27±0.33ab
T6 - Anhydrous ammonia + PK + $ZnSO_4$	51.37±0.78ef	62.60±0.65ef	79.23±0.69ef	92.03±0.90d	32.63±0.77de	47.73±0.33cd	65.47±0.49cd	70.23±0.94de
T7 - RDF + $ZnSO_4$	51.57±0.62e	63.47±0.49e	81.20±0.83d	93.23±0.69d	34.33±0.66c	46.80±0.54de	65.03±0.79d	73.070.77c
T8 – RDF + S + Zn-EDTA	57.27±0.94d	69.87±0.34d	83.30±1.02c	98.33±0.74c	35.50±0.45b	49.03±0.58b	68.40±0.54b	74.43±1.84bc

Table 4.7.1.2 Effect of modified fertilizers on total tillers and effective tillers (mean± S.E) of rice- wheat crop in pot experiment.

Treatments	Rice				Wheat	
	20 DAT	40 DAT	60 DAT	Productive tillers	Total tillers m^{-2}	Productive tillers m^{-2}
T0- Control (RDF)	4.00±0.16f	7.17±0.31d	8.60±0.36e	7.33±0.34ef	31.0±0.8e	27.3±1.7e
T1 - Neem coated urea + PK recommended	5.37±0.48cd	8.47±0.25c	10.37±0.31c	8.27±0.12d	36.0±0.8bc	32.0±0.8bc
T2 - Anhydrous ammonia + PK recommended	4.23±0.17f	8.33±0.33c	9.37±0.37d	7.07±0.25ef	26.3±1.2f	23.0±1.4f
T3 - Neem coated urea+ PK + S + Zn-EDTA	7.67±0.42a	10.47±0.25a	12.50±0.45a	10.80±0.24a	41.0±0.8a	37.3±0.9a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	4.97±0.17de	8.83±0.21bc	10.13±0.21c	7.87±0.56de	27.0±0.8f	23.3±1.2f
T5- Neem coated urea + PK + $ZnSO_4$	6.43±0.29b	9.37±0.21b	12.30±0.22a	9.83±0.12b	36.3±1.2b	33.0±1.6b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	4.37±0.25ef	7.60±0.29d	9.03±0.25de	6.90±0.57f	31.7±0.5d	28.7±0.5de
T7 - RDF + $ZnSO_4$	5.70±0.29c	8.37±0.31c	10.77±0.29c	8.60±0.51cd	34.0±0.8c	30.0±0.8cd
T8 - RDF+ S+ Zn-EDTA	5.87±0.25bc	8.77±0.26c	11.47±0.25b	9.30±0.22bc	35.7±1.2bc	31.7±1.2bc

4.7.1 Fresh weight and dry weight of plant (g): - Fresh weight and dry weight of rice crop recorded at 40 and 80 DAT and at 60 and 75 DAS the weight recorded in wheat crop presented in table 4.7.1.3. In case of fresh and dry weight of plant the data significantly varied among treatments. In wheat and rice crop, the mean of two years data presented. The scrutiny of date presented in table for rice crop indicate that fresh weight of plant ranged from 52.73 g to 81.37 g at 40 DAT and 100.7 g to 174.6 g at 80 DAT. The maximum fresh weight (81.37 g and 174.63 g) recorded with the application of NCU + PK + S + Zn-EDTA (T_3) which was followed by T_5 with 74.77 and 149.93 g at 40 and 80 DAT respectively. The minimum fresh weight (52.77, 100g) recorded under T_2 at 40 DAT and under T_0 at 80 DAT which was at par with T_2 with 100.77g weight. All the treatments were significantly different from each other in case of fresh weight. The dry weight ranged from 20.42 g to 29.33 at 40 DAT and 31.49 to 66.29 g at 80 DAT. The maximum dry weight (29.33 g and 56.29 g) recorded at 40 and 80 DAT under T_3 (NCU + PK + S + Zn-EDTA) which was followed by T_5 (NCU + PK + $ZnSO_4$) with 26.21 and 56.59 g respectively. T_8 and T_1 also showed more weight over other treatments (24.05 g, 47.43 g and 23.41, 46.30 g). The lowest dry weight (20.4g) at 40 DAT recorded under T0 and 30.43 g at 80 DAT recorded under T_2. In wheat crop, fresh weight recorded at 60 and 75 DAS. The fresh weight ranged from 27.8 g to 34.8 g at 60 DAS and 33.87 to 41.63 g at 75 DAS. The maximum fresh weight (34.8 g and 41.63 g) recorded with application of NCU + PK + S + Zn-EDTA (T_3) followed by T_5 (32.8, 38.6 g). The next higher fresh weight (31.77, 36.4.7.1.45 g) recorded with T_1. The lowest fresh weight 27.8, 33.8 recorded with the application of AA + PK (T_2) which was followed by T_0 with 29.6 at 60 DAS respectively. The dry weight ranged from 16.8 to 22.7 g at 60 DAS and 21.4 to 30.5 g at 75 DAS. The maximum dry weight (22.7, 33.5 g) recorded under T_3 followed by T_5 (21.3, 27.2 g). The lowest dry weight (16.8 g, 21.4 g) recorded under T_2 followed by T_0 (18.3, 23.4 g). The date of wheat presented in fig 4.7.1.3 (b).

4.7.1.3 A, B

4.7.1.3 C, D

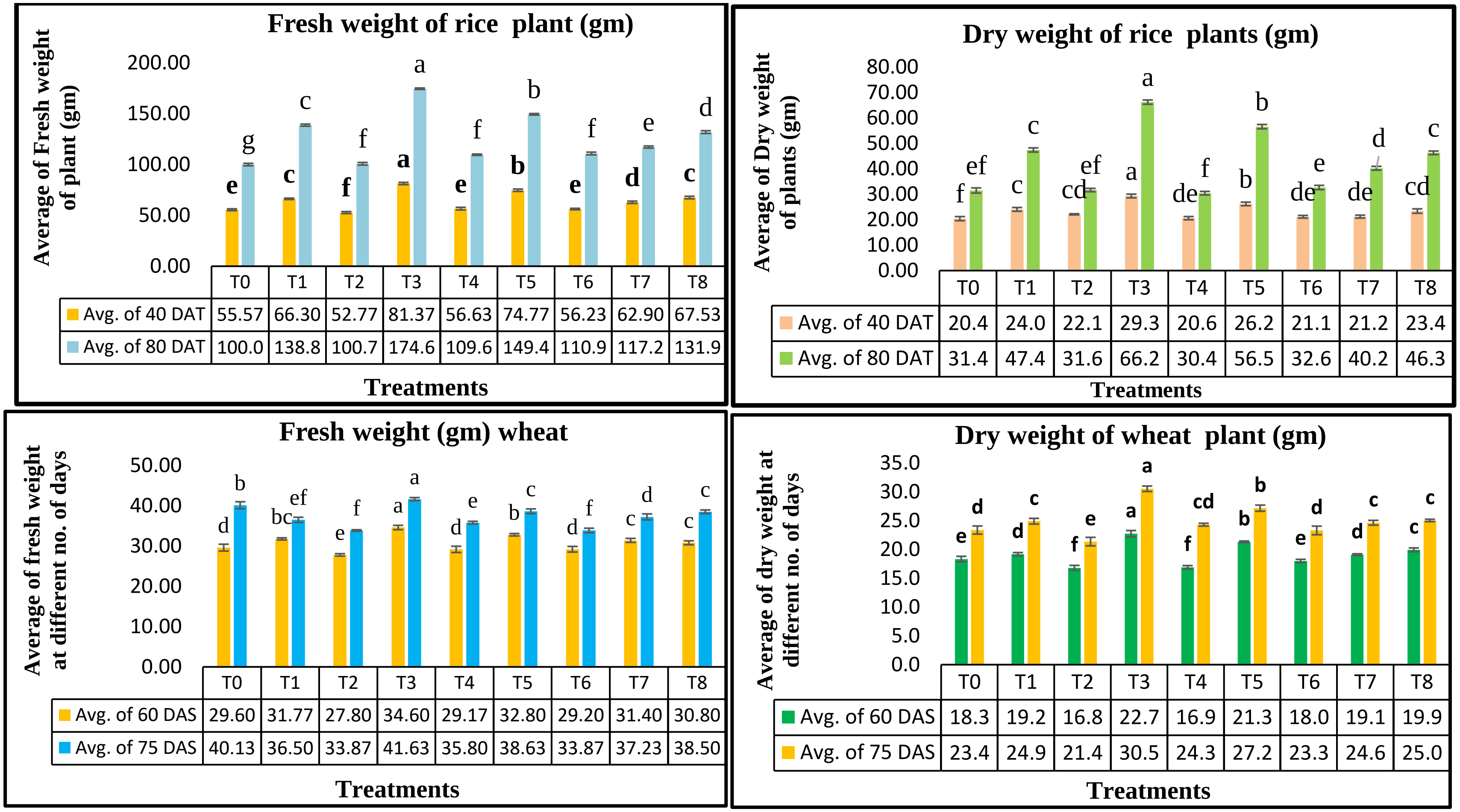


Fig.4.7.1.3 A&B, C&D representing the fresh weight and dry weight (g) at different intervals of rice and wheat crop in pot experiment. Data shown as mean of S.E. Means with common letters for each figure are not significantly different according to LSD at $p<0.05$.

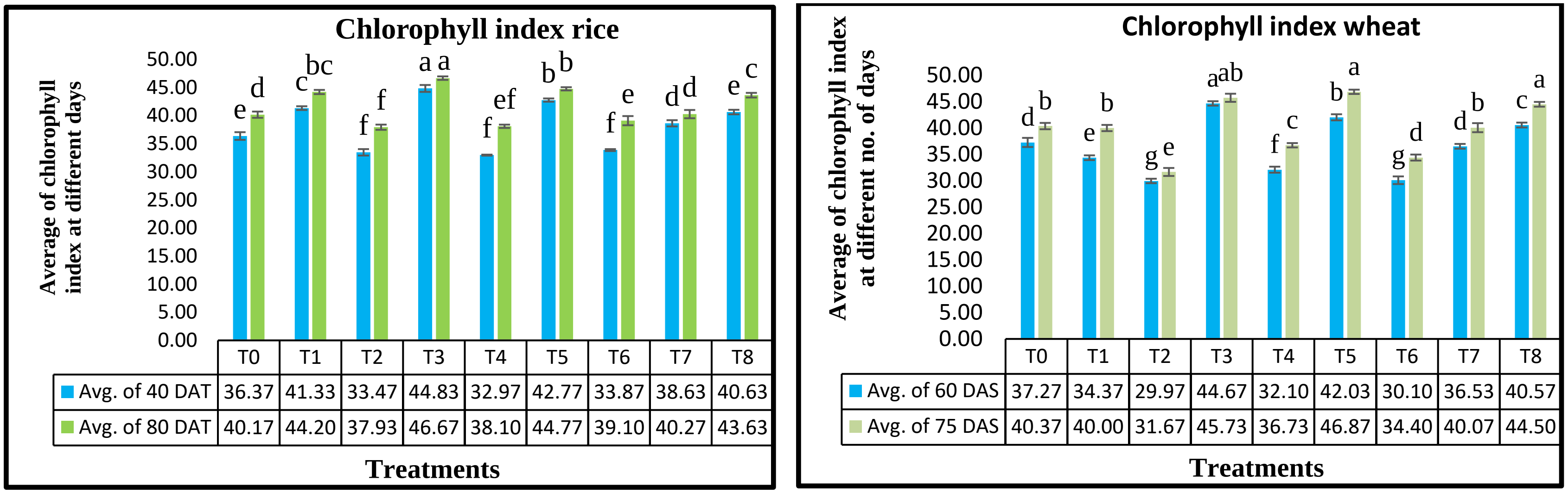
Table 4.7 .1.3Effect of different modified fertilizers on fresh and dry weight (g) (mean± S.E) of plants of rice wheat crop at different intervals in pot experiment.

Treatments	RICE				WHEAT			
	Fresh weight (g) 40 DAT	Dry weight (g) 40 DAT	Fresh weight (g) 80 DAT	Dry weight (g) 80 DAT	Fresh weight (g) 60 DAS	Dry weight (g) 60 DAS	Fresh weight (g) 75 DAS	Dry weight (g) 75 DAS
T0- Control (RDF)	55.57±0.87e	20.42±0.81f	100.00±1.18g	31.49±1.01ef	29.60±0.85d	18.3±0.47e	40.13±0.86b	23.4±0.70d
T1 - Neem coated urea + PK recommended	66.30±0.70c	24.05±0.74c	138.80±1.02c	47.43±0.82c	31.77±0.26bc	19.2±0.29d	36.50±0.64ef	24.9±0.50c
T2 - Anhydrous ammonia + PK recommended	52.77±0.97f	22.12±0.22cd	100.77±1.29f	31.67±0.66ef	27.80±0.29e	16.8±0.43f	33.87±0.17f	21.4±0.74e
T3 - Neem coated urea + PK + S + Zn-EDTA	81.37±1.11a	29.33±0.72a	174.63±0.70a	66.24±0.84a	34.60±0.54a	22.7±0.56a	41.63±0.3a	30.5±0.47a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	56.63±1.28e	20.61±0.63de	109.67±0.66f	30.43±0.69f	29.17±0.78d	16.9±0.29f	35.80±0.33e	24.3±0.24cd
T5- Neem coated urea + PK + $ZnSO_4$	74.77±1.16b	26.21±0.70b	149.43±0.74b	56.59±0.86b	32.80±0.29b	21.3±0.12b	38.63±0.58c	27.2±0.53b
T6 - Anhydrous ammonia + PK+ $ZnSO_4$	56.23±0.69e	21.17±0.52de	110.90±1.31f	32.67±0.84e	29.20±0.70d	18.0±0.28e	33.87±0.56f	23.3±0.75d
T7 - RDF + $ZnSO_4$	62.90±1.12d	21.21±0.58de	117.23±1.03e	40.23±0.74d	31.40±0.49c	19.1±0.14d	37.23±0.74d	24.6±0.42c
T8 – RDF + S + Zn-EDTA	67.53±1.23c	23.41±0.87cd	131.93±1.36d	46.30±0.70c	30.80±0.49c	19.9±0.33c	38.50±0.45c	25.0±0.21c

4.7.1.4 Chlorophyll index (SPAD): - The chlorophyll index in rice crop recorded at 40 and 80 DAT and in wheat crop at 60 and 75 DAS presented in table 4.7.4. The data presented in table indicated that chlorophyll index was statistically significant. In rice crop, the chlorophyll content ranged from 32.97 to 44.83 SPAD at 40 DAT and 37.93 to 46.67 SPAD at 80 DAT. The highest chlorophyll content (44.83, 46.67 SPAD) recorded in T_3 followed by T_5 (42.77, 44.77 SPAD). The next recorded under T_8 (43.6) and T_1 (41.3, 44.2). The lowest chlorophyll index under T_4 and 37.93 SAPD recorded under T_2. The data of chlorophyll index of rice presented in fig. 4.7.4.In wheat crop, the chlorophyll content ranged from 29.97 to 44.67 SPAD at 60 DAS and 31.67 to 46.87 SPAD at 75 DAS. The maximum chlorophyll index (44.67 SPAD) at 60 DAS recorded under T_3 followed by T_5 (42.03). at 75 DAS, maximum chlorophyll index 46.87 recorded under T_5 which was at par with T_3 (45.73). The lowest chlorophyll content 29.97, 31.67 SPAD recorded under T_2 which was followed by T_4 with values 32.10 and 36.73 respectively. The data of chlorophyll content of wheat crop depicted in fig. 4.7.4

4.7.1.5 Leaf area: - The leaf area of rice crop measured at 40 and 80 DAT and in wheat crop at 60 and 75 DAS. The leaf area in rice crop ranged from 60.6 to 67.3 cm^2 at 40 DAT and 69.1 to 78.3 cm^2 at 80 DAT. The maximum leaf 67.3, 78.3 cm^2 recorded with T_3 which was immediately followed by T_5 (66.5, 73.1 cm^2). The next highest leaf area recorded with T_8 (64.3, 72.5 cm^2) and T_1 (65.1, 73.1 cm^2). The lowest leaf area (60.6 cm^2) recorded under T_0 and 69.1 cm^2 at 75 DAS under T_2. In wheat crop, there was significant variation recorded in leaf area measurement at 60 and 75 DAS. The maximum leaf area (61.3, 74.3 cm^2) recorded under T_3 followed by T_5 (56.2, 70.5 cm^2). The next highest leaf area (54.6, 65.5 cm^2) recorded under T_8. The lowest leaf area (42.2, 51.53) recorded with T_0 which was at par with T_2 (42.6, 50.83 cm^2). The data of wheat leaf area presented in fig. 4.7.1.5 (b).

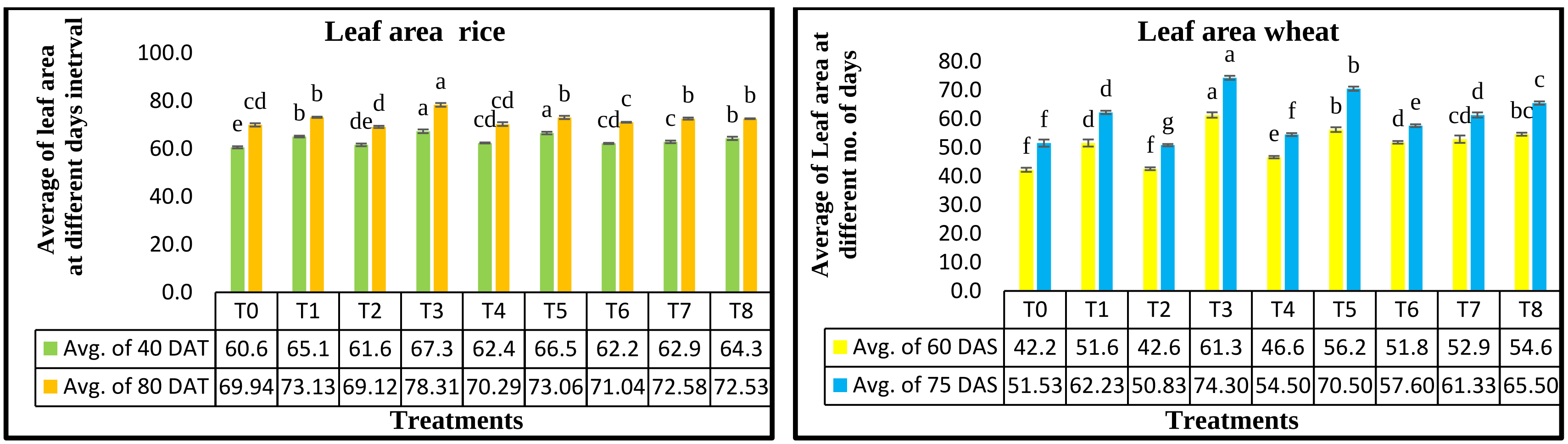
4.7.1.4A, B



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 40 DAT	36.37	41.33	33.47	44.83	32.97	42.77	33.87	38.63	40.63
Avg. of 80 DAT	40.17	44.20	37.93	46.67	38.10	44.77	39.10	40.27	43.63

	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	37.27	34.37	29.97	44.67	32.10	42.03	30.10	36.53	40.57
Avg. of 75 DAS	40.37	40.00	31.67	45.73	36.73	46.87	34.40	40.07	44.50

4.7.1.5A, B



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 40 DAT	60.6	65.1	61.6	67.3	62.4	66.5	62.2	62.9	64.3
Avg. of 80 DAT	69.94	73.13	69.12	78.31	70.29	73.06	71.04	72.58	72.53

	T0	T1	T2	T3	T4	T5	T6	T7	T8
Avg. of 60 DAS	42.2	51.6	42.6	61.3	46.6	56.2	51.8	52.9	54.6
Avg. of 75 DAS	51.53	62.23	50.83	74.30	54.50	70.50	57.60	61.33	65.50

Fig.4.7.1.4 A&B representing the chlorophyll index at different intervals and Fig. 4.7.1.5 A&B representing leaf area of rice and wheat crop in pot experiment .Data shown as mean of S.E. Means with common letters for each figure are not significantly different according to LSD at $p<0.05$

Table 4.7.1.4 Effect of modified fertilizers on chlorophyll index (SPAD) and leaf area (cm2) of rice-wheat cropping system in pot Experiment.

Treatments	**RICE**				**WHEAT**			
	Chlorophyll index (SPAD) 40 DAT	Chlorophyll index(SPAD) 80 DAT	Leaf area (cm^2) at 40 DAT	Leaf area (cm^2) at 80 DAT	Chlorophyll index (SPAD) 60 DAS	Chlorophyll index (SPAD) 75 DAS	Leaf area (cm^2) at 60 DAS	Leaf area (cm^2) at 75 DAS
T0- Control (RDF)	36.37±0.68e	40.17±0.56d	60.6±0.4e	69.9±0.7cd	37.27±0.87d	40.37±0.60b	42.2±0.71f	51.53±1.25f
T1 - Neem coated urea + PK recommended	41.33±0.33c	44.20±0.37bc	65.1±0.4b	73.1±0.2b	34.37±0.45e	40.00±0.59b	51.6±1.24d	62.23±0.57d
T2 - Anhydrous ammonia + PK recommended	33.47±0.57f	37.93±0.46f	61.6±0.6de	69.1±0.5d	29.97±0.42g	31.67±0.76e	42.6±0.49f	50.83±0.39g
T3 - Neem coated urea + PK + S + Zn-EDTA	44.83±0.61a	46.67±0.31a	67.3±0.8a	78.3±0.8a	44.67±0.42a	45.73±0.77ab	61.3±0.94a	74.30±0.70a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	32.97±0.09f	38.10±0.29ef	62.4±0.2cd	70.3±0.8cd	32.10±0.58f	36.73±0.41c	46.6±0.42e	54.50±0.51f
T5- Neem coated urea + PK + $ZnSO_4$	42.77±0.29b	44.77±0.29b	66.5±0.5a	73.1±0.7b	42.03±0.5b	46.87±0.41a	56.2±0.82b	70.50±0.73b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	33.87±0.17f	39.10±0.82e	62.2±0.2cd	71.0±0.2c	30.10±0.7g	34.40±0.57d	51.8±0.45d	57.60±0.50e
T7 - RDF + $ZnSO_4$	38.63±0.56d	40.27±0.74d	62.9±0.5c	72.6±0.4b	36.53±0.45d	40.07±.86b	52.9±1.28cd	61.33±0.90d
T8 – RDF + S+ Zn-EDTA	40.63±0.40e	43.63±0.41c	64.3±0.7b	72.5±0.2b	40.57±0.46c	44.50±0.45a	54.6±0.53bc	65.50±0.57c

4.7.1.6 CGR, RGR, NAR: - The CGR, RGR, NAR of rice and wheat presented in fig. 4.7.1.6 (A) and 4.7.1.6 (B) and table 4.7.1.6. in rice and wheat crop CGR was significantly different among treatments. The maximum CGR (0.92 and 0.52) in rice and wheat crop was recorded under T_3 followed by T_5 with values 0.76 and 0.38 gm-^{2}. The lowest CGR (0.28 g cm-^{2}) recorded under T_0 in rice crop and (0.304 g cm^{-2}) and in wheat recorded under T_2.The RGR in rice and wheat crop recorded maximum (0.0088, 0.0085 g^{-1}g^{-1}cm^{-2}) under T_3 which was immediately followed by T_5 (0.0084 g^{-1}g^{-1}cm^{-2}). The lowest RGR (0.0039 and 0.0070 g^{-1}g^{-1}cm^{-2}) recorded under T_2 in rice and wheat crop. NAR recorded maximum (0.000167 and 0.106 g^{-1} cm^2) recorded under T_1, T_4 in rice and wheat which was at par with T_2 (0.00166 in rice and 0.106 in T_4 in wheat crop. The lowest NAR (0.0001) in rice recorded under T_3 and in wheat (0.048) under T5.

4.7.1 Flag leaf length: - The flag leaf length recorded in wheat crop at 60 and 75 Das. The maximum flag leaf length 34.6 and 41.63 cm recorded under T_3 which was at par with T_5 having values 32.8, 38.63 cm respectively. The next highest flag leaf length (30.8, 38.5 cm) recorded under T_8 and 31.77, 36.55 cm under T_1. The lowest flag leaf length (27.8, 33.87 cm) recorded under T_2 which was followed by T_0 (29.6, 40.13 cm). The data presented in table 4.7.7 and fig. 4.7.7. (A).

4.7.2 Yield attributing characters and yield: - The yield attributing parameters i.e. panicle/spike length, filled grains, 1000 grain weight, grain yield, straw yield and harvest index are discussed under this section and presented with the help of figures and tables.

4.7.2.1 Panicle/spike length: - The data of panicle length in rice and spike length in wheat presented in table 4.7.2.1 and fig. 4.7.2.1(a). the panicle length in rice crop ranged from 18.77 to 25.6 cm. the maximum panicle length 25.6 cm recorded under T_3 followed by T_5 (23.73 cm). The next highest panicle length 23.70 observed in T_8 which was at par with T_5. In wheat crop, the highest spike length 10.7 cm recorded in T_3 followed T_1 (10.33), T_8 (10.13 cm) and T_5 (9.90 cm0. The lowest spike length (7.30 cm) recorded under T_4 followed by T_2 (7.90 cm).

4.7.1.6A, B

4.7.1.6 C, D

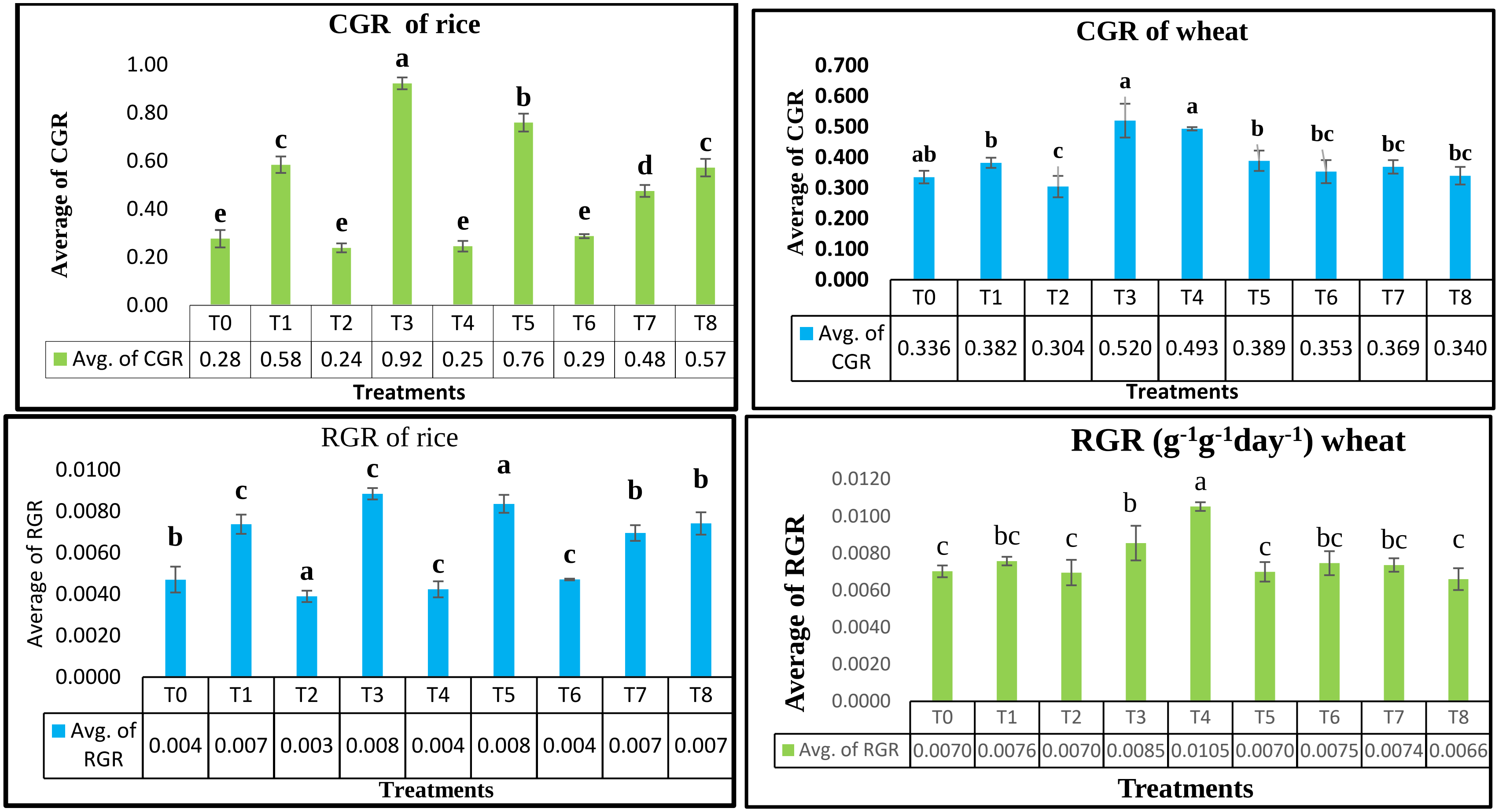


Fig.4.7.1.6 A&B , C& D representing CGR, RGR of rice and wheat crop .Data shown as mean of S.E. Means with same letters for ach figure are not significantly different according to LSD at $p<0.05$

4.7.1.6 E, F

4.7.2.1 A, B

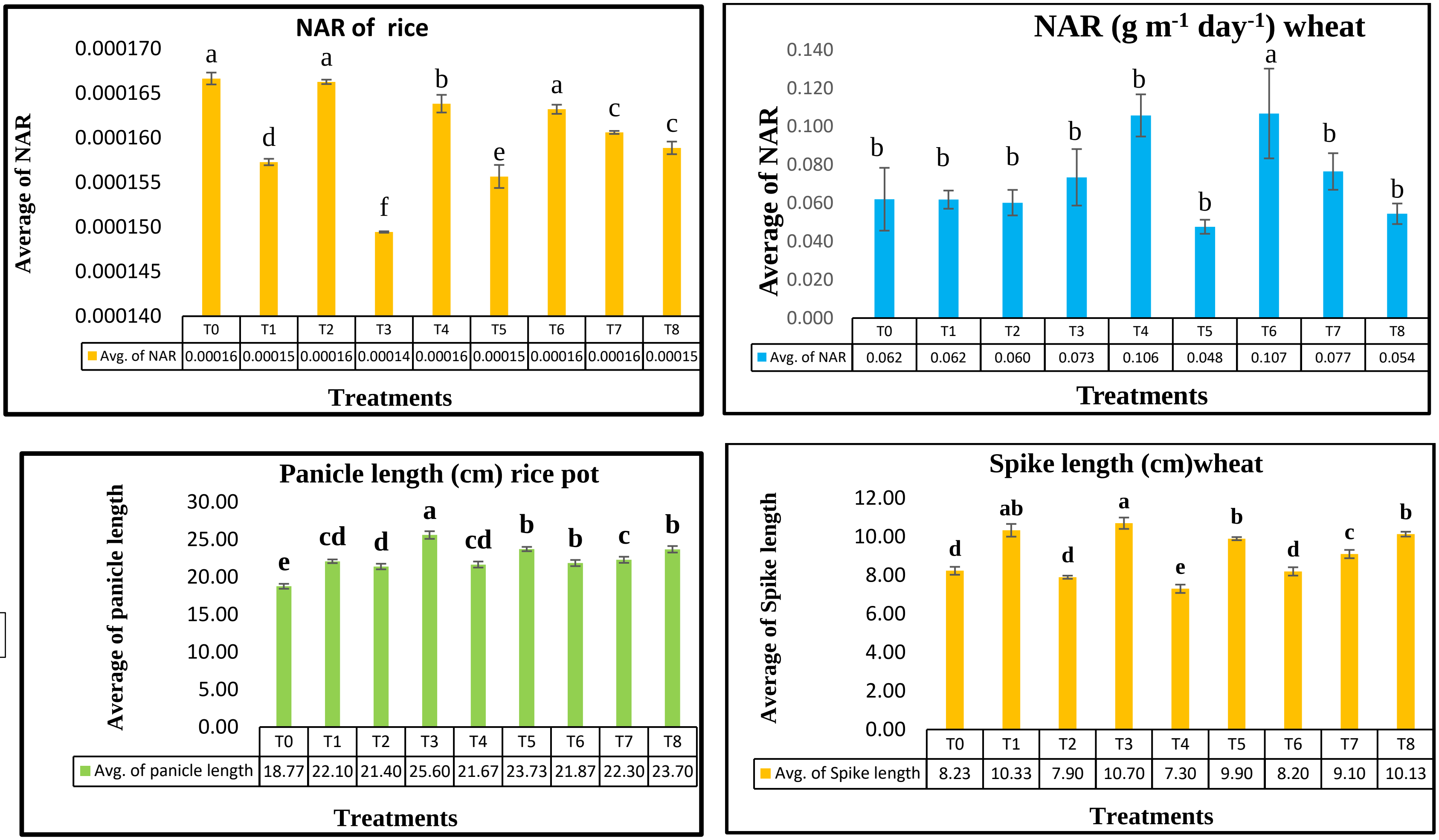


Fig.4.7.1.6 E&F representing the NAR at different intervals and Fig.4.7.2.1 A&B representing panicle and spike length of rice and wheat crop .Data shown as mean of S.E. Means with same letters for each figure are not significantly different according to LSD at $p<0.05$

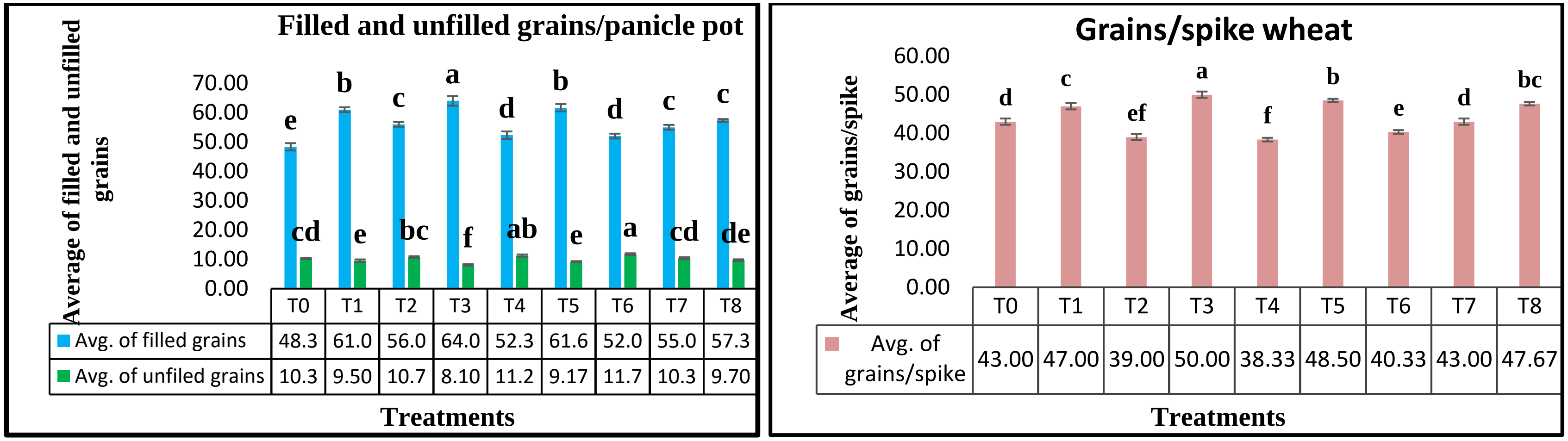
Table 4.7.1.6 Effect of biochar based amendments on CGR, RGR and NAR of rice-wheat cropping system in pot experiment.

Treatments	RICE			WHEAT		
	CGR	RGR	NAR	CGR	RGR	NAR
T0- Control (RDF)	0.28±0.04e	0.0047±0.0006c	0.000167±0.0000007a	0.336±0.021ab	0.0070±0.0003c	0.062±0.016b
T1 - Neem coated urea + PK recommended	0.58±0.03c	0.0074±0.0005b	0.000157±0.0000004d	0.382±0.017b	0.0076±0.0002bc	0.062±0.005b
T2 - Anhydrous ammonia + PK recommended	0.24±0.02e	0.0039±0.0003c	0.000166±0.0000002a	0.304±0.035c	0.0070±0.0007c	0.060±0.007b
T3 - Neem coated urea+ PK + S + Zn-EDTA	0.92±0.02a	0.0088±0.0003a	0.000149±0.0000001f	0.520±0.055a	0.0085±0.0009b	0.073±0.015b
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	0.25±0.02e	0.0042±0.0004c	0.000164±0.0000010b	0.493±0.005a	0.0105±0.0002a	0.106±0.011a
T5- Neem coated urea + PK + $ZnSO_4$	0.76±0.04b	0.0084±0.0004a	0.000156±0.0000013e	0.389±0.033b	0.0070±0.0005c	0.048±0.004b
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	0.29±0.01e	0.0047±0.0000c	0.000163±0.0000005a	0.353±0.038bc	0.0075±0.0006bc	0.107±0.023a
T7 - RDF + $ZnSO_4$	0.48±0.02d	0.0070±0.0004b	0.000161±0.0000002c	0.369±0.022bc	0.0074±0.0004bc	0.077±0.010b
T8 - RDF+ S+ Zn-EDTA	0.57±0.04c	0.0074±0.0005b	0.000159±0.0000007c	0.340±0.029bc	0.0066±0.0006c	0.054±0.005b

4.7.2.2 Number of filled, unfilled grains/spike/panicle: - In rice crop and wheat crop filled grains per panicle presented in table 4.7.2.2 and fig 4.7.2.2(a). In rice crop filled and unfilled grains/panicle was significantly affected by modified fertilizers. The maximum filed grains per panicle (64) recorded under T_3 follow by T_5 with 6167 and T_1 (61). The minimum filled grains per panicle (48.33) recorded under T_0. In case of unfilled grains, the minimum (8.10) recorded in T_3 immediately followed by T_5 (9.17) and T_1 (9.50). The maximum unfilled grains per panicle (11.77) recorded under T_6 followed by T_4 (11.27) respectively. In wheat crop, the number of grains per spike ranged from 38.3 to 50. The maximum no. of grains per spike (50) recorded under T_3 followed by T_5 (48.5). T_8 and T_1 also recorded more grains per spike (47.67, 47) over other treatments. The minimum grains per spike (3.33) recorded under T_4 followed by T_6 (40.33).

4.7.2.3 1000 grains weight: - Test weight is the important characteristic of the grain yield. 1000 grain weight is the weight of 1000 seeds. The data of test weight of rice and wheat presented in table 4.7.2.3 and 4.7.2.3 (a). Test weight in case of rice ranged from 19.3 to 21.3 g. The maximum test weight (21.3 g) recorded under T_3 which was followed by T_5. There was non-significant variation recorded all treatments except T_3 in case of test weight. The lowest test weight (19.3 g) recorded under. In wheat crop, test weight ranged from 32.97 to 44 g. the highest test weight (44 g) observed in T_3 which was at par with T_5 (43.6 g). The next highest test weight (41.67 g) recorded in T_8. The lowest (31.33 g) test weight was recorded under T_2 which was followed by T_4 (32.97 g). All the treatments were significantly affected by modified fertilizers in case of test weight.

4.7.2.2 A, B



4.7.2.3 A, B

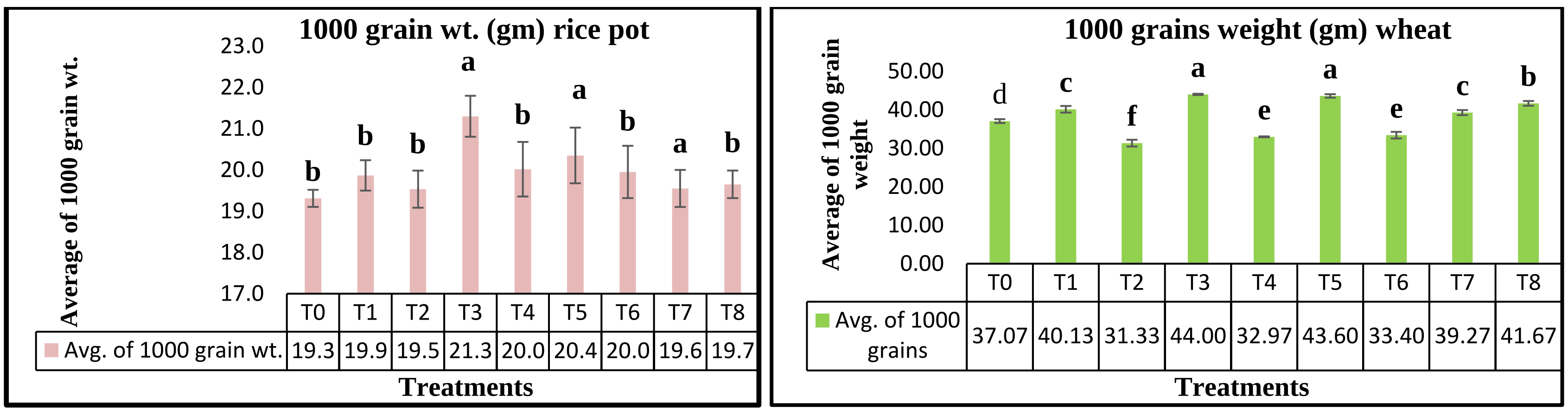


Fig.4.7.2.2 (A, B) indicate number of grains per panicle/spike, 4.7.2.3(A, B) represent test weight (g) of rice wheat crop in pot experiment. Common letters indicate that treatments are non- significant among themselves according to DMRT ($p<0.05$)

Table 4.7.2.1 Panicle length, filled grains, unfilled grains of rice and spike length, grains/ spike, flag leaf length of wheat in pot experiment

Treatments	Rice			wheat			
	Panicle length (cm)	Filled grains	Unfilled grains	Spike length (cm)	Grains/ spike	Flag leaf length 60 DAS	Flag leaf length 75 DAS
T0- Control (RDF)	18.77±0.33e	48.33±1.25e	10.30±0.22cd	8.23±0.21d	43.00±0.82d	29.60±0.85d	40.13±0.86f
T1 - Neem coated urea + PK recommended	22.10±0.24cd	61.00±0.82b	9.50±0.45e	10.33±0.33ab	47.00±0.82c	31.77±0.26ab	36.50±0.64bc
T2 - Anhydrous ammonia + PK recommended	21.40±0.37d	56.00±0.82c	10.77±0.29bc	7.90±0.08d	39.00±0.82ef	27.80±0.29e	33.87±0.17e
T3 - Neem coated urea + PK + S + Zn-EDTA	25.60±0.51a	64.00±1.63a	8.10±0.22f	10.70±0.29a	50.00±0.82a	34.60±.54a	41.63±0.39a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	21.67±0.40cd	52.33±1.25d	11.27±0.39ab	7.30±0.22e	38.33±0.47f	29.17±0.78c	35.80±0.33cd
T5- Neem coated urea + PK + $ZnSO_4$	23.73±0.29b	61.67±1.25b	9.17±0.21e	9.90±0.08b	48.50±0.41b	32.80±0.29a	38.63±0.58b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	21.87±0.41b	52.00±0.82d	11.77±0.29a	8.20±0.22d	40.33±0.47e	29.20±0.70bc	33.87±0.56de
T7 - RDF + $ZnSO_4$	22.30±0.41c	55.00±0.82c	10.37±0.33cd	9.10±0.22c	44.00±0.82d	31.40±0.49cd	37.23±0.74e
T8 – RDF + S + Zn-EDTA	23.70±0.43b	57.33±0.47c	9.70±0.29de	10.13±0.12b	47.67±0.47bc	30.80±0.49ab	38.50±0.45bc

4.7.2.4 Grain and straw yield: - Grain and straw yield are the important parameters which are additive effects of crop growth parameters and yield attributing parameters. The data depicted in fig. 4.7.2.4 (a) and 4.7.2.4 9(b) and table 4.7.2.3. The grain and straw yield in rice and wheat crop recorded per plot in grams. In rice crop maximum grain yield and straw yield (5.57 g/pot) and (9.53 g) recorded with NCU + PK + S + Zn-EDTA (T_3) which was immediately followed by T_5 having yield (4.71, 8.47 g/pot) respectively. The next highest grain and straw yield (4.20, 8.36 g/pot) recorded under T_1. The lowest grain and straw yield (2.20, 4.77 g) recorded under T_0.In wheat crop, the maximum grain yield straw yield (5.08, 6.89 g/pot) recorded under T_3 which was followed by T_5 (4.90, 5.85 g). The next highest grain yield (4.88) recorded with application of NCU + PK (T_1) and straw yield (5.65) under T_8. The lowest grain and straw yield (3.20, 4.61 g/pot) recorded under T_0. All the treatments were statistically significant from others.

4.7.2.5 Harvest index (%): - Harvest index (%) data presented in table 4.7.2.3 and fig 4.7.2.5 (a). In case of rice crop, the treatments were statistically significantly different from each other. The harvest index ranged from 30.21% to 36.88%. The highest H.I (36.88%) recorded under T_3 which was followed by T_5 with value 35.73%. The lowest harvest index (30.21%) recorded under T_2 which was followed by T_0 with 31.5% respectively. In wheat crop, the maximum harvest index (45.2%) recorded under T_3 which was at par with T_5 (45%), T_7 (45%), T_8 (44.8%), T_1 (44.3), T_2 (44). The lowest harvest index (41%) recorded under T_0.

4.7.2.4 A, B

4.7.2.5 A, B

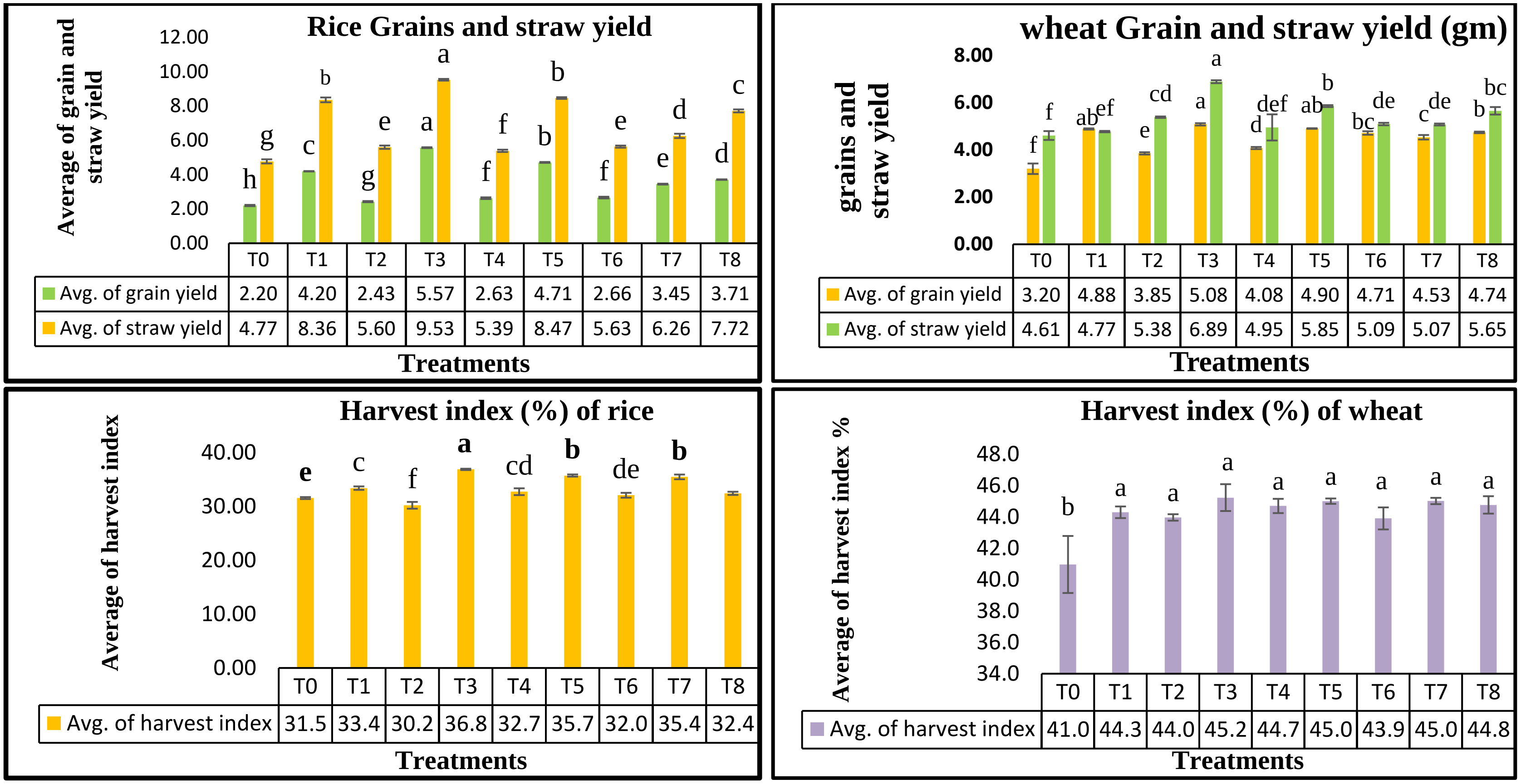


Fig. 4.7.2.4(A, B) represent grain yield and straw yield of rice wheat and 4.7.2.5 (A, B) represent harvest index (%) of rice- wheat crop.

Table 4.7.2.4 Effect of modified fertilizers on test weight (g), grain yield, straw yield and harvest index (%) of rice- wheat crop in pot experiment.

Treatments	2018				2019			
	Test weight (g)	Grain yield (g/pot)	Straw yield (g/pot)	Harvest index (%)	Test weight (g)	Grain yield (g/pot)	Straw yield (g/pot)	Harvest index (%)
T0 Control (RDF)	19.3±0.2b	2.20±0.04h	4.77±0.12g	31.55±0.18e	37.07±0.50d	3.20±0.22f	4.61±0.19f	41.0±1.8b
T1 - Neem coated urea +PK recommended	19.9±0.4b	4.20±0.01c	8.36±0.14b	33.40±0.32c	40.13±0.86c	4.88±0.03ab	4.77±0.03ef	44.3±0.4a
T2 - Anhydrous ammonia+ PK recommended	19.5±0.4b	2.43±0.03g	5.60±0.10e	30.21±0.63f	31.33±0.88f	3.85±0.05e	5.38±0.03cd	44.0±0.2a
T3 - Neem coated urea+ PK+S+ Zn-EDTA	21.3±0.5a	5.57±0.02a	9.53±0.05a	36.88±0.12a	44.00±0.16a	5.08±0.05a	6.89±0.06a	45.2±0.9a
T4 - Anhydrous ammonia +PK+ S+ Zn-EDTA	20.0±0.7b	2.63±0.05f	5.39±0.07f	32.73±0.63cd	32.97±0.12e	4.08±0.04d	4.95±0.55def	44.7±0.5a
T5 Neem coated urea +PK+$ZnSO_4$	20.4±0.7a	4.71±0.02b	8.47±0.05b	35.73±0.20b	43.60±0.45a	4.90±0.01ab	5.85±0.04b	45.0±0.2a
T6 - Anhydrous ammonia +PK+ $ZnSO_4$	20.00.6b	2.66±0.05f	5.63±0.06e	32.07±0.45de	33.40±0.86e	4.71±0.07bc	5.09±0.05de	43.9±0.7a
T7 - RDF + $ZnSO_4$	19.6±0.4a	3.45±0.03e	6.26±0.13d	35.48±0.44b	39.27±0.65c	4.53±0.10c	5.07±0.04de	45.0±0.2a
T8 - RDF+ S+ Zn-EDTA	19.7±0.3b	3.71±0.02d	7.72±0.09c	32.43±0.29de	41.67±0.62b	4.74±0.03b	5.65±0.16bc	44.8±0.6as s

4.7.3 Nutrient uptake

4.7.3.1 Nutrient uptake by grain and straw: - The nitrogen uptake by grain and straw of rice and wheat crop significantly affected is presented in table 4.7.3.1 and fig 4.7.3.1 (A) and 4.7.3.1 (B). In rice crop maximum N uptake by grain and straw (871.4 mg/pot and 549.1 mg/pot) recorded in T3. The next to T_5, the highest uptake (792.1, 515.56 g) recorded under T_1. The lowest (523.7 and 296.11 g) recorded under T_0 which was followed by T_2 (550.2, 355.53 mg/pot). In wheat crop, the maximum N uptake by grain and straw (861.6 mg, 590.0 mg/pot) recorded under T_3. The second and third highest N uptake by grain and straw recorded under T5 (810.3, 526.3 mg/pot) and T_8 (808, 514.3 mg/pot). The lower N uptake (550.3, 330 mg/pot) recorded under T2-.

4.7.3.2 P uptake by grain and straw: - The data presented in table 4.7.3.1 and fig. 4.7.3.2 (A) and 4.7.3.2 (B). The scrutiny of data presented in table 4.7.3.1 indicates P uptake was significant influenced by different treatments. In rice crop, the highest P uptake by grain and straw (42.31, 65.5 mg/pot) recorded with application of NCU + PK + S + Zn-EDTA (T_3) which was followed by T_5 (39.2, 5.23 mg). The next highest P uptake by straw and grain (37.24, 43.9 mg/pot). The lowest P uptake by grain and straw (15.53, 2.17 mg/pot) recorded in T_0 followed by T_2 (19.62, 2.59 mg/pot). In wheat crop the maximum P uptake was recorded in T3 followed d by T5 and minimum in T0.

4.7.3.3 K uptake grain and straw: - The K uptake by grain and straw of rice and crop presented in fig. 4.7.3.3 (a) and 4.7.3.3 (b). The data was significantly affected by various treatments. The maximum K grain and straw uptake (240, 883 mg/pot) observed with the application of NCU + PK + S + Zn-EDTA. This treatment was followed by T_5 (218.7, 817.4 mg/pot) and T_1 (189.7, 797.1 mg/pot). The least K uptake by grain and straw (106.4, 559 mg/pot) recorded under T_0 followed by T_2 (113.2, 620 mg/pot) in rice crop. In wheat crop the maximum K uptake by grain and straw **(**251.3, 832) recorded under T_3. The second highest K uptake (229.7, 801 mg/pot) recorded in T_5 which was followed by T_1 (198, 782 mg/pot). The lowest K uptake by grain and straw was recorded (108 mg in T_2 and 574 mg) in T_0.

4.7.3.4 S uptake by grain and straw: - The S uptake by grain and straw was significantly influenced by additional S application depicted in table 4.7.3.4 and fig 4.7.3.4 (A) and 4.7.3.4 (B). The maximum S uptake by grain and straw (92.7,184.6 mg/pot) noted in T_3 followed by T_8 (43.24, 4.73 mg). The next highest (40.87, 40 mg/pot) recorded in T_8. The lowest uptake from applied plots recorded in T_6 (18.77, 2.89 mg/pot0 in rice crop. In wheat crop the maximum S uptake (48.07, 6.8 mg/pot) recorded in T_3 followed by T_5 (46.5, 5.0 mg) recorded in T_5. The lowest S uptake by grain and straw (19.97, 2.8 mg/pot) noted in T_6.

4.7.3.5 **Zn uptake by grain and straw**: - The Zn uptake by grain and straw was significantly influenced by additional Zn application depicted in fig 4.7.3.5 (A) and 4.7.3.5 (B). The maximum Zn uptake by grain and straw (46.9, 4.77 mg/pot) noted in T_3 followed by T_8 (65.94, 120.3 mg). The lowest uptake from applied plots recorded in T_4 (41.11,89.4 mg/pot) in rice crop. In wheat crop the maximum Zn uptake (90.2,215.3 mg/pot) recorded in T_3 followed by T_8 (59.6,160.2 mg) recorded in T_8. The lowest Zn uptake by grain and straw (41.2,75.2 mg/pot) noted in T_4.

4.7.4 Nutrient use efficiency: - In case of nutrient use efficiency, the response of modified fertilizers to crop demonstrated. The data of nutrient use efficiency of (N, P, K, and S) in rice and wheat crop presented in table 4.7.4. Nitrogen use efficiency of rice and wheat crop presented in fig 4.7.4 (a). Highest NUE (36.7,34%) recorded in T_3 followed by T_5 with (30.2, 32.5%). The lowest nitrogen use efficiency (9.53) in rice recorded in T_2 and 5.22% in wheat crop in T_4. PUE maximum (16.57, 56.9%) in rice and wheat crop recorded under T_3 followed by T_5 (14.22, 47.7%) and T_1 (12.73, 40.6%) and T_8 (10.26, 41.3%). The lowest PUE (2.40% and 13.2%) over control recorded in T_2. The data presented in 4.7.4(c). KUE also significantly affected by various modified fertilizers in rice and wheat crop presented in fig. The maximum KUE (46,48.2%) observed in T_3 in rice and wheat crop. The second highest KUE (42 and 45.2%) recorded in T_5 follow by T_1 (39.6,39.6%). The lowest KUE (13.6, 5.3%) recorded under T_2 over control. SUE also influenced by various treatments of modified fertilizers. Maximum SUE (17.24, 18.3%) in rice and wheat crop noted in T_3 followed by T_5 (16.01, 17.2%). The lowest (7.23 and 7.6%) noted in T_6. Maximum ZnUE(32.3,34.2%) in rice and wheat crop noted in T3 followed by T8 (21.2,22.5%). The lowest ZnUE (4.2,5.3%) recorded in T6.

4.7.3.1
A, B

4.7.3.2 A,
B

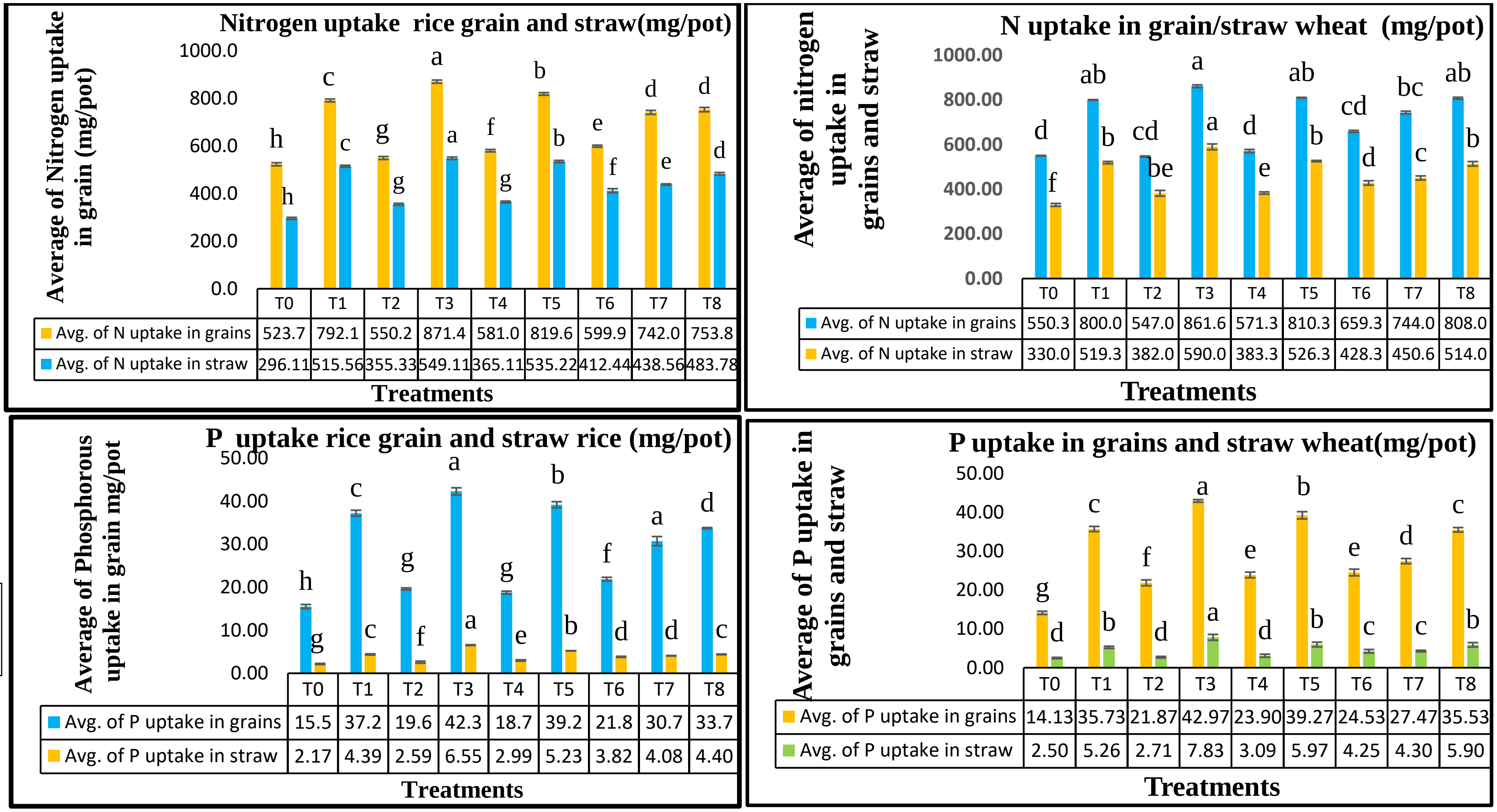
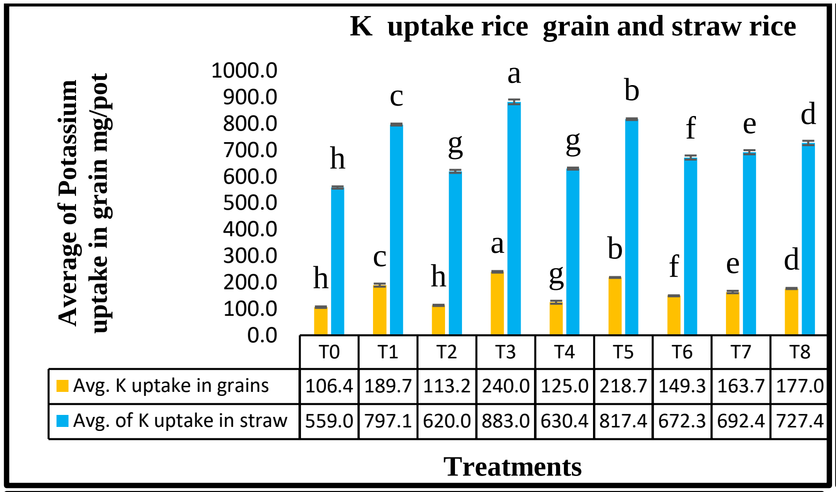
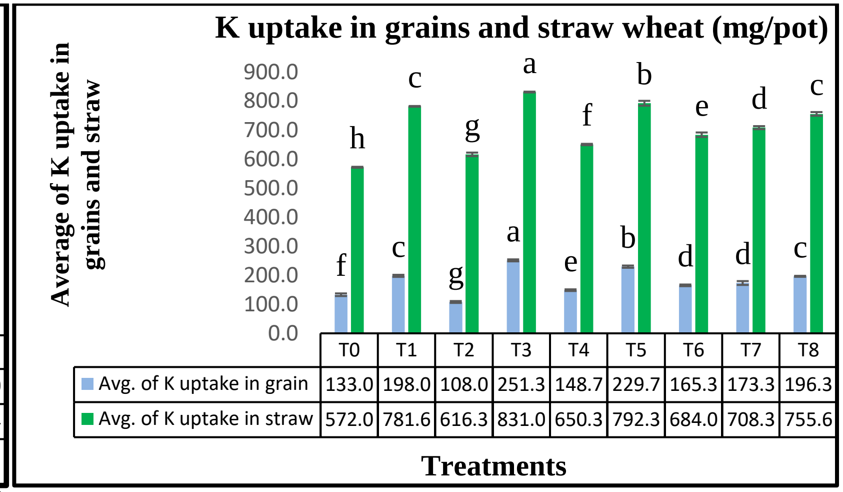


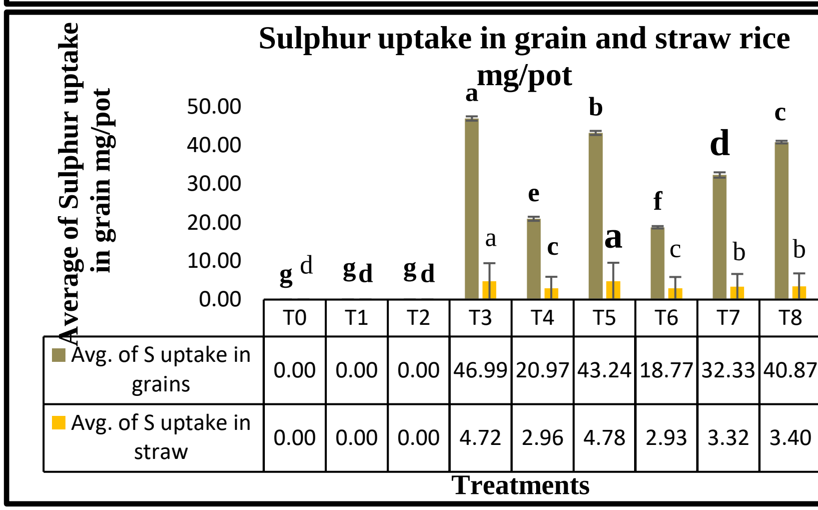
Fig.4.7.3.1 (A, B) depicting N uptake and Fig.4.7.3.2 (A, B) by grain and straw of rice & wheat in pot experiment. Different letters above the error bars indicate that treatments are non- significant among themselves.

4.7.3.3 A, B





4.7.3.4 A, B



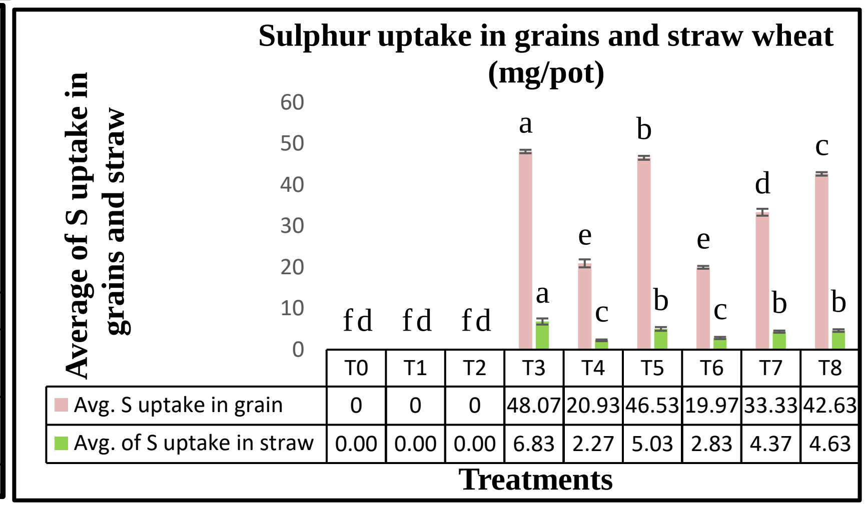


Fig. 4.7.3.3(A, B) & 4.7.3.4 (A, B) represent P & K uptake by grain and straw of rice- wheat in pot experiment. Different letters above the error bars indicate that treatments are non- significant among themselves according to DMRT (p<0.05).

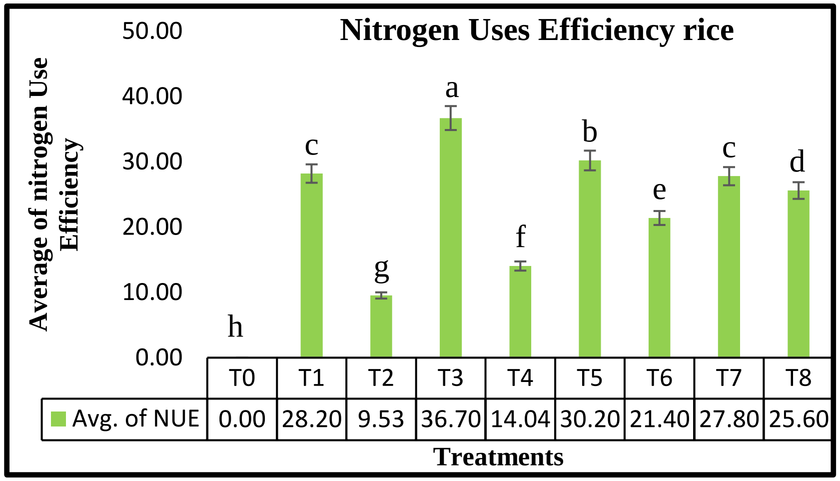
Table 4.7.3.1 Effect of different combination of fertilizers on Nutrient uptake (mean± S.E) of rice and wheat crop in pot experiment

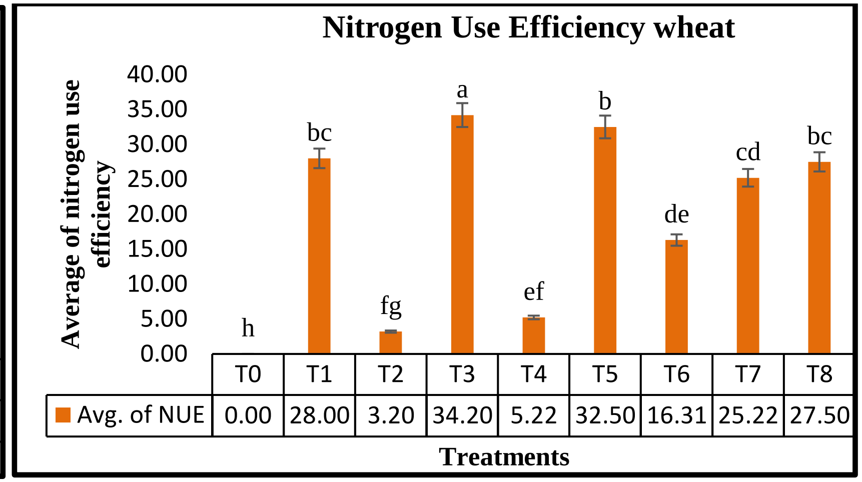
Treatments	Rice						Wheat					
	N uptake grain (mg/pot)	N uptake straw(mg/pot)	P uptake grain(mg/pot)	P uptake straw(mg/pot)	K uptake grain(mg/pot)	K uptake straw(mg/pot)	N uptake grain(mg/pot)	N uptake straw(mg/pot)	P uptake grain(mg/pot)	P uptake straw(mg/pot)	K uptake grain(mg/pot)	K uptake straw(mg/pot)
T0- Control (RDF)	523.7±6.5h	296.11±4.17h	15.53±0.47h	2.17±0.13g	106.4±2.79h	559.00±4.24h	550.33±1.25d	330.00±6.53f	14.13±0.41g	2.50±0.163d	133.0±4.55f	574.0±1.63h
T1 - Neem coated urea + PK recommended	792.1±5.9c	515.56±3.85c	37.24±0.68c	4.39±0.13c	189.7±5.79c	797.11±3.62c	800.00±1.63ab	519.33±5.19b	35.73±0.66c	5.26±0.277b	198.0±3.56c	782.0±1.25c
T2 - Anhydrous ammonia + PK recommended	550.2±6.1g	355.33±4.03g	19.62±0.23g	2.59±0.24f	113.2±2.28h	620.00±5.72g	547.00±2.16cd	382.00±12.83be	21.87±0.75f	2.71±0.202d	108.0±3.27g	612.0±6.53g
T3 - Neem coated urea+ PK + S + Zn-EDTA	871.4±6.6a	549.11±5.04a	42.31±0.83a	6.55±0.09a	240.0±2.94a	883.00±8.98a	861.67±6.02a	590.00±12.96a	42.97±0.32a	7.83±0.750a	251.3±3.40a	832.0±1.41a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	581.0±5.0f	365.11±3.40g	18.77±0.33g	2.99±0.15e	125.0±5.72g	630.44±3.85g	571.33±6.94d	383.33±4.99e	23.90±0.72e	3.09±0.392d	148.7±2.87e	652.0±2.36f
T5- Neem coated urea + PK + $ZnSO_4$	819.6±5.4b	535.22±4.79b	39.20±0.71b	5.23±0.01b	218.7±1.70b	817.44±3.15b	810.33±1.25ab	526.33±2.87b	39.27±0.92b	5.97±0.609b	229.7±3.86b	801.08.38b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	599.9±4.2e	412.44±8.57f	21.89±0.43f	3.82±0.13d	149.3±1.89f	672.33±7.76f	659.33±4.50cd	428.33±9.74d	24.53±0.85e	4.25±0.442c	165.3±2.87d	684.0±7.79e
T7 - RDF + $ZnSO_4$	742.0±8.2d	438.56±2.57e	30.73±1.07e	4.08±0.06d	163.7±4.50e	692.44±7.76e	744.00±5.89bc	450.67±8.99c	27.47±0.66d	4.30±0.194c	173.3±6.60d	708.3±5.31d
T8 – RDF + S + Zn-EDTA	753.8±9.0d	483.78±5.32d	33.74±0.14d	4.40±0.08c	177.0±2.16d	727.44±8.20d	808.00±4.32ab	514.00±10.03b	35.530.57c	5.90±0.572b	196.3 ±1.70c	755.7±6.34c

Table 4.7.4 Effect of different combination of fertilizers on Sulphur uptake (mean± S.E) of rice and wheat crop in pot experiment

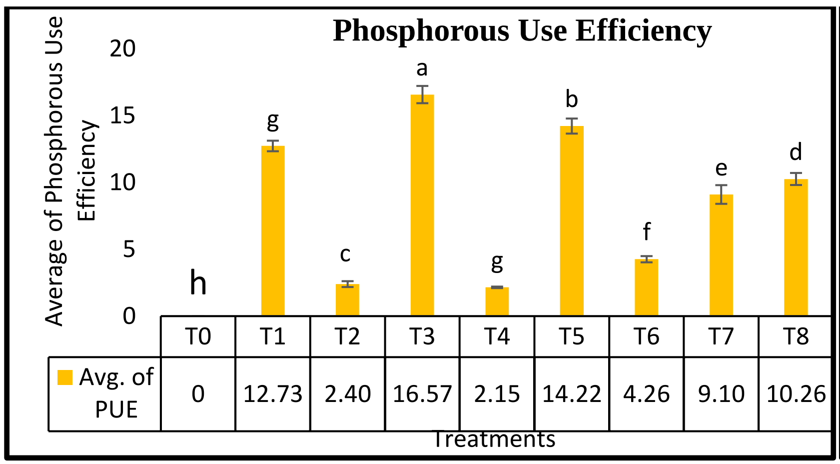
Treatments	Rice				wheat			
	S uptake by grain (mg/pot)	S uptake by straw (mg/pot)	Zn uptake by grain(mg/pot)	Zn uptake by Straw(mg/pot)	S uptake by grain (mg/pot)	S uptake by straw (mg/pot)	Zn uptake by grain(mg/pot)	Zn uptake by Straw(mg/pot)
T0- Control (RDF)	0.00±0.00g	0±0.00d	0.00±0.00g	0±0.00d	0±0f	0±0d	0.00±0.00g	0±0.00d
T1 - Neem coated urea +PK recommended	0.00±0.00g	0±0.00d	0.00±0.00g	0±0.00d	0±0f	0±0d	0.00±0.00g	0±0.00d
T2 - Anhydrous ammonia+ PK recommended	0.00±0.00g	0±0.00d	0.00±0.00g	0±0.00d	0±0f	0±0d	0.00±0.00g	0±0.00d
T3 - Neem coated urea + PK + S + Zn-EDTA	46.99±0.56a	4.77±4.72a	96.27±0.36 a	193.6±4.82 a	48.07±0.42a	6.8±0.74a	90.2±0.56a	215.3±4.72a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	20.97±0.53e	2.97±2.96c	40.11±0.33 f	98.5±1.96e	20.93±0.97e	2.3±0.21c	41.2±0.53e	75.2±2.96f
T5- Neem coated urea + PK + $ZnSO_4$	43.24±0.53b	4.73±4.78a	84.22±0.43 b	168±4.78b	46.53±0.47b	5.0±0.45b	70.3±0.53b	181.2±4.78b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	18.77±0.31f	2.89±2.93c	46.12±0.34 e	104 ±2.93e	19.97±0.34e	2.8±0.26c	47.2±0.31d	85.6±2.93e
T7 - RDF + $ZnSO_4$	32.33±0.69d	3.27±3.32b	54.55±0.39 d	120.8±3.32 d	33.33±0.84d	4.4±0.26b	55.6±0.69c	152.3±3.32cd
T8 – RDF + S + Zn-EDTA	40.87±0.34c	3.40±3.40b	68.94±0.24 c	135.8±3.40 c	42.63±0.42c	4.6±0.31b	59.6±0.42c	160.2±0.31c

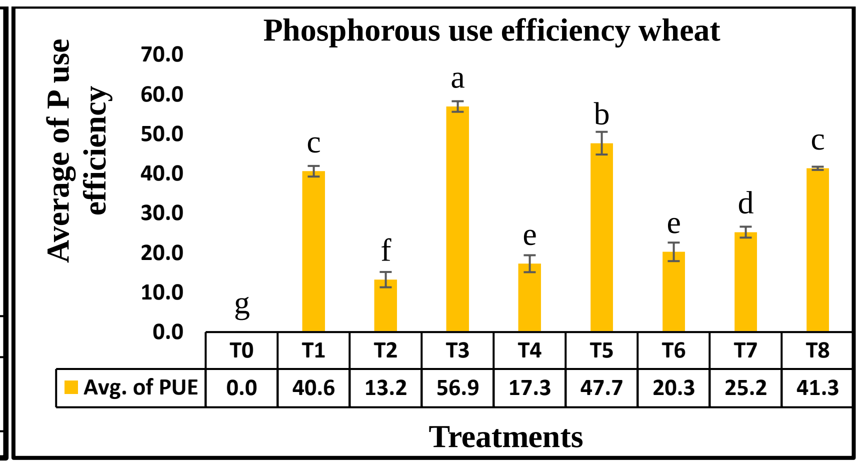
4.7.4 A, B


Nitrogen Uses Efficiency rice
Average of nitrogen Use Efficiency
50.00
40.00
30.00
20.00
10.00
0.00
h c g a f b e c d
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of NUE 0.00 28.20 9.53 36.70 14.04 30.20 21.40 27.80 25.60
Treatments

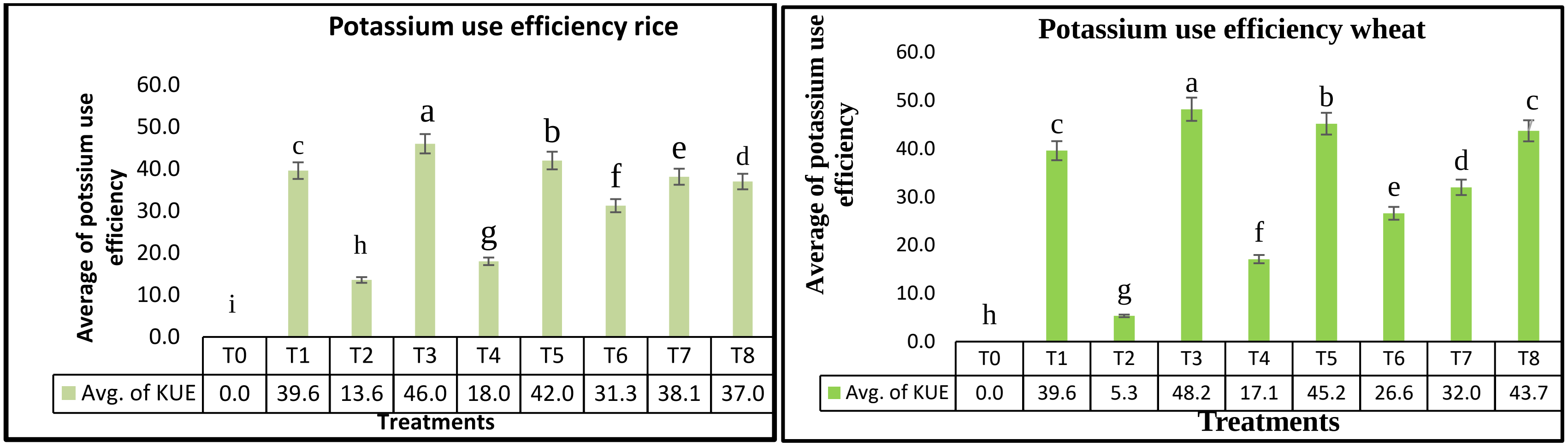

Nitrogen Use Efficiency wheat
Average of nitrogen use efficiency
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
h bc fg a ef b de cd bc
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of NUE 0.00 28.00 3.20 34.20 5.22 32.50 16.31 25.22 27.50
Treatments

4.7.4 C, D


Phosphorous Use Efficiency
Average of Phosphorous Use Efficiency
20
15
10
5
0
h g c a g b f e d
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of PUE 0 12.73 2.40 16.57 2.15 14.22 4.26 9.10 10.26
Treatments


Phosphorous use efficiency wheat
Average of P use efficiency
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
g c f a e b e d c
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of PUE 0.0 40.6 13.2 56.9 17.3 47.7 20.3 25.2 41.3
Treatments

4.7.4 E, F



4.7.4 G, H

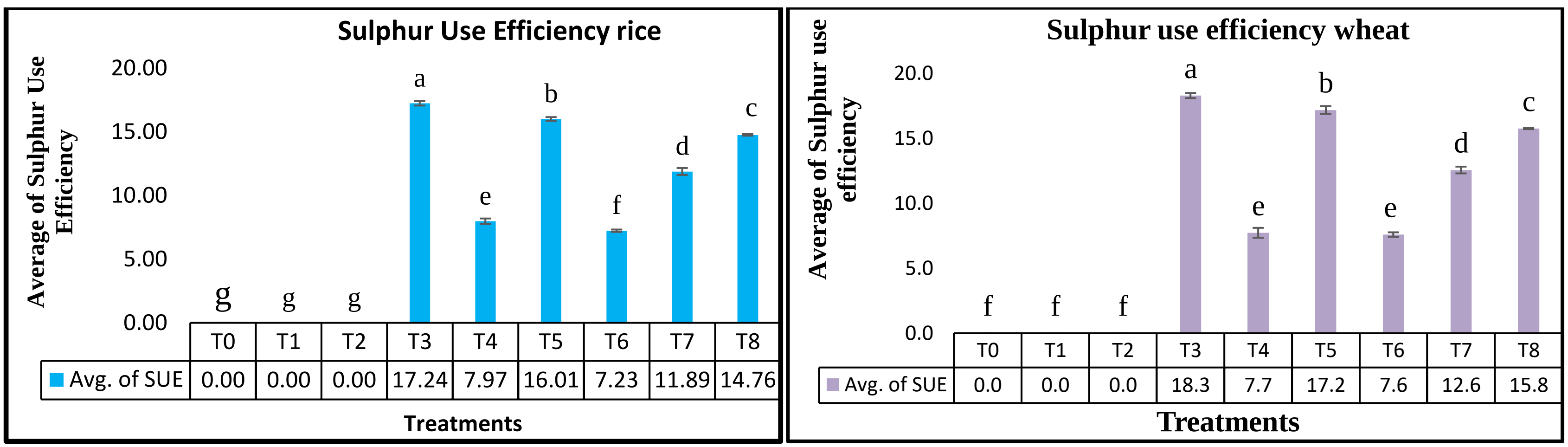
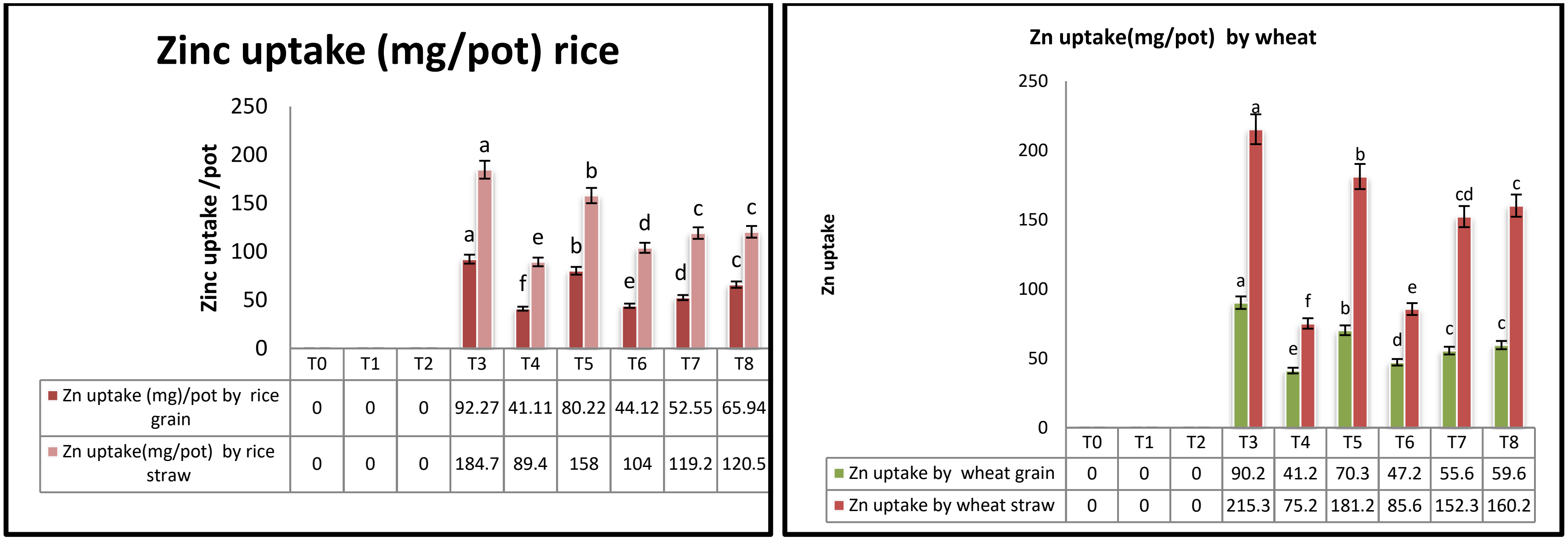


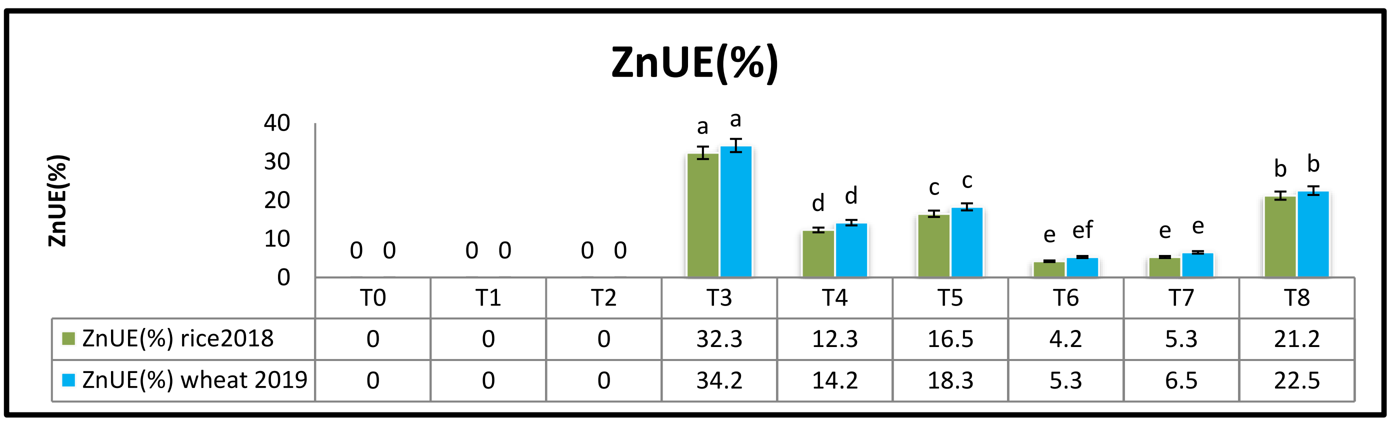
Fig. 4.7.4(A,B,C,D,E,F,G& H) represent nutrient use efficiency (%) of rice & wheat crop of pot experiment. Values with same alphabet are not significantly different from each other according to DMRT ($p<0.05$).



	T0	T1	T2	T3	T4	T5	T6	T7	T8
Zn uptake (mg)/pot by rice grain	0	0	0	92.27	41.11	80.22	44.12	52.55	65.94
Zn uptake(mg/pot) by rice straw	0	0	0	184.7	89.4	158	104	119.2	120.5

	T0	T1	T2	T3	T4	T5	T6	T7	T8
Zn uptake by wheat grain	0	0	0	90.2	41.2	70.3	47.2	55.6	59.6
Zn uptake by wheat straw	0	0	0	215.3	75.2	181.2	85.6	152.3	160.2

Fig. 4.7.3(a,b) Impat of modified fertilizers on Znic uptake (mg/pot) by rice and wheat crop.



	T0	T1	T2	T3	T4	T5	T6	T7	T8
ZnUE(%) rice2018	0	0	0	32.3	12.3	16.5	4.2	5.3	21.2
ZnUE(%) wheat 2019	0	0	0	34.2	14.2	18.3	5.3	6.5	22.5

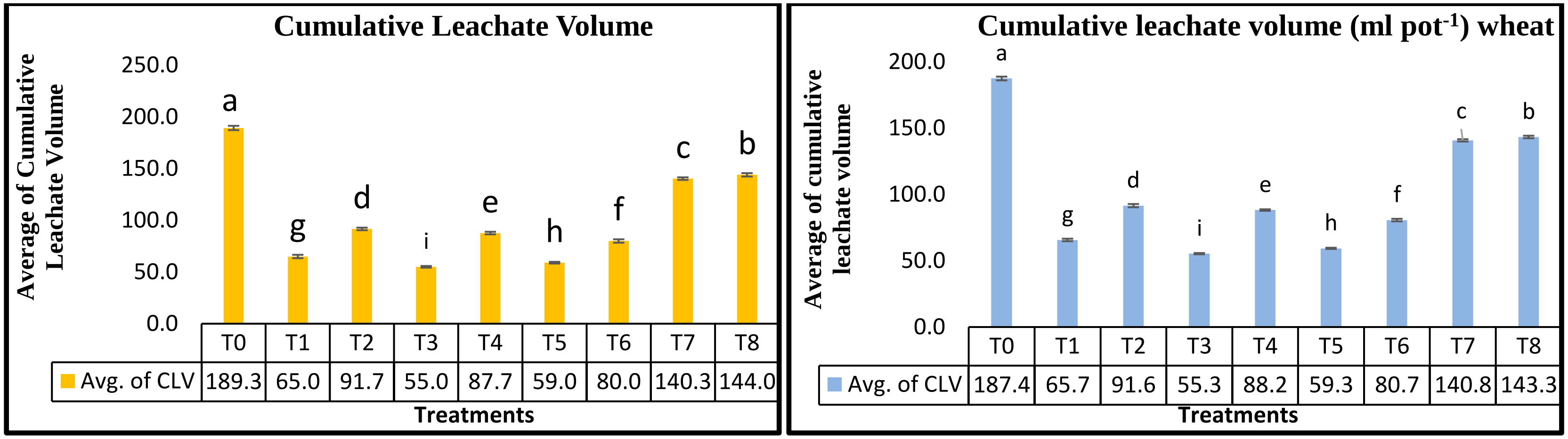
Fig. 4.7.4 Impact of modified fertilizers on ZnUE(%).

Table 4.7.4 Effect of modified fertilizers on nutrient use efficiency (%) of rice wheat pot crop.

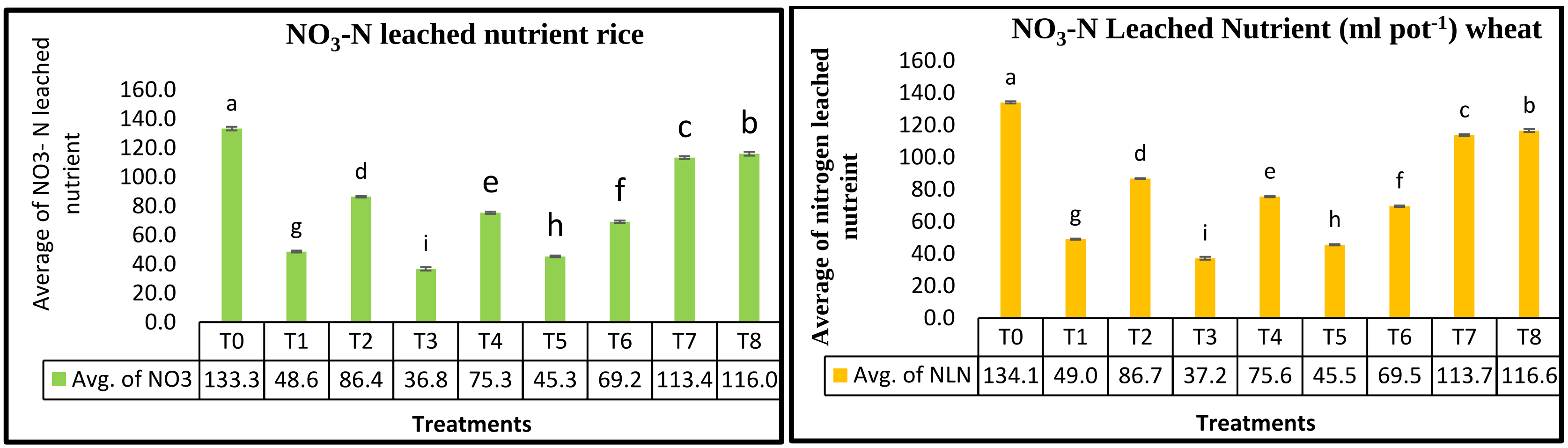
Treatments	Rice					Wheat				
	NUE (%)	PUE (%)	KUE (%)	SUE (%)	ZnUE (%)	NUE (%)	PUE (%)	KUE (%)	SUE (%)	ZnUE (%)
T0- Control (RDF)	0.00±0.00i	0±0h	0.0±0.0i	0.00±0.00g	0.00±0.00	0.00±0.00g	0.0±0.0g	0.0±0.0h	0.0±0.0f	0.0±0.0
T1 - Neem coated urea + PK recommended	28.2±1.42c	12.73±0.39c	39.6±0.7c	0.00±0.00g	0.00±0.00	28±0.61bc	40.6±1.3c	39.6±1.0c	0.0±0.0f	0.0±0.0
T2 - Anhydrous ammonia + PK recommended	9.53±1.32h	2.40±0.22g	13.6±1.8h	0.00±0.00g	0.00±0.00	9.5±1.02ef	13.2±1.9f	5.3±2.8g	0.0±0.0f	0.0±0.0
T3 - Neem coated urea + PK + S + Zn-EDTA	36.7±0.60a	16.57±0.65a	46.0±0.9a	17.24±0.17a	32.3±0.17a	436.67±1.50a	56.9±1.3a	48.2±2.5a	18.3±0.2a	34.2±0.2a
T4 - Anhydrous ammonia + PK + S+ Zn-EDTA	14.04±1.99g	2.15±0.06g	18.0±2.9g	7.97±0.22e	12.3±0.22d	14.04±1.08fg	17.3±2.1e	17.1±1.6f	7.7±0.4e	14.2±0.4d
T5- Neem coated urea +PK + $ZnSO_4$	30.2±1.25b	14.22±0.56b	42±1.7b	16.01±0.15b	16.5±0.15c	30.2±0.95b	47.7±2.9b	45.2±1.4b	17.2±0.3b	18.3±0.3c
T6 - Anhydrous ammonia + PK + $ZnSO_4$	21.40±0.78f	4.26±0.23f	31.3±2.9f	7.23±0.09f	4.2 ±0.09e	21.4±1.08de	20.3±2.3e	26.6±0.7e	7.6±0.2e	5.3±0.2e
T7 - RDF + $ZnSO_4$	27.8±0.36e	9.10±0.70e	38.1±0.4e	11.89±0.27d	5.3±0.27e	27.8±1.49cd	25.2±1.4d	32.0±1.7d	12.6±0.3d	6.5±0.3e
T8 – RDF + S+ Zn-EDTA	25.6±1.73d	10.26±0.45d	37±2.3d	14.76±0.06c	21.2±0.06b	25.6±1.29bc	41.3±0.4c	43.7±1.2c	15.8±0.0c	22.5±0.0b

4.7.5 Leached nutrients and Leachate volume: - The leachate volume and leached nutrients were measured to know the leaching from containerized pots. That was discussed under this heading in table 4.7.5. Leachate volume in rice and crop was measured during whole life cycle at weekly intervals and total average value depicts in table and fig. the minimum leachate volume (55 mml, 55.3 ml/pot) counted in T_3 where NCU + PK + S + Zn-EDTA applied in rice and wheat crop. The treatments were followed by T_5 (59 ml) and T_1 (65 ml). Respectively in rice and wheat crop. The maximum leachate volume (189.3 ml) recorded in T_0 where ordinary urea applied. T_7 and T_8 also recorded more leachate (144, 143.3 ml) and (140.3, 140.8 ml/pot) in rice and wheat crop. The plots where normal urea applied more leachate volume recorded over NCU and anhydrous ammonia. The data of leachate volume presented in fig. 4.7.5 (a). NO_3^- -N concentration measurement from leachate volume. The minimum NO_3^- -N (36.8, 37.2 mg/pot) in rice and wheat crop measurement in T_3 followed by T_5 (45.3, 45.5 mg/pot). The highest NO_3^- -N concentration (133, 134.1 mg/pot) noted in T_0 followed by T_8 and T_7 (116, 116.6 mg and 113.4, 113.7 mg/pot). The data of NO_3^- -N concentration presented in fig 4.7.5 (b). Leachate P also demonstrated from collected leachate volume. The minimum leached P (0.38, 0.38 mg/pot) recorded in T_3 in both rice and wheat crops. The second minimum leached P (0.47, 0.48 mg/pot) measured in T_5. The highest leached P (1.26, 1.27 mg/pot) recorded under T_0 at par with T_8 (1.23, 1.24 mg/pot). The date of leached P depicted in fig 4.7.3 (c). Leached K also measured which was significantly affected by various combinations of treatments. The minimum leached K (15.8, 16 mg/pot) noted in T_3 followed by T_5 (11, 11.1 mg/pot). The maximum leached K (19.6, 19.6) measured under T_0 followed by T_8 (18, 18.1 mg/pot). The data of leached K presented in fig 4.7.5 (D).

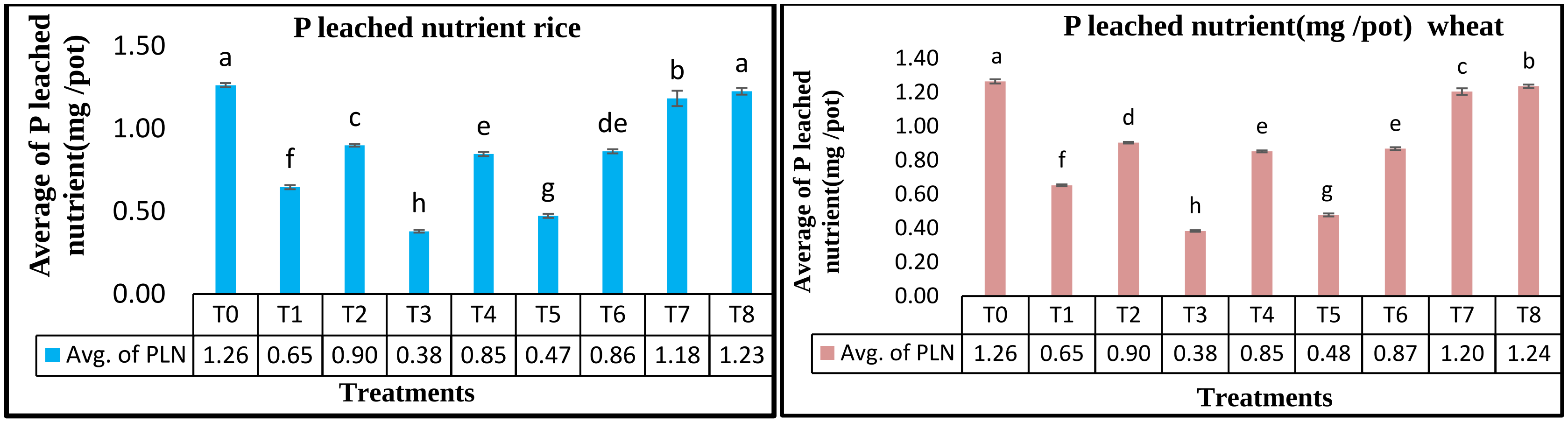
4.7.5 A, B


Cumulative Leachate Volume
Average of Cumulative Leachate Volume
250.0
200.0
150.0
100.0
50.0
0.0
a g d i e h f c b
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of CLV 189.3 65.0 91.7 55.0 87.7 59.0 80.0 140.3 144.0
Treatments
Cumulative leachate volume (ml pot-1) wheat
Average of cumulative leachate volume
200.0
150.0
100.0
50.0
0.0
a g d i e h f c b
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of CLV 187.4 65.7 91.6 55.3 88.2 59.3 80.7 140.8 143.3
Treatments

4.7.5 C, D


NO3-N leached nutrient rice
Average of NO3- N leached nutrient
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
a g d i e h f c b
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of NO3 133.3 48.6 86.4 36.8 75.3 45.3 69.2 113.4 116.0
Treatments
NO3-N Leached Nutrient (ml pot-1) wheat
Average of nitrogen leached nutreint
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
a g d i e h f c b
T0 T1 T2 T3 T4 T5 T6 T7 T8
Avg. of NLN 134.1 49.0 86.7 37.2 75.6 45.5 69.5 113.7 116.6
Treatments

4.7.5 E, F



4.7.5 G, H

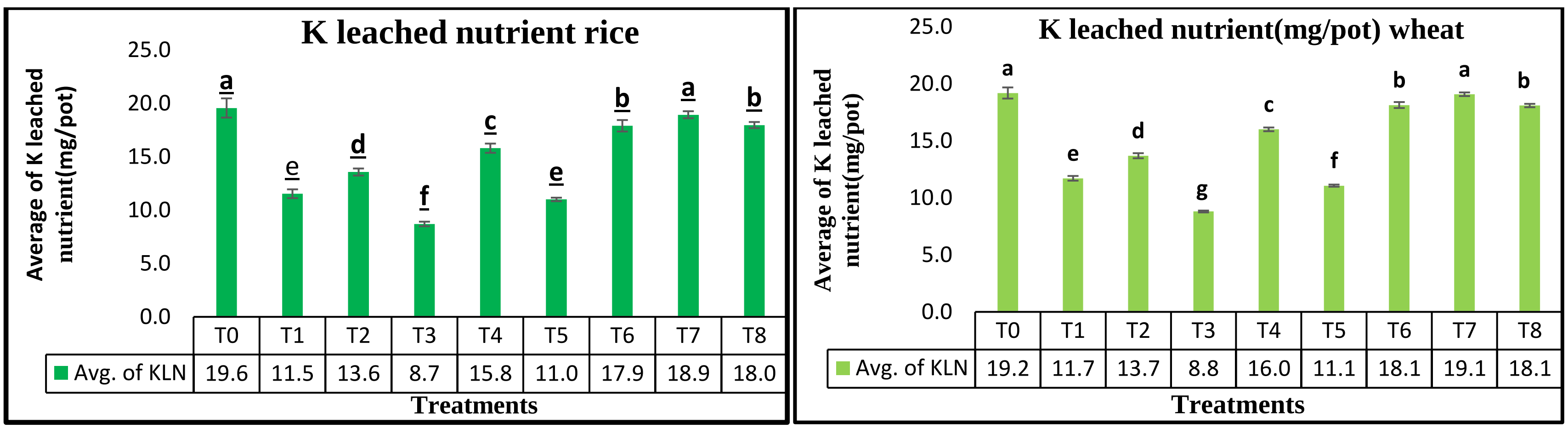


Fig. 4.7.5 (A, B, C, D, E, F, and G &H) depicted the leachate volume, No_3-N and leached P, K (mg/pot) in pot experiment. Similar letters above standard error bars reflect that treatments are non -significant

Table 4.6.6 Effect of modified fertilizers on leached nutrients and leachate volume in pot (mean± S.E)

Treatments	**Rice**				**Wheat**			
	Leachate volume (ml/pot)	NO_3^-N (mg/pot)	Leached P (mg/pot)	Leached K (mg/pot)	Leachate volume (ml/pot)	NO_3-N (mg/pot)	Leached P (mg/pot)	Leached K (mg/pot)
T0- Control (RDF)	189.3±2.1 a	133.3±1.2a	1.26±0.01a	19.6±0.9a	187.4±1.4 a	134.1±0.7 a	1.26±0.01 a	19.2±0.5a
T1 - Neem coated urea + PK recommended	65.0±1.6g	48.6±0.7g	0.65±0.01f	11.5±0.4e	65.7±0.9g	49.0±0.4g	0.65±0.01f	11.7±0.2e
T2 - Anhydrous ammonia + PK recommended	91.7±1.2d	86.4±0.6d	0.90±0.01c	13.6±0.3d	91.6±1.2d	86.7±0.3d	0.90±0.00 d	13.7±0.2d
T3 - Neem coated urea+ P K + S + Zn-EDTA	55.0±0.8i	36.8±1.2i	0.38±0.01h	8.7±0.2f	55.3±0.5i	37.2±0.9i	0.38±0.00 h	8.8±0.1g
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	87.7±1.2e	75.3±0.7e	0.85±0.01e	15.8±0.4c	88.2±0.6e	75.6±0.5e	0.85±0.01 e	16.0±0.2c
T5- Neem coated urea + PK + $ZnSO_4$	59.0±0.8h	45.3±0.6h	0.47±0.01g	11.0±0.2e	59.3±0.5h	45.5±0.4h	0.48±0.01 g	11.1±0.1f
T6 - Anhydrous ammonia + PK + $ZnSO_4$	80.0±1.6f	69.2±0.8f	0.86±0.01d e	17.9±0.5b	80.7±0.9f	69.5±0.5f	0.87±0.01 e	18.1±0.3b
T7 - RDF + $ZnSO_4$	140.3±1.2 c	113.4±0.9c	1.18±0.05b	18.9±0.3a	140.8±0.9 c	113.7±0.6 c	1.20±0.02 c	19.1±0.2a
T8 - RDF+ S+ Zn-EDTA	144.0±1.6 b	116.0±1.3b	1.23±0.02a	18.0±0.3b	143.3±0.9 b	116.6±0.9 b	1.24±0.01 b	18.1±0.1b

4.7.6 Soil nutrient status after harvesting of crop: - After harvesting of rice and wheat crop, the major soil nutrients tested to check the fertility level. The data of soil nutrients presented in table 4.7.6.Soil organic carbon was tested pot wise. Which was significantly affected by various treatments. The maximum soil organic carbon (33.4, 33.7 m/pot) in rice and wheat crop observed in T_3 followed by T_5 (32.10, 32.07 g/pot). The lowest (22.47, 22.5 mg/pot) soil organic carbon observed in T_0 followed by T_2 (24.37, 24.69 g/pot) in rice and wheat crop. Soil N was also recorded per pot after harvesting of rice crop and wheat crop. The maximum soil N/pot (2.33, 2.38 g) recorded under T_5. The second highest N (2.33, 2.28 g/pot), recorded in T_3. The lowest N (1.42 m/pot) observed in T_0. The data presented in fig. 4.7.3 (b). In case of soil available P maximum available P (108.7, 109.2 mg/pot) noted under T_3 followed by T_5 (98.5, 98.8 mg/pot). The minimum P recorded (50, 50.3 mg/pot) in T_0 followed by T_2 (70, 70.7 mg/pot). The treatments were significantly different from each other. The data of available P presented in fig. 4.7.6 (C).

4.7.6 A, B

4.7.6 C, D

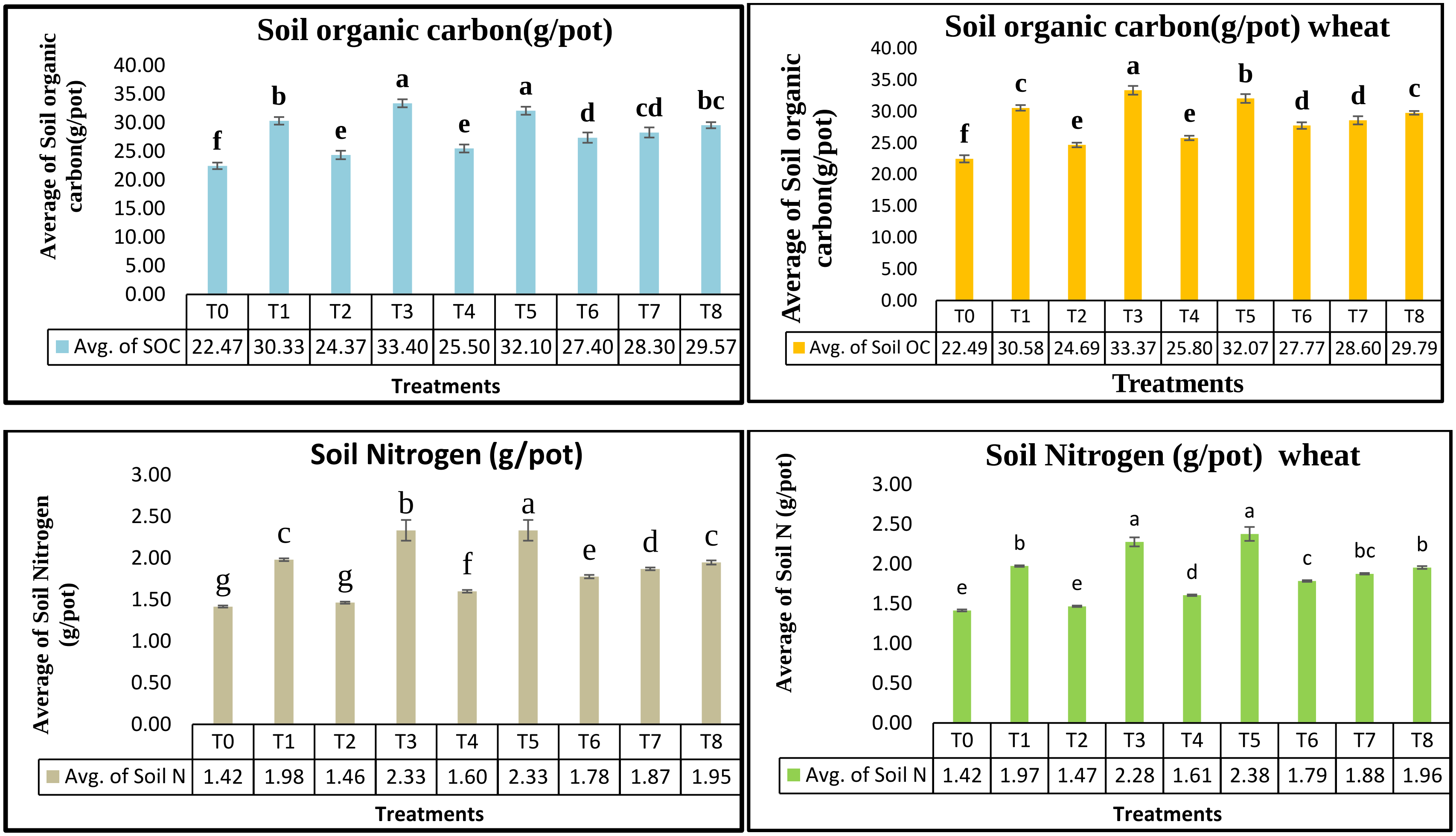
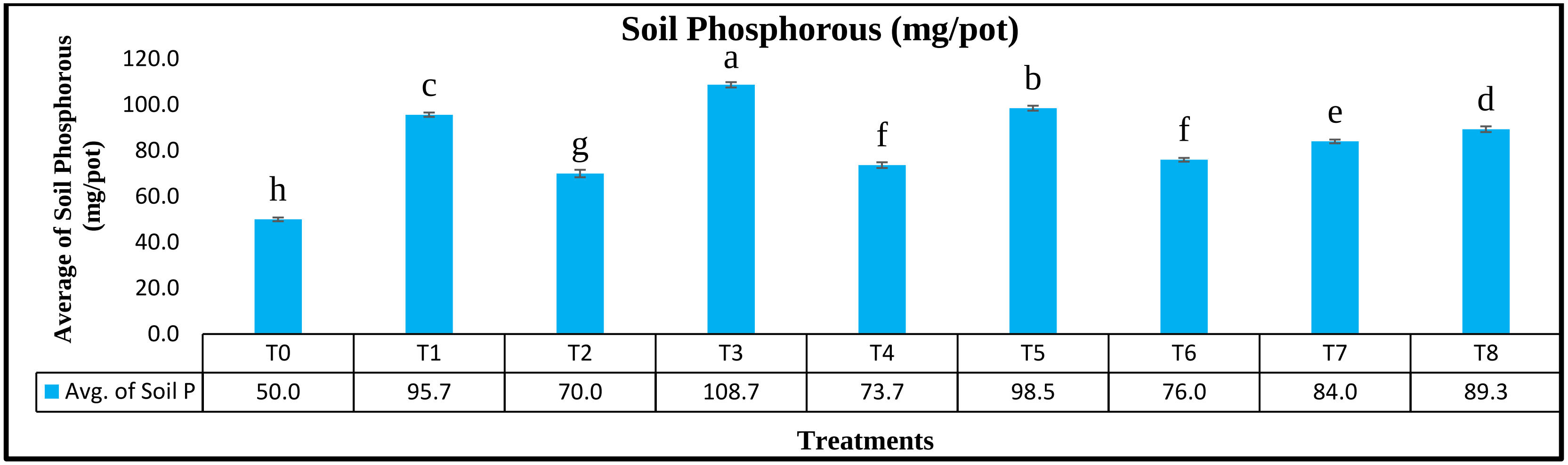


Fig. 4.7.6(A, B, & C, D) represent soil organic carbon and Soil nitrogen of rice & wheat crop of pot experiment. Values with same alphabet are not significantly different from each other according to DMRT ($p<0.05$)

4.7.6 E, F



4.7.6 G, H

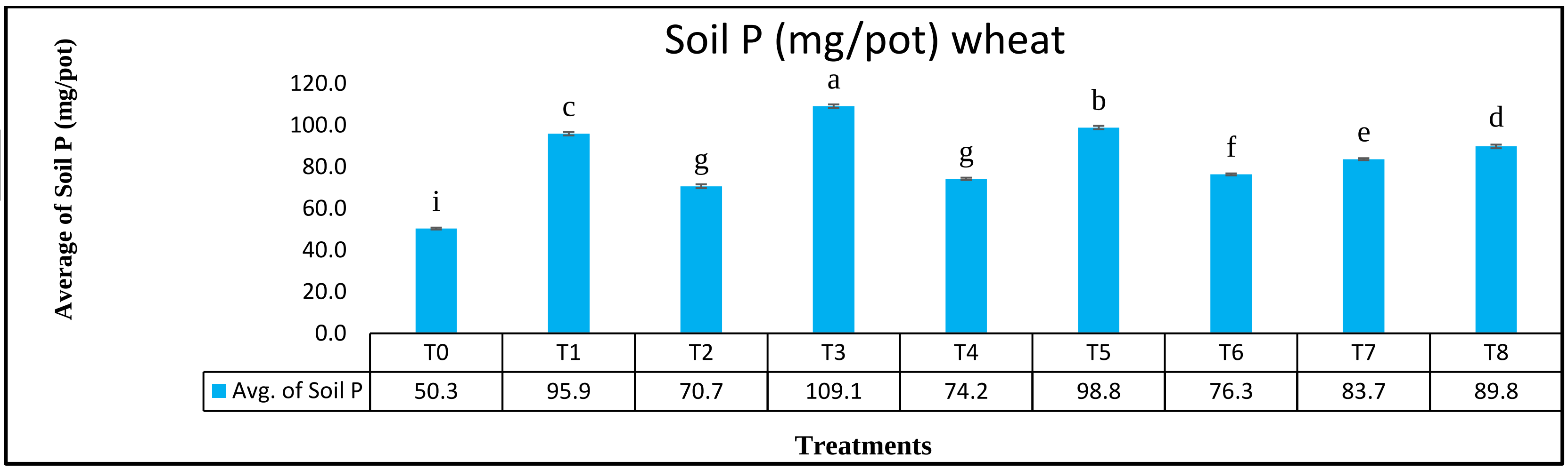


Fig. 4.7.6 (E, F & G, H) represent soil nutrient status of rice wheat crop of pot experiment. Same letters above the error bars indicate that treatments are non -significant among themselves.

Table 4.6.5 Effect of modified fertilizers on soil nutrient status of pot experiment (mean± S.E) of rice- wheat crop.

Treatments	RICE			WHEAT		
	Soil organic carbon (g /pot)	Soil N(g/pot)	Soil P (mg/pot)	Soil organic carbon (g /pot)	Soil N(g/pot)	Soil P(mg/pot)
T0- Control (RDF)	22.47±0.57f	1.42±0.01g	50.0±0.8h	22.49±0.57f	1.42±0.01e	50.3±0.5i
T1 - Neem coated urea + PK recommended	30.33±0.66b	1.98±0.02c	95.7±0.9c	30.58±0.44c	1.97±0.01b	95.9±0.8c
T2 - Anhydrous ammonia + PK recommended	24.37±0.74e	1.46±0.01g	70.0±1.6g	24.69±0.37e	1.47±0.01e	70.7±0.9g
T3 - Neem coated urea + PK +S + Zn-EDTA	33.40±0.70a	2.33±0.12b	108.7±1.2a	33.37±0.69a	2.28±0.06a	109.1±0.9a
T4 - Anhydrous ammonia + PK + S + Zn-EDTA	25.50±0.70e	1.60±0.02f	73.7±1.2f	25.80±0.36e	1.61±0.01d	74.2±0.6g
T5- Neem coated urea + PK + $ZnSO_4$	32.10±0.70a	2.33±0.12a	98.5±1.1b	32.07±0.69b	2.38±0.09a	98.8±0.8b
T6 - Anhydrous ammonia + PK + $ZnSO_4$	27.40±0.90d	1.78±0.02e	76.0±0.8f	27.77±0.52d	1.79±0.01c	76.3±0.5f
T7 - RDF + $ZnSO_4$	28.30±0.88cd	1.87±0.02d	84.0±0.8e	28.60±0.65d	1.88±0.01bc	83.7±0.5e
T8 - RDF+ S+ Zn-EDTA	29.57±0.53bc	1.95±0.02c	89.3±1.2d	29.79±0.29c	1.96±0.02b	89.8±0.9d

4.8 Discussion: The results presented above provided a detail description of the performance of rice – wheat crop in terms of growth, yield and yield contributing characters, uptake of nutrients as influenced by modified fertilizers. To evaluate and describe the important observations recorded in the present study in terms of cause and effect an attempt has been made with scientific reasons. Soil fertility commonly dose not favour the optimum growth and yield due to low status of specific nutrients. For proper development of crop seventeen essential elements required. Each one of the nutrients is equally important for the plant but in different amount. The supply of N, P, K, S and zinc is commonly supplied by fertilizers.

The nitrogen requirements of all field crops are more as compared to other nutrients like phosphorous, potassium, sulphur, and zinc. The use efficiency of applied nitrogen fertilizers are less due to the hydrolysis of fertilizer and convert by means of soil chemical reactions in soil or by microbes with in short period of time. This lead to mismatch of the nitrogen requirement according to crop growth stages. The unused nitrogen by crop leads to lost either by leaching or volatilization process. This is the main problem in less use efficiency of N added through fertilizers. To overcome this problem in increasing the nutrient use efficiency of applied fertilizers in soil present study was planned. A pot experiment of periodic release of nitrogen through modified fertilizers under controlled conditions and periodic release of nitrogen through coated fertilizersin field under natural conditions in rice – wheat cropping system grown on Typic – Haplustept soils was studied. The discussion on the findings in preceding chapter was done with scientific reason and practical values. The results obtained are discussed under the suitable headings: -

4.8.1 Effect of modified fertilizers on crop growth parameters, yield parameters and yield of rice-wheat crop: -

4.8.1.1 Crop growth parameters: - Application of NCU + PK + S + Zn-EDTA (T3) significantly increase plant height in rice (67.03, 76.31, 101.45 and 114.23 cm) and wheat (38.17, 51.67, 69.27, 79.27 cm) during 2018-2019 and (66.2, 74.27, 103.3, 113.73 cm) in rice and (37.93, 52.10, 71.43, 80.23 cm) in wheat during 2019-2020 at all growth stages. The number of tillers per plant in rice, m^{-2} in wheat also recorded highest in T3 during both years. Fresh weight, dry weight, chlorophyll index, leaf area, CGR, RGR and NAR recorded maximum in T3 over control but it was at par with T5 (NCU + PK + $ZnSO_4$) in all crop growth parameters. In some of growth parameters lowest values recorded under T2 (AA + PK) especially in case of chlorophyll index. The crop growth is the manifestation of interaction between genetic traits, environmental factors and soil factors. In case of soil factors, nutrient availability specially plays important role in improving plant growth. The noticed improvement in plant growth due to the application of nutrients which leads to better supply of nutrients to soil due to combination of macro and micro-nutrients in form of coated fertilizers and chelates. This fact was the proof of the higher nutrient uptake in fertilized plots with NCU over control (Ordinary urea) in present study. These results are in conformity with the findings of Ndaeyo *et al.,* (2008), Supta Das (2014), Islam *et al.,* (2011) who reported that coated fertilizers improved the vegetative growth in rice and wheat. The increase in plant height, number of tillers, fresh weight, dry weight, chlorophyll content, leaf area, flag leaf length, CGR, RGR and NAR due to application of Zn-EDTA and $ZnSO_4$ along with NCU + PK + S might be attributed to supply of nutrients through external source which show positive response to soil because Zn status was below critical limit. The interaction between them was synergistic and significant. The improvement in growth parameters of rice and wheat crop due to application of NCU + PK + S + Zn-EDTA could be due to enhancement in activity of meristematic cell and elongation of cell because of zinc which increased the production of growth promoting substances i.e. auxin at different growth stages and helps in increasing growth and yield of crop (Kaur *et al.,* 2012, Ali *et al.,* 2015). The maximum positive response in combination which includes Zn-EDTA and $ZnSO_4$ might be attributing to better availability of Zn with application which increased cell division and expansion (Muthu Kumararaja and Sriram Chandra Sekhram, 2012). The result corroborates with the findings of Shanmugam and Veeraputhram, 2000.

Similar findings of improvement in growth parameters due to balanced supply of nutrients was also found by Karasu *et al.,* (2012), Kaur *et al.,* (2012). The increased in plant height due to neem coated urea because of N is a growth element which is a part of protoplasm which is a site of cell division and hence plant growth increased. There was a synergistic effect of Zn on Nitrogen use efficiency which regulated N metabolism type reactions in form of chlorophyll and improves photosynthesis. The reduction in plant height in control and T2 might be due to less production of growth hormones and short height plant was reported by Hosseini *et al.,* (2007) due to disturbance in photosynthesis.The application of S to soil decreased the pH of soil, the decrease in pH of soil increased availability of N in soil, which improved the vegetative growth of crop. The interaction of N, P and S is synergistic which improved the efficiency of fertilizers. The S nutrition induced the use of N for the synthesis of amino acids and proteins (Qahar *et al.,* 2016, Piotr *et al.,* 2012). The result indicated that application of zinc to rice, wheat through Zn-EDTA, $ZnSO_4$ along with NPK either through coated urea or normal urea are useful for plant weight over other treatments (Sorkhi *et al.,* 2014).In case of number of tillers per plant, the improvement in the production of tillers with N application through NCU in present study could be due to enhancement in the nitrogen availability which increase tillering. The application tillering. The application of NCU along with PK + S + S + Zn-EDTA improved soil physico- chemical and biological properties which attributed to better crop growth in terms of root and shoot development of crop. This result is in conformity with the findings of Supta DAS, 2014, Raj *et al.,* (2014), Kumar *et al.,* (2007) and Singh and Singh (2003). Chlorophyll index, fresh weight, dry weight, leaf area and flag leaf, length was increased due to application of NCU + PK + S + Zn-EDTA followed by NCU + PK + $ZnSO_4$ could be due to combination of primary and secondary nutrients. In carbohydrate metabolism zinc is involved which plays a vital role in photosynthesis, sugar transformation and uphold the membrane integrity which increased chlorophyll index of plant. The leaf area also improved due to maintenance of membrane structure and transport of ions to other parts of plant by application of zinc. Similar results were found by Maqsood *et al.,* 2011, Surfaaz *et al.,* 2014. Sulphur as elemental S or as $ZnSO_4$ also improved plant height number of tillers, chlorophyll index and leaf area could be due to better utilization of S in growth of plant. The optimum supply of S to crop increased metabolic activities and performed in carbohydrate metabolism which induced more tillers, expand leaf area and improve chlorophyll content. The result is in conformity with the findings of Chandel *et al.,* (2003). The findings indicated that application of Zn to rice and wheat through Zn-EDTA was more useful for synthesis of chlorophyll than zinc application through $ZnSO_4$. The improvement in chlorophyll content could be due to zinc which acts as catalyst in various physiological process and biochemical processes in plants and in oxidation and reduction in plant cells. In control and AA + PK (T2) less chlorophyll content observed that could be due to zinc deficiency in redox system which is related with chlorophyll synthesis. Indulkar and Malewar (1997) reported zinc catalyst role in chlorophyll synthesis. Similar findings were reported by Kumar *et al.,* (2015) who reported that neem coated urea performd best which improve growth, plant height, number of tillers, leaf area and dry matter accumulation. The stunting plant height was observed due to anhydrous ammonia which reflects the toxic effect of anhydrous ammonia due to high rate of NH_3 application at a single time. The dry matter accumulation was also less in anhydrous ammonia treated plots due to its adverse effect which restricts root development. The adequate supply of N increases the assimilation of NH_3, which increased both protein content and leaf area, chlorophyll content and net photo synthesis when S applied with nitrogen it increases the photosynthetic assimilation in crop plants (Ahmad and Abdin, 2000). The improvement in the number of tillers might be ascribed to improvement in enzymatic activities and auxin metabolism in plants due to zinc application (Mahendra and Singh, 1981).

4.8.1.2 Yield attributing Parameters: - The data presented in table 4.1.2(a) and 4.1.2(b) revealed that panicle length (cm), test weight, no. of grains per panicle/ spike were significantly increased due to application of NCU + PK + S + Zn-EDTA (T3) as compared to control but followed by NCU + PK + $ZnSO_4$ (T5) in all parameters. These findings are due to the availability of nutrients to rice-wheat crop following the fertilizer application over to (control) and T2 (AA + PK). The natural phenomenon of crop to adequately utilize available nutrients and divide its photosynthates for dry matter accumulation happen in the presence of adequate supply of nutrients (Krishn Kumar *et al.,* 2005) found the same result. There was significant variation in panicle/spike length due to integrated application of S, $ZnSO_4$, and Zn-EDTA along with NCU + PK. The test weight and no. of grains per panicle/spike also influenced and recorded maximum with NPK + S + Zn-EDTA or $ZnSO_4$. The maximum values of yield attributing parameters could be due to increased transportation of photosynthates from source to sink because of zinc and sulphur application as reported by Jena *et al.,* 2006. The superiority of yield attributes because of combined application of N, P and K along with Zn, and S could be due to increased plant vigour, increased photosynthesis and more translocation of photosynthates from source to sink. Kumar *et al.,* 2015 reported that neem coated urea resulted best which improve plant height, number of tillers m^{-2}, number of panicles/ $spike^{-1}$, length of panicle, number of grains panicle^{-1}, test weight. Kumar *et al.,* 2007 and Raj *et al.,* (2014) also recorded same result. Pushpanathan *et al.,* (2005) reported that coated fertilizers increased the performance of yield components like productive tiller, panicle length filled grains per spike, 1000 grains weight when applied at correct time. These results also supported by Kumar *et al.,* (2011), Islam *et al.,* (2011) and Rahman *et al.,* (2009). The increase in number of grains per spike due to zinc application which helps in seed formation. Zinc is a constituent of dehydrogenase ,proteins, peptidase enzymes and growth hormones which attributes to starch formation and promotes grain filling (Mrinal and Sharma 2008). The improvement in yield attributing due to NCU might be related to slow release of nitrogen in soil, which was absorbed by crop throughout its critical growth stages. The supply of N slowly in available form during whole life cycle of rice-wheat which increased growth, development and showed in yield attributing parameters and yield (Hala *et al.,* 2014). Sulphur, NCU, Zn-EDTA, Zn-SO_4 could be act as an amendment to soil which improved soil physico-chemical and biological properties (Bahr *et al.,* 2001). The toxicity effects of anhydrous ammonia due to one-time application reduced the number of grains per panicle/spike and also decrease the test weight. The application of N to cereal crops improves tillering and no. of spikes/panicles and no. of grains per panicle based on tillering capacity (Mengel and Kirk by 2001). The nitrogen and S supply improves the initiation of spike which decides the number of grains per spike during spike development (Shiferaw *et al.,* 2008). The grain weight has positive correlation with no. of grains/panicle, leaf area, number of panicles per plant panicle length (Mengel and Kirkby, 2001). The increase in number of panicles/spikes could be due to the optimum supply of zinc which increased the availability and uptake of other essential nutrients. This result is in accordance with the findings of Borduzzman *et al.,* (2000) who stated that optimum supply of zinc resulted more number of panicles per plant. The increase in number of spikes due to zinc fertilization that might be due to effect of zinc in increasing physiological functions of crop (Photosynthesis, translocation). These results supported by Bordruzznab *et al.,* 2000. The 1000 grain weight increased with NCU + PK + S + Zn-EDTA that might be due to the efficient participation of zinc in various metabolic processes which results in the production of healthy seeds. This result is in conformity with the findings of Sarhad *et al.,* 2007, Maqsood *et al.,* 1999.

4.8.1.3 Yield: - The data of grain and straw yield presented in tables reveal that grain and straw yield increased with application of NCU + PK + Zn-EDTA + S (T3) and NCU + PK + $ZnSO_4$ (T5) and RDF + S + Zn-EDTA during both years in rice – wheat. The increase in yield due to NCU + PK, RDF + S + Zn-EDTA might be attributed to improvement in growth and yield parameters, nutrient availability and nutrient uptake. These results are in conformity with the findings of Lin *et al.*, 2009 and Krishn Kumar *et al.*, (2005). Enhancement in yield could be due to improvement in yield parameters because of partitioning of photosynthates, carbohydrates from source to sink (Leaf to reproductive part) resulting in more yield .The maximum grain and straw yield was recorded due to NCU, PK, S, Zn-EDTA, $ZnSO_4$ might be related to slow release of nitrogen from neem coated urea, which was absorbed by crop throughout its life cycle most commonly at critical stages. The availability of N in available form increased the uptake of N in plant and increased grain and straw yield (Blayock *et al.*, 2005). Along with slow releasing nature of NCU, it also gave the carbon to soil, which provides energy to soil micro-organisms for their activities. The transformation of nutrients into plant available form done by soil microorganisms which increase the yield. S, Zn-EDTA, $ZnSO_4$, Neem coated urea act as soil amendment which improve soil environment in case of microbial population, activities, increased the soil reaction, nutrient availability and create beneficial environment for root development as well as growth and development of crop (Amekha *et al.*, 2009). The increase in straw yield might be attributed to nitrogen which increased the vegetative growth of plant. The grain and straw yield increased with the application of $ZnSO_4$, Zn-EDTA, and S along with NCU + PK might be due to role of zinc in various enzymatic activities and act as catalyst in metabolic and growth hormone production. It is because of improvement in metabolic enzymes system regularly and production of auxin (Jena *et al.*, 2006, Sachdeva *et al.*, 1988, Kumar *et al.*, 1999). Kumar *et al.*, 2015 and Naresh *et al.*, 2014 (a) reported increase in straw yield due to application of $ZnSO_4$ and Zn-EDTA because of high growth and yield attributing characters- no. of tillers/plant, plant height, dry matter accumulation, leaf area. Similar results were obtained by Jena *et al.*, (2006). The enhancement in yield due to application of elemental S or $ZnSO_4$ might be ascribed to increment supply of S and further improvement in yield due to combined application of NCU, PK, S, Zn-EDTA and $ZnSO_4$ attributed to synergistic effect of these nutrients. The combined application of NPK with $ZnSO_4$, Zn-EDTA and S increased vegetative growth of plant and yield contributing character because of improvement in activity of meristematic cell and cell elongation as a result of S and Zn application. Nectar and Hossain *et al.*, 2001 observed combined application of NPK and zinc increase grain yield and growth of rice crop. The increase in grain, straw yield, harvest index, 1000 grain weight, number of grains/panicles because of nitrogen which helps in photosynthesis, vegetative growth and grain formation. N is a constituent of amino acid, protein and enzymes which resulted more yield (Sharar *et al.*, 2003). Sarangi *et al.*, 2016 found higher grain and straw yield with NCU because of increase in nitrogen use efficiency which regularly supply nitrogen and boost the vegetative growth. Tanwar (2014), Mangat and Narang (2004) also found the same result. The harvest index % was non-significant when N was applied without S. The combined application of N with S, the utilization of N in grain increased which increased grain yield (Aamer *et al.*, 2000, Habtegebrial and Singh, 2006). This result also supported by Walker *et al.*, 2008 and Shiferaw *et al.*, 2012. The combined application of N and S, improved net photosynthesis rate which increased the dry matter and grain yield (Walker *et al.*, 2008). The results clearly indicate that effect of neem coated urea us more pronounced in rice as compare to wheat. The useful effect of neem coated urea in reduction in losses of the nitrogen i.e. leaching and voltalization. The coated fertilizer produced higher grain yield than ordinary urea when applied in 3 equal splits. The application of NCU + PK + S + Zn-EDTA increased the straw yield that might be ascribed to the fact of zinc fertilization which interacts with the proliferation of roots and uptake of nutrients supplied to aerial parts of plant and increased the vegetative growth of plants. This result is in conformity with the findings of Srivastva *et al.*, 1999 and Rahman *et al.*, 2001.

4.8.2 Effect of modified fertilizers on nutrient uptake by grain and straw: Uptake of nutrients by crop is a function of total biomass produced by crop. The variation in uptake by grain and straw because of different treatments attributed with yield differences and partly with nutrient content in grain and straw. More the availability of nutrient in soil higher is the uptake of nutrients and plant growth. The highest uptake of N recorded with NCU + PK + S + Zn-EDTA (T3) and NCU + PK + $ZnSO_4$ (T5). The uptake of N, P, K significantly affected by modified fertilizers.

4.8.2 .1 Nitrogen uptake by grain and straw: - The application of NCU + PK + S + Zn-EDTA (T3) and NCU + PK + $ZnSO_4$ (T5) recorded significantly more N uptake by grain and straw during both years in rice – wheat crop. The higher N uptake by grain and straw of rice – wheat crop due to the coating of urea with neem, which decreases the contact with soil particles, prevent the activity of micro -organisms upon urea fertilizer and urease enzyme activity also so, that N slowly release in soil and availability of N in soil increased. The slow releasing nature of N availability matched with the physiological growth stages of rice-wheat crop and plants absorb nutrients in optimum quantity. The absorbed nutrients results into production of economic and biological yield in terms of nutrient uptake. These results were in conformity with the findings of Zhao *et al.,* 2013. The more uptakes were ascribed to improved availability of nutrients upon balanced fertilization as compared to control. This result is in accordance with the findings of Ranjta Bezbaruha (2011 and Pandey *et al.,* (2007). Application of Zn-EDTA, $ZnSO_4$ and elemental S along with NCU + PK increased the uptake of N in grain and straw because of quick transformation of urea into available N which is very essential for biomass production (Kumar *et al.,* 1999, Kamla Kumar and Singaram 1996) and due to correction of Zn deficiency, the translocation of applied nutrients increased. The higher N uptake might be due to the synergistic effect of N and Zn. Significant increase in N content in grain and straw due to application of coated fertilizer has also been reported by Bhaskaram and Krishna (2009), Afroj 2014. The balanced nutrition resulted more uptake of nutrients. Raj Kumar *et al.,* (2014) reported that NCU maintained more availability of N in soil as compared to ordinary urea. Upadhyay amnd Tripathi (2000), shivay *et al.,* (2000) and Thind *et al.,* (2010) also reported superiority of NCU as compared to normal urea in N uptake. In case of N uptake by grain and straw the combination of AA with Zn-EDTA, $ZnSO_4$ also improved uptake. This might be due to addition of ammonia as N fertilizer creates physiological reaction when nitrification process transforms the ammonium ion to nitrate, then Hydrogen ions released. So, the fertilizer containing ammonium N increase soil acidity and plants absorbs ammonium ions directly. But when zinc applied within combination of anhydrous ammonia it causes precipitation which decreases the availability of N and uptake (Abd El Kader, 2002, Siam *et al.,* 2012. But as compared to control, they showed superiority. The lowest uptake recorded in control and T2 because of deficiency of zinc. The zinc fertilizer along with N increased the nitrogen content

(Intodia and Kumad, 2007). Grzebisz *et al.,* 2008 reported that maize plants fertilized with zinc enhance the rate of N uptake that attributed to zinc helps in new organs formation. The plants receive zinc accumulate more nitrogen which resulted more dry matter accumulation. This result is in accordance with the findings of Potarzycki (2010b), Parama Sivan *et al.,* 2011, Intodia and Kumad, 2007, Hossian *et al.,* 2008 who reported that application of zinc increased the N uptake in grain and straw.

4.8.2.2 Phosphorous uptake by grain and straw: - Phosphorous uptake in grain and straw were significantly influenced by various combinations. Highest phosphorous uptake in grain and straw recorded with NCU + PK + S + Zn-EDTA and second highest phosphorous uptake in T5 (NCU + PK + $ZnSO_4$). This might be due to slow release of nitrogen through neem coated urea which increase the vegetative growth of the crop and resulted more biomass. The improved biomass absorbed more amount of phosphorous so, it leads to improvement in phosphorous uptake. The coating fertilizer neem coated urea might be decomposing slowly in the rhizosphere. When the coating fertilizer decompose then that coated fertilizer release mineral acid in soil which solubilize the phosphorous to available form. Neem coatef urea may act as source of C and N for micro-organisms. These micro-organisms convert the fixed or unavailable form of phosphorous to available form for absorption by maize. This result is in accordance with the findings of Iszaki 2011, Nassar *et al.,* 2002 and Kurumthattecal and Jose 2007. The behaviour of phosphorous uptake was similar to that of N-content in straw and grain. The uptake in grain and straw was increased when along with NPK, Zn and S supplied as compared to control. It might be due to the micro elements plays a vital role in assimilation process of organic and inorganic compounds of phosphorous (i.e. phospholipids, phosphoproteins and phosphor-carbohydrates). These results are in accordance with the findings of Iszaki 2009, Ghodpage *et al.,* 2008. A synergistic interaction observed between Zn, N source and P uptake by grain and straw. The increment in P uptake by the addition of S and Zn is due to their role in protein synthesis, nucleic acid and carbohydrate metabolism and use of N and P. This result is in accordance with the findings of Siam *et al.,* 2012, Abd El-kader 2002. The combination of AA + PK + Zn-EDTA +S and AA + PK + $ZnSO_4$, showed less uptake of P might be due to the antagonistic effect of anhydrous ammonia and zinc which decreased P uptake also.

4.8.2.3 Potassium uptake by grain and straw: - The data presented in previous chapter for potassium uptake by grain and straw revealed that the application of NCU + PK + Zn-EDTA + S and NCU + PK + $ZnSO_4$ was significantly better than other treatments. It was observed that K uptake was improved with increase in N and K (Shilpa *et al.*, 2017). The significant effect of zinc fertilizer on potassium uptake observed because of enhancement in diffusion and mass flow in the vicinity of root zone which increased the uptake of nutrients. This is in conformity with the findings of Prasad and Sinha 198. Potassium helps in to keep the plant erect, reduce lodging, and enhance resistance power of the plant. The uptake of K in plant is directly related with N and P. the K uptake by grain and straw in rice-wheat crop related to positive effect of Zn and S on plant growth and enzymatic functions and reactions. Abd El-Kadey 2002 and Divivedi *et al.*, 2002 reported that uptake of nitrogen, phosphorous and potassium increased with the zinc and S. this result is according with Bakry *et al.*, 2009 and Yosefi *et al.*, 2011.

4.8.2.4 Sulphur uptake by grain and straw: - The Sulphur uptake increased with NCU + S + PK + Zn-EDTA might due to the S application which improved nutritional environment of rhizosphere and plant which increase the uptake of nutrients. S application also improved metabolic and photosynthesis activity which improved dry biomass and also uptake of nutrients. This result is in accordance with Dwivedi *et al.*, 2014and Inamullah 2014 findings. Sulphur helps in the synthesis of containing amino acids which improve the uptake quality in grains. The S application along with N increased, the N content. Fazli *et al.*, 2008 observed synergistic effect of combined application of S and N on the uptake of nutrients. Ahmad *et al.*, 2000 revealed that S and N fertilization enhance the total uptake S in grain. Randall *et al.*, 2000 also supported the result that S application improved the S content in grain. Zinc plays on important role in the absorption of S. So, uptake of S increased in grain and straw. In the absence of zinc, the S absorption decreased. The S uptake in grain and straw increased with N and S application, because S application increases protein content in grains as well as straw, which improved the S uptake (Rahman *et al.*, 2011, swain *et al.*, 2013)?

4.8.3 Effect of modified fertilizers on nutrient use efficiency: - Interaction among the nutrients is a main feature of biological system. This interaction manifestation in case of crop yield, and returns from investment done by farmers on inorganic fertilizers. The interaction among the nutrients may be synergistic or antagonistic. Both the antagonistic and synergistic responses are beneficial in case of minimizing losses and maximize the returns. Most of the researches show the synergistic relation of N, P, K, N and Zn, S, K with Zn, S but antagonistic relation of P and zinc. On nutrient use efficiency indicates the response of fertilizer towards crop. The results of present study indicate that NCU + PK + S + Zn-EDTA were applied to crop as per recommended dose. The response of (NCU + PK + S + Zn-EDTA) recorded highest grain yield. This showed the interaction between macro and micro-nutrient use efficiency. The contribution of N, P and K interactions become negligible in S uptake. The neem coated urea slowly release nitrogen which decreases the losses of N and save fertilizer, leading to efficient proper uptake and utilization of applied N. This result is in accordance with the findings of Siddika 2007 who reported that N use efficiency was higher in NCU over ordinary urea. This result also supported by Jena *et al.*, 2003 who stated that coated fertilizers improved the nitrogen use efficiency of rice and wheat by reducing volatilization loss of ammonia as compared to normal urea and anhydrous ammonia. In case of NCU the nitrogen use efficiency high that might be due to nitrification inhibiter property of NCU. It also decreases the fertilization rate. This result is in accordance with the findings of Shoji *et al.*, 2001, Mishra *et al.*, 1999. The split application of N fertilizer and at proper timing during crop season increases the use efficiency. The N, P, K, S, Zn having synergistic effect on crop growth and development. The balanced fertilization of macro and micro-nutrient increase the nutrient use efficiency (Pasoquin *et al.*, 2010), Khwana *et al.*, 2008 support this result. In case of nitrogen use efficiency, Khanna *et al.*, 2000 observed that neem coated urea produced maximum yield and N use efficiency. This was significantly superior over ordinary urea and anhydrous ammonia. Singh and Shivay (2003) stated that urea coated with neem-based product not only improve grain yield but also increased nitrogen use efficiency apparent N recovery. This result is also in accordance with the findings of Dinesh *et al.*, 2010 and Kumar *et al.*, 2011. There was synergistic effect of N with P and K. So, if N use efficiency improved than P and K use efficiency also increases. This result is in accordance with the findings of (Mulan *et al.*, 2014), Duan *et al.*, 2014) and Yaduvanshi *et al.*, 2013. Sulphur use efficiency increased with NCU + PK + S +Zn-EDTA. The application of S decrease pH of soil, which changes unavailable form of S to available form and also increased N availability N shows synergistic effect which increased S availability. The elemental S is oxidized to sulphate by micro-organisms and transform into available form to plant (Salva Giotto *et al.,* 2009. In case of source of S-$ZnSO_4$ SSP and elemental S all responded well towards SUE. The addition of S with N increases grain yield that might be due to increase in nitrogen use efficiency by application of S. This result is in accordance with Ali *et al.,* 2013 and Adhikary *et al.,* 2013. Fernando *et al.,* 2009 and Fismes *et al.,* 2000 reported that SUE increased with nitrogen because of its synergistic effect between N and S. The same results also supported by Surfaaz *et al.,* 2014. Who clarified that S fertilizer improved nitrogen use efficiency.

4.8.4 Effect of modified fertilizers on soil physico chemical properties

4.8.4.1 pH; EC and Organic carbon (%): - There was significant difference in soil pH, EC ad OC due to effect of various combination of modified fertilizers with secondary and minor elements. The pH value varied from 6.89 to 7.12 in rice and 6.96 to 7.15 in wheat, EC value varied from 0.20 to 0.42 dSm^{-1} in rice, 0.22 to 0.40 dSm^{-1} in wheat and organic carbon content varied from 0.40 to 0.75% in rice and 0.42 to 0.78% in wheat. The pH, EC and OC values are higher under treatment NCU + PK + S + Zn-EDTA follow by NCU + PK + $ZnSO_4$ which was significantly higher than other treatments. In all treatments pH, EC and OC remained above the initial value. The combination of macro and micro-nutrients increased the pH, EC and OC content. This result is in accordance with the findings of Tran Quang Tuyen *et al.,* 2006. The application of Sulphur and Zinc increases the EC, pH of soil. The organic carbon content also increased in fertilized treatments with NCU that might be attributed to the increment in root biomass due to more availability of nutrients. Similar findings were reported by Murthy *et al.,* 2014 and Kumar *et al.,* 2015. The status of organic carbon improved in soil by addition of NCU. Improvement in soil properties (pH, EC, OC) was when balanced fertilization provided (Bhadur *et al.,* 2013). This result is in accordance with the findings of Upadhyay *et al.,* 2011 and Sardo *et al.,* 2013.

4.8.4.1.2 Available nutrient status

4.8.4.2.1 Available nitrogen (kg ha^{-1}): - The fertility status of soil at harvest deviate from initial status of soil by the application of modified fertilizers. It was observed from the data that available N in soil was found significantly higher in treatment T3- NCU + PK + S + Zn-EDTA followed by T_5 – NCU + PK + $ZnSO_4$. That might be due to the neem coated urea which maintained high availability of nitrogen in soil for long period of time. This result is in accordance with the findings of Kumar *et al.,* 2015 and Kashiri *et al.,* 2013. The higher available N in soil in treatment T3 and T5 because of use neem coated urea which inhibit the nitrification which is responsible for nitrogen fixation, slow and constant release of nitrogen into soil system and decreases the losses of applied nitrogen. This result is corroborated with the findings of Guo C *et al.,* 2016 and Hussain S, *et al.,* 2016. The lowest available N recorded in t2, T4 and T0 where ordinary urea and anhydrous ammonia used but S and Zn not used.

4.8.4.2.2 Available Phosphorous (Kg ha^{-1}): - Available phosphorous in soil significantly varied from initial value after the harvest of rice-wheat crop with the modified fertilizers. Available P was recorded highest in T3 – NCU + PK + S + Zn-EDTA which was followed by T5 – NCU + PK + $ZnSO_4$ that might be due to the reduction of the iron phosphate which is present in soil and release of occluded phosphate that release phosphorous absorbed on amorphous iron and manganese oxide by following submergence. The lowest available phosphorous recorded in control. This result is in conformity with the findings of Krishnamurthy *et al.,* 2010 and they reported that medium P fertility level reflected more grain yield. Murthy *et al.,* 2014 reported that phosphorous levels and availability influenced by NCU, S and zinc. The combination of macro and micro-nutrient increased the phosphorous availability in soil. There was positive/synergistic relation observed between N and P. If nitrogen increased ultimately phosphorous also increased. This result is in accordance with the findings of Kumar *et al.,* 2015, Laxminarayan and Partiram (2006), Bhardwaj and Omnawer 1994. The increase in soil available phosphorous might be related to neem coated urea which provide energy to microorganisms i.e. C and N slowly during whole life cycle of rice-wheat crop due to this the activities of microorganisms increase which responsible for release of phosphorous in soil in available form from fixed and unavailable form (Sridharan *et al.,* 2017). This result is in accordance with the findings of Sanjay Kumar *et al.,* 2015, who stated that neem powder has insecticidal and fungicidal properties for soil micro flora for release of available. These results are in accordance with the findings of Chandel 2014.

4.8.4.2.3 Available Potassium (Kg ha^{-1}): - The available potassium in soil was found significantly higher in treatment T3 – NCU + PK + S + Zn-EDTA followed by T5. The more availability of potassium in these plots might be attributed to the addition of nitrogen through neem coated urea which release nitrogen slowly to crop which is utilized by crop according to their physiological growth stages and showed in growth and development of crop. The neem coated urea contains some sugars and carbon which might be beneficial phosphorous and potassium in soil. This result is in accordance with the result of Murthy *et al.,* 2013, Kumar *et al.,* 2015. Increment in the available potassium status in soil could be attributed to more potential if colloids to more potential of colloids to hold the nutrients at exchange site and reduce potassium fixation and release of potassium to available pools of soil. This result supported by Hasan *et al.*, 2016 and Kapoor, 2003. The lowest potassium content found in control and due to quick release of nitrogen from ordinary urea and anhydrous ammonia.

4.8.4.2.4 Available sulphur (Kg ha^{-1}) – The availability of S in soil varied from its initial value. The availability of S increased in those plots where elemental S and $ZnSO_4$ added. The highest available S recorded in T3 – NCU + PK + S + Zn-EDTA which was followed by T5- NCU + PK + $ZnSO_4$. The elemental S is oxidized to sulphate by soil microbial population which makes the S availability in soil and plot. So, the positive interaction of S with N also increased the sulphur or availability. Neem coated slowly release nitrogen and provide energy to microorganisms in form of carbon and nitrogen which act as substrate and increase the availability other elements. This result is in accordance with findings of Afroj (2013), Hassan *et al.,* 2016. The lowest availability recorded in control and T2 (AA + PK) due to scarcity of elemental S.

4.8.4.2.5 Available zinc: - The availability of zinc in soil ranged from 3.5 to 0.9 mg ka^{-1} in rice and 3.8 to 1.3 mg kg^{-1} in wheat. After the application of synthetic fertilizers, there was a variation recorded in the availability of zinc in soil. The low availability of zinc in soil might be due to submergence. The higher availability of zinc in T3- NCU + PK + S + Zn-EDTA which was followed by T5 – NCU + PK + $ZnSO_4$ might be attributed to application of chelated zinc. The chelated zinc has very less interaction with the soil, components which inhibit the harmful reactions in soil. On the other hand, $ZnSO_4$ increase the fixation and adsorption and resulted more fixation with soil components. This result is in conformity with the findings of Naik and Das 200, Shivay *et al.,* 2008 and Srivastva *et al.,* 2008. The result also in accordance with Ortiz and Garcia 1998 who reported that chelated zinc fix less in soil as compared to $ZnSO_4$. Tariq *et al.,* 2007 reported that chelated zinc is the best source of zinc fertilizer for rice crop.

4.8.5 Effect of modified fertilizers on soil biological indicators: -

4.8.5.1 Urease enzyme activity: - Urease in soil is a microbial extracellular enzyme accumulated through release of urea from microbial and living cells. Urease producing microorganisms present in soil which enhance the activities of urease in soil. The urease enzymes activity recorded maximum at heading stage at upper surface of soil (0-15 cm) as compared to subsurface (15-30 cm) that might be attributed to active pools of carbon and nitrogen in surface soil (Rama Lakshmi *et al.,* 2012). The results of the present investigation showed that highest urease activity in both crops rice-wheat recorded at heading (90 DAS) and after those activities decreased. This result is in accordance with the findings of Vajantha *et al.,* 2010, Nayak and Manjappa 2010. The highest urease activities recorded in NCU + PK + S + Zn-EDTA and NCU + PK + $ZnSO_4$ that could be due to the balanced fertilization of synthetic fertilizers. Balanced fertilization improved the growth of plant and left large number of stubbles in soil which on decomposition act as source of carbon and energy and resulted in production of extracellular enzymes (Kadlag *et al.,* 2008). The nitrogen slowly released through neem coated urea in soil up to 90 Days after application. The addition of nitrogen through neem coated urea prevents the release of nitrogen by chemical reaction or microbial processes in initiation period of its application and slowly increasing with the time. This result is in conformity with the findings of Reddy and Reddy 2012, Rai and Yadav 2011. During the whole study the neem coated urea release nitrogen slowly to longer period that is because of nitrogen applied through NCU is in organic form and it has to be converted into inorganic form i.e. NH_4^+-N or NO_3^-N to become available to crop. This process of conversion mainly done by urease enzyme and microbial process which was slower as compared to chemical reaction occur in soil. The lowest urease enzyme activity recorded in control followed by T2 (AA + PK) which might be attributed to absence of sufficient substrate (carbon) which acts as a source of energy for micro-organisms similar results supported by Ramalakshmi 2011. Elayaraja and Singarvel 2011 revealed that

100% NPK + Zinc enhance urease activity by increasing microbial population and nitrogenous substances in root exudates which increase urease activity. Decline in urease activity with soil depth might be due to reduction in soil organic carbon (Baligar *et al.*, 1991). Urease activities positively correlated with inorganic P, Organic S (Speir *et al.*, 1984).

4.8.5.1.2 Dehydrogenase enzyme activities: - For the soil quality determination, dehydrogenase enzyme activity is one of the vital soil characteristic because it reflects the available of nitrogen and microbial population. The dehydrogenase enzyme activity significantly influenced by NCU + PK + S + Zn-EDTA and NCU + PK + $ZnSO_4$ at heading stage. The neem coated urea is a source of carbon and nitrogen which act as a source of energy to soil microorganisms and increase microbial population. The major source of soil dehydrogenase enzyme in soil is the lysis of the microbial cells. These results are in accordance with Prakash *et al.*, 2002, Sheng *et al.*, 2005, Tejda and Gonzalez 2009 and Ramalakshmi 2002. Same as urease activity dehydrogenase activity also decreased after heading stage. The other mechanism behind the increment in dehydrogenase activity is the balanced fertilization of NPK with Zn and S which maintained the active pools of carbon and nitrogen in soil. The pools of carbon linked with nutrients mainly nitrogen which maintain organic matter and enzyme activities in the rhizosphere. Similar results supported by Bharti *et al.*, 2011. Bhavani *et al.*, 2017 and Gill *et al.*, 2016 lowest values of dehydrogenase activity recorded under control and followed by T2 (AA + PK). The decrease in dehydrogenase activity with 100% NPK is attributed to redox potential of soil, which increased due to accumulation of nitrate which lowers dehydrogenase activity. This result corroborates with the findings of Bhatt *et al.*, 2016 and Mandal *et al.*, 2007. The addition of S along with NPK enhances dehydrogenase activity because S is a main constituent of amino acids and co-enzymes which play important role in microbial metabolism (Romero *et al.*, 2010). The lower activity of dehydrogenase with 100% NPK and AA + PK indicated that the imbalance fertilization inhibit the availability of carbon and enhance the retention of carbon which increase the osmatic potential of soil solution due to fertilizer salts which lowers the activity of dehydrogenase (Bhart *et al.*, 2017, Kaur and Brar 2008).

4.8.5.1.3 Aryl Sulfatase: - Aryl sulfatase is the enzyme which catalyzes the hydrolysis of organic sulphate esters releasing inorganic sulphates. These enzymes played important role in the availability of sulphur to plants. It is a measure of the inherent capacity of soil to catalyze hydrolysis of ester sulphates. The aryl sulphates activities recorded highest in those plots which received elemental sulphur along with NPK. The highest activities recorded in T3 (NCU + PK + $ZnSO_4$). The aryl sulphate activities reduced with increasing soil depth that could be attributed to decreasing content of organic carbon and moisture with depth. C late bati and Bremner, 1970, Baligar and Wright, 1991, the more activities of aryl sulphate due to the positive relation of NCU and carbon with aryl sulphate noted in T3. This result is in accordance with the findings of Candid *et al.,* 2012, Hat field *et al.,* 2015.The less activities of aryl sulfatase recorded under those plots which not received sulphur and those which combined with anhydrous ammonia. That could be due to low amount of carbon, nitrogen and organic matter. From this, it is clear that organic matter plays important role in aryl sulfatase activities. However, there is a synergistic relation of aryl sulfatase with organic sulphur and phosphorous (Ram *et al.*, 2014(a)). Aryl sulfatase activity in rice – wheat increased with sulphur application @ 45 Kg ha^{-1}. Commonly bacteria and Fungi mainly synthesized aryl sulfatase and recognized as a key enzyme for the mineralization of sulphur. This result is in accordance with the findings of Ye *et al.,* 2010, Palsaniya and Ahkawat 2009. Aryl sulfatase activity was more at heading stage with elemental sulphur and $ZnSO_4$ might be due to highly soluble in water which release sulphur immediately after application which attributed to immobilization of inorganic sulphate (Nayak *et al.,* 2011).

4.8.5.1.4 Acid and Alkaline phosphatase activity: - Phosphatase activity is necessary for transformation of organic substrates containing phosphorous into inorganic form by hydrolysis in soil. Phosphorous act as oxidoreductase which played vital role in P-cycle. Alkaline phosphatase enzymes activities recorded more as compare to acid phosphatase irrespective of different treatments in both rice and wheat crops. Acid and alkaline phosphatase activities significantly influenced by NCU + PK + S + Zn-EDTA and NCU + PK +$ZNSO_4$. The more acid and alkaline phosphatase activities recorded with NCU + PK +S + Zn-EDTA followed by NCU + PK + $ZnSO_4$ could be ascribed to the fact of balanced fertilization which favours more plant biomass and return more organic residues in soil by leaf fallow stubbles, which lead to increase the activities of micro-organisms. This result is in accordance with the findings of Bhatt *et al.*, 2016, and Mishra *et al.*, 2008, Reddy and Reddy 2012 and Rai and Gaurav 2011. The acid and alkaline phosphatase activity reduced with soil depth (Garg and Bhal 2008). Lowest activity of acid and alkaline phosphatase recorded under control due to lack of substrate for micro - organisms (Rai and Yadav 2011).

4.8.5.1.5 Nitrate reductase: - Nitrate reductase is the enzyme in soil which catalysis the reduction of NO_3^- to NO_2^- under anaerobic conditions nitrate reductase activities recorded highest in NCU + PK + S + Zn-EDTA and NCU + PK + $ZnSO_4$ plots. That might be due to slow release of nitrogen by coated fertilizers. The nitrate content increased in soil with increase in pH (Soil acidity). The availability of nitrate positively related with the enhancement in NR activity because it acts as substrate for enzyme. Similar results were obtained by Celestino 2006) and P acheco *et al.*, 2011. As crop leads towards maturity/reproductive phase the NR activities increased. The lowest activities recorded in control, in the absence of N, because ordinary urea released nitrogen quickly and nothing left behind at reproductive phase (Fageria, 2000).

Chapter 5

Summary and conclusion

5.1 Summary

The present investigation entitled' Improving Nitrogen and Phosphorous Use Efficiency in rice – wheat cropping system through application of modified fertilizers" was conducted during 2018-2019, 2019-2020 at the Agronomy Farm of Lovely Professional University, Phagwara (Punjab). The experiment was laid out in Randomized block design with three replications. Total nine treatments were used in experiment i.e. T0 Control (RDF), T1 Neem Coated Urea, T2 Anhydrous ammonia + PK recommended,T3 Neem coated urea + PK + S + Zn –EDTA,T4 Anhydrous ammonia + PK + S + Zn- EDTA, T5 Neem coated urea + PK + $ZnSO_4$,T6 Anhydrous ammonia + PK + $ZnSO_4$,T7 RDF + $ZnSO_4$,T8 RDF + S + Zn-EDTA. In this dissertation an approach was initiated to understand the effect of modified fertilizers on nitrogen and phosphorous use efficiency. Also the research was inducted to understand the impact of modified fertilizers on different soil parameters. During the course of investigation, different growth and yield parameters were recorded at different stages of crop growth, also initial and final nutrient status, quality parameter recorded at harvest. The results obtained from investigation are summarized below:

1. Application of modified fertilizers favored plant growth of rice and wheat crops at different intervals. In rice plant height measured at 20, 40, 60 and 80 DAT and in wheat at 30, 60, 90 and 120 DAS. In rice and wheat T3 - Neem coated urea + PK + S + Zn – EDTA registered highest plant height during both crop cycles. Minimum plant height recorded in T2- Anhydrous ammonia + PK recommended during both years in both crops.
2. Total number of tillers per plant in rice and per meter square in wheat was recorded maximum in T3- Neem coated urea + PK + S + Zn –EDTA followed by T5 Neem coated urea + PK + $ZnSO_4$ -and minimum under the T2.

3. The results revealed that fresh weight, dry weight, chlorophyll index, leaf area, CGR, RGR and NAR of rice and wheat crop responded significantly due to application of modified fertilizers. Highest fresh weight , dry weight, chlorophyll index, leaf area, CGR, RGR, and NAR recorded under T3- Neem coated urea + PK + S + Zn –EDTA in rice crop and in wheat crop during both years. Minimum improvement in crop growth parameters recorded under control and T2.
4. The number of productive tillers per plant in rice and per meter square in wheat was significantly influenced by different modified fertilizers. The maximum number of productive tillers was found significantly under treatment T3- Neem coated urea + PK + S + Zn –EDTA followed by T5. The minimum productive tillers were found under T2.
5. The panicle length was recorded maximum in T3 followed by T5 and minimum was recorded under treatment T2.
6. The filled grains panicle^{-1} and number of grains per spike in wheat were observed maximum in the treatment T3 followed T5 and T1 and minimum was found under treatment T2, T4.
7. The test weight of rice grain and wheat grain was found maximum in T3 , which was higher than other treatments (Name of the treatments) followed by T5, and minimum was found in T2 and T0 control
8. The grain yields of rice and wheat were significantly af fected with different treatments imposed. Significantly maximum grain yield of rice was recorded in T3-Neem coated urea + PK + S + Zn –EDTA followed by T5 - Neem coated urea + PK + $ZnSO_4$and minimum grain yield was recorded in the treatment T2 control.
9. The highest straw yield of rice and wheat was recorded significantly in T3- Neem coated urea + PK + S + Zn –EDTA followed by T5 - Neem coated urea + PK + ZnSO4 and minimum straw yield was recorded in T2 .
10. The trend which was observed in grain yield also observed in yield contributing parameters i.e. number of filled grains, panicle/spike length, and 1000 grain weight and harvest index.

11. The Nitrogen uptake was found significant and higher in T3- Neem coated urea + PK + S + Zn –EDTA followed by T5 and minimum was found in T0 and T2.
12. The phosphorus, potassium and sulphur uptake was found significantly maximum in treatment T3 followed by T5 -100% NCU and minimum was found under T0& T2.
13. Nitrogen use efficiency , phosphorous use efficiency , potassium use efficiency and sulphur use efficiency of rice and wheat crop was found maximum in treatment T3 - Neem coated urea + PK + S + Zn –EDTA followed by T5 - Neem coated urea + PK + $ZnSO_4$.
14. Dehydrogenase activity in soil was highest at heading stage and at 0-15 cm surface of soil. T3- Neem coated urea + PK + S + Zn –EDTA followed by T5 - Neem coated urea + PK + $ZnSO_4$ recorded significantly more DHA in soils of rice –wheat crop as compared to other treatments.
15. Urease activity in soil was somewhat more in wheat as compared to rice crop at heading stage. Highest activity recorded at upper surface soil. T3- Neem coated urea + PK + S + Zn –EDTA followed by T5 - Neem coated urea + PK + $ZnSO_4$ during both years of rice crop and wheat recorded more enzyme activities than other treatments.
16. Alkaline and acid phosphatase activities decreased with the maturation of experiment. All treatments except T0, T2 recorded more acid and alkaline phosphatase activities being highest with T3 in rice and wheat.
17. Nitrate reductase and aryl sulfatase enzyme activities recorded maximum at heading stage of rice and wheat crop. All treatments were significantly different from each other. Highest NR and AS activity in rice crop recorded by application of Neem coated urea + PK + S + Zn –EDTA.
18. Different treatments significantly affected the pH, EC and OC of soil after harvest of rice and wheat crop. There is variation in pH, EC and OC observed by different combinations of fertilizers.
19. N, P and K availability status in soil improved after the addition modified fertilizers over control. Highest NP K being recorded with T3 in rice and wheat crop. Minimum availability of NPK recorded under T0and T2.

20. Sulphur and Zinc status in soil also improved by application of modified fertilizers. Maximum S and Zn availability recorded in T3 followed by T5.
21. The lowest leaching of NO3-N and P recorded in T3 in wheat and rice crop. The leachate volume recorded lowest in T3.
22. Cost of cultivation of Rs 32000 in rice and Rs.29991 in wheat was same cost of cultivation for all treatments. Cost of cultivation changed due to different combinations. Among 9 treatments T0 and T1 recorded lowest cost of cultivation as compare to other treatments whereas T3 recorded maximum (48115) cost of cultivation in rice and Rs 35891 in wheat. Among all maximum (106851.00) gross returns in wheat and in rice (191230.6) recorded under T3. The lowest gross returns recorded in T2 in rice and wheat crop.
23. The maximum net returns in rice crop and in wheat recorded under T3. The lowest net returns recorded under T2. The maximum B: C ratio in rice and in wheat recorded under T5. The lowest B: C ratio recorded in T2.

5.2 Conclusions:

These results concluded that neem coated urea performed better than ordinary urea and anhydrous ammonia. Neem coated urea has the potential to increase the nitrogen use efficiency, grain and straw yield. From results it can be concluded that coated fertilizer increases yield and nutrient uptake of rice and wheat crop. The nutrient uptake by grain and straw of rice wheat crop was significantly influenced by neem coated urea and its combinations. Coated fertilizers provide the nitrogen regularly and coincide with the physiological growth stages of rice-wheat crop. The yield attributing growth parameters i.e. plant height, number of tillers , panicle length (cm) and filled grain per panicle and 1000 grain weight of rice-wheat was observed maximum under the treatment T3 –Neem coated urea +PK+ S+ Zn-EDTA. Grain and straw yield of rice-wheat was recorded significantly higher under treatment T3 –Neem coated urea +PK+ S+ Zn-EDTA Followed by T5 - Neem coated urea +PK+ $ZnSO_4$ and minimum was recorded under T2 – Anhydrous ammonia+ PK. Uptake of Nitrogen, Phosphorus, Potassium and Sulphur by grain was higher in T3- followed by T5 and minimum was noticed under T2 T0. Similar trend recorded in NUE, PUE, KUE and SUE was found higher under T3-&T5 respectively. The soil nutrient status was improved by application of neem coated urea along with Zn EDTA, PK and S. The results indicated that the available nitrogen, Phosphorus, Potassium and micronutrient status was recorded maximum under T3 -Neem coated urea+ PK+ S+ Zn-EDTA. Enzymatic activities also recorded maximum in T3 a surface soil during both crops. In pot study also , T3-Neem coated urea+ PK+ S+ Zn-EDTA responds better in all agronomic and soil parameters .Minimum leaching was recorded in those treatments where coated fertilizers used as compared to control and uncoated fertilizers.

5.3 Scope of study: The use of modified fertilizers decreases nutrient losses and enhances nutrient use efficiency. Decrease of 20-30% of recommended application rate of conventional fertilizers. Reduces lodging and injury from ammonium ions. Application of coated fertilizers increases the acidity of soil which favours the uptake of P and Fe. Release nutrients in a sigmoidal pattern and contribute towards agronomic safety. Improve the uptake of nutrients by plants through synchronized nutrient release; significantly reduce possible losses of nutrients specially leaching and voltalization.

5.4 Suggestions for future work

In this investigation only one controlled release urea (CRU) namely neem coated urea (NCU), one chelate –Zn EDTA were taken to study their impact on soil properties and nutrient use efficiency under rice-wheat cropping systems. But there are so many controlled releases Fertilizers are present in international market which was not used. Other controlled release urea fertilizers could be incorporated in experiments for choosing best coated fertilizer which enhance crop yield and also maintain soil sustainability. The release rate of nitrogen for various released fertilizers could be investigated for selecting appropriate combination under various combinations. For assessing the responses of plants to concerned fertilizers application of new formulation of coatings could be made. Multi location trials should be conducted in different zones for recommending most suitable modified fertilizer for concerned cropping patterns in those areas. There is a need to find out the response of neem coated urea under different soil conditions in different agro- climatic zones .

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