Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area

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VINOD KUMAR YADAV

Thesis

Doctor of Philosophy in Agriculture

(Soil Science)

2021

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
RAJASTHAN COLLEGE OF AGRICULTURE

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
UDAIPUR – 313001 (RAJASTHAN)

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Thesis

Submitted to the

Maharana Pratap University of Agriculture and Technology, Udaipur

In partial fulfillment of the requirements for the Degree of

Doctor of Philosophy in Agriculture

(Soil Science)

By

VINOD KUMAR YADAV

2021

CERTIFICATE - I

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis titled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** submitted for the award of degree of **Doctor of Philosophy** in Agriculture in the subject of **Soil Science** to Maharana Pratap University of Agriculture and Technology, Udaipur (Raj.) is original and bona fide record of research work carried out by me under the supervision of **Dr. S. C. Meena,** Associate Professor, Department of Soil Science and Agricultural Chemistry, Rajasthan College of Agriculture. The content of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or University for the award of any degree or diploma.

The work embodied in the thesis represents my ideas in my words and where others' ideas have been included; I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE - II

Dated: / /2021

This is to certify that the thesis entitled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** submitted for the degree of **Doctor of Philosophy** in Agriculture in the subject of **Soil Science** embodies bona fide research work carried out by **Mr. Vinod Kumar Yadav** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on / /2021.

The manuscript has been subjected to plagiarism check by software Urkund.

It is certified that as per the check, the similarity index of the content is 6% and is within permissible limit as per the MPUAT guideline on checking Plagiarism.

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This is to certify that **Mr. Vinod Kumar Yadav** student of **Doctor of Philosophy in Agriculture, Department of Soil Science and Agricultural Chemistry**, Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** which were suggested by the external examiner and the advisory committee in the oral examination held on…………….. . The final copies of the thesis duly bound and corrected were submitted on……………….. are enclosed here with for approval.

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Date:

Place: Udaipur (Raj.) **(Vinod Kumar Yadav)**

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ACRONYMS

%	:	Per cent
°C	:	Degree Celsius
°E	:	Degree East
°N	:	Degree North
/	:	Per
@	:	At the rate of
ANOVA	:	Analysis of variance
B.P.	:	Boiling point
B:C	:	Benefit cost ratio
C.D.	:	Critical difference
CEC	:	Cation exchange capacity
cm	:	Centimeter
cm hr^{-1}	:	Centimeter per hour
CR	:	Crop residue
Cu	:	Copper
d.f.	:	Degree of freedom
DAP	:	Di-ammonium phosphate
DAS	:	Days after sowing
DMA	:	Dry matter accumulation
dSm^{-1}	:	Deci siemens/meter
DTPA	:	Diethylene Triamine Penta-acetic Acid
EC	:	Electrical Conductivity
et al.	:	(et alibi) or elsewhere
Fe	:	Iron
mg	:	Milligrams
Mg	:	Megagramme
mg kg^{-1}	:	Milligramme per kilogramme
min.	:	Minimum
mm	:	Millimeter
Mn	:	Manganese
M.P.	:	Madhya Pradesh
MSS	:	Mean sum of square
mt	:	Million tonne
N/N_2	:	Nitrogen
No.	:	Number
C_{min}	:	Carbon Mineralization
NS	:	Non-significant
p	:	Page
P/P_2O_5	:	Phosphorus
	:	
pH	:	pH of 1:2, soil : water suspension
ppm	:	Part per million
q ha^{-1}	:	Quintal per hectare
R.H.	:	Relative humidity
R.P.	:	Rock phosphate
Rs.	:	Rupees
S.No.	:	Serial Number
SEm±	:	Standard error of mean

Fig.	:	Figure
FYM	:	Farmyard manure
g	:	Gram
ha	:	Hectare
hr	:	Hour
i.e.	:	That is
K/K_2O	:	Potassium
kg ha^{-1}	:	Kilogram per hectare
m	:	Meter
m ha	:	Million hectare
MBC	:	Microbial Carbon Biomass
m^3	:	Meter cube
Max.	:	Maximum
sq.m.	:	Square meter
t ha^{-1}	:	Tonnes per hectare
Temp.	:	Temperature
viz.	:	(Videlicet) Namely
w.r.t.	:	With respect to
Zn	:	Zinc
DOC	:	Dissolved Organic Carbon
POMC/N	:	Particulate Organic Matter Carbon/ Nitrogen
SOC	:	Soil Organic Carbon
TOC	:	Total Organic Carbon
WSC	:	Water Soluble Carbon

1. INTRODUCTION

In the anxiety of rising food production to meet the needs of the nation's ever increasing population, the green revolution started in the mid-sixties became a milestone in India's agricultural transformation. Since then, the improved seed, chemical fertilizers, plant health, irrigation and allied intensive technologies promoted have paved the way for a significant increase in the production of agriculture, leading to self-sufficiency and even export surpluses. This was considered a 'fait accompli' and it was 'jubiliant' for the nation. Synthetic fertilizers consumption is estimated to rise by 7 times and pesticides by 375 fold, although food production had only doubled during the first twenty years of India's beginning of the green revolution (Ramanathan, 2006).

In agriculture, crop residue contributes to the soil much required organic and mineral matter. The incorporation of crop residue plays an important role in sustaining and improving the fertility and productivity of the soil. The careful handling of these helps to enhance the productivity of soil and improve the added nutrients (Ipsita das and Singh, 2014).Soil harbours a dynamic microbial population arthropods and others. This living process is significantly stimulated by the incorporation of crop residue, which serves as a source of carbon and energy for micro-organisms that proliferate and they will change the internal corresponding enzyme status accordingly. Interest in the behavior of soil enzymes has recently increased as their actions are assumed to reflect the soil's possible ability to perform nutrient transformations. Since the absorption of crop residue into soil is correlated with soil microbial and enzyme processes, it not only plays an important role in soil chemical and biological activity, but also influences the rate at which nutrients are made available to crop plants and other types of life (Usharani *et al*., 2013).

The combined use of crop residue with chemical fertilizers provides the advantages of preserving or altering soil fertility and plant nutrient supply at an appropriate level to preserve the required productivity. This is accomplished by the combined optimization of the advantages of all possible sources of plant nutrients in order to obtain optimum economic yield without deleterious effects on the soil's physico-chemical and biological properties. In addition to natural soil stocks, the main components of the advanced nutrient management scheme include crop residues and bio inoculants. Crop residue enhances the physical state of the soil by increasing the ability to retain water for optimum water use. They also enhance the chemical and biological state of the soil by increasing the exchange ability of cations and by supplying various vitamins, hormones and organic acids that are very important for soil aggregation and for beneficial micro-organisms involved in different biochemical processes and nutrient release (Urra *et al*., 2019).

Legumes are usually referred to as food legumes, which in India are secondary to cereals in consumption and production. The much more precious and natural component of vitamins, proteins, minerals and calories are legumes. Legumes play a key role in agriculture sector by nitrogen fixation from atmosphere through their root nodules to maintain soil fertility. "Because of their deep root system with dense ground coverage, legumes are resistant to drought and prevent soil erosion. Due to these strong characters that's why these are named as "Marvel of Nature''. It is also possible to refer to legumes as mini fertilizer factories, as they fix symbiotic atmospheric nitrogen (Mus *et al*., 2016).

India holds a prominent role on the world's oilseed map, both in terms of region and development. Oilseeds are second only to food grains in terms of production and economic value. After USA, China and Brazil, India is the world's fourth largest edible oil economy and accounts for about 10 per cent of the world's oilseed production, 6-7 per cent of the world's vegetable oil production and almost 7 per cent of the world's oil production. In addition to constituting an integral part of the human diet, oils and fats often act as vital raw materials for the manufacturing of soaps, paints and varnishes, hair oils, lubricants, textiles, pharmaceuticals, etc. Oilcakes and seed-based meals (after extraction of oil) are used in animal feed and as manure. Soybean [*Glycine max* (L.) Merrill] is the 3rd most important oilseed crop after groundnut and rapeseed-mustard and it is also known as the 'Golden Bean' of the 20th century and is native to East Asia, where it appears to have been cultivated from a wild species knows as '*Glycine soja'* starting about 5000 year ago. It contains about 20 per cent oil and protein 40 per cent with 6-7 per cent total mineral, 5-6 per cent crude fiber, 5 per cent ash and 17-19 per cent carbohydrates. Soybean contains a good amount of is flavones which helps in preventing the heart disease. It may be a good substitute such as ‘soya milk’. Soybean is highly versatile bean that can be processed in to oil, flour and milk (Messina *et al.*, 2006).

In India, Madhya Pradesh, Maharashtra and Rajasthan are three dominating states with a contribution of about 92-93 per cent of area as well as in production. During 2020-21, soybean was grown on an area of 12.12mha with a production of 13.58 mt and the average productivity of 1125 kg ha^{-1}. While in Rajasthan it was grown in an area of 1.10 million hectares with production of 1.23 million tonnes (Anonymous, 2020-21).

Approximately 640-650 mt of crop residue is produced annually in India and most of India's metropolitan cities are currently facing the issue of air pollution caused by the burning of these residues of crops. By turning these residues into useful sources of plant nutrients, both problems can be solved. The agricultural residues got effectively converted into enriched compost and its nutritive value is further enhanced by incorporation of nutrient sources *viz.,* incorporation of rock phosphate in soil enhances the crop productivity as well as soil quality. In general, crop residues serve a range of beneficial functions, including soil surface defense against erosion, water conservation and soil organic matter maintenance (OM). Crop residues contain a significant amount of nutrients and can be effective ways of sustaining soil organic matter and soil nutrients. When crop residue is incorporated into the soil and properly managed, it can be a potential source of nutrients. Improved management practices such as no-tillage management, crop residue management and balance nutrient application improves agriculture stability (Yadav *et al.*, 2017). Plant residues contains eight times greater quantity of nutrients compared to the amount of nutrients added as inorganic fertilizers and as well as it contains micronutrients which are not found in inorganic fertilizers. Proper management of crop residues could, therefore, reduce the use of costly chemical fertilizers, improve crop productivity and alleviate water and nutrient stress. However, most of the farmers used crop residue as fodder, fuel or construction material, thus minimizing the retention of crop residues.

Organic soil carbon plays a crucial role in the functioning of the ecosystem. The conservation and development of SOC is extremely important for soil physical, chemical and biological health (Lal, 2016). The combined use of crop residues with optimum NPK fertilizer levels enhances the physical quality of the soil by enhancing the capacity to retain water for full water utilization. This also enhances the biological and chemical quality of the soil environment by enhancing the ability of cation exchange and providing multiple hormones and organic acid that are very important for soil aggregation and for beneficial micro-organisms involved in different biological processes and nutrient releases.

In the growing area, the soybean has shown revolutionary improvement. It is known an exhaustive crop that needs high soil nutrients, but is cultivated in either medium to low-nitrogen and phosphorus soils or in lower organic sources. This has contributed to a decrease in the production of crops and a decline in soil quality and productivity. The use of crop residue along with chemical fertilizers could be a viable choice for preserving soybean productivity and contributing life to the soil.

Keeping the above consideration an experiment entitled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** is proposed to be conducted during *Kharif*, 2019 and 2020 at Agricultural Research Station, Ummedganj-Kota with the aforesaid objectives.

1. To study the effect of crop residue and nutrient management on growth, yield and quality of soybean in Chambal command area.
2. To work out the nutrient content and uptake by soybean.
3. To assess the physico-chemical and biological properties of soil.
4. To evaluate different chemical pools of Carbon and their significance in relation to soil and crop.

2. REVIEW OF LITERATURE

Nutrient management involves combining old and new methods into an environmentally friendly and financially optimal farming system that is judicious, efficient, and integratedly incorporates the benefits of all possible sources of organic, inorganic and biological components. It also tries to enhance the soil health and minimize land deterioration. Crop residue and nutrient management are more widely recognized for their ability to boost crop output, while also preserving soil resources in an almost imperceptible manner.

A concise review of the research was carried out on **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** during two *Kharif* seasons of 2019-20 and 2020-21are being presented below:

2.1 EFFECT OF CROP RESIDUE

2.1.1 Effect of Crop Residue on Growth and Yield of Soybean

A field trial was conducted at New Delhi and results revealed that using the recommended amount of NPK with FYM and biofertilizers was superior than using the recommended NPK level for pods plant^{-1}, seeds pod^{-1} and seed index of soybean. The largest number of pods plant^{-1} (38.45 and 37.89) and seeds pod^{-1} (2.90 and 2.00) was reported when NPK + FYM + biofertilizers were applied together (Singh and Rai, 2004).

Sabale, (2005) studied and compared to alternative sources of nitrogen, nitrogen delivered by FYM has resulted in a larger quantity of pods plant^{-1}, seeds pod^{-1}, seed index and yield in soybean and it is considerably superior to control.

Chaturvedi and Chandel, (2005) conducted a field experiment on the impact of organic and inorganic source of manure and fertilizer on soil fertility and yield of soybean and found that maximum pods plant^{-1} (94.4) and 100 seed weight (10.7 g) of soybean were noted with the application of RDF and FYM @ 10 tonnes ha^{-1}.

Dash *et al*., (2005) a field experiment was carried out at instructional farm, IGAU, Raipur and found that plant height at flowering stage, dry matter accumulation at various stages, number of total nodule and grain yield were significantly higher with the application of crop residues @ 5 t ha^{-1} followed by FYM 5 t ha^{-1} among the other treatments. Similarly, 100% recommended dose of fertilizer recorded highest plant height and dry matter accumulation over 50 % recommended dose of fertilizer and control.

Sabale (2005) conducted an experiment and found that the use of 50 kg N ha^{-1}50 per cent *via* urea and 50 per cent *via* FYM was substantially higher over the remaining treatments, resulting in greater number of pods $plant^{-1}$, seeds pod^{-1}, seed index and yield.

Lakhpade and Shrivastava (2006) conducted a field research experiment at Raipur to determine the influence of integrated nutrient management on soybean productivity and economics and found that optimum fertilizer dose considerably improved plant height and branches $plant^{-1}$by application of 5 tonnes crop residue ha^{-1} + 5 tonnes farm yard manure ha^{-1} with approved fertilizer dosage resulted in considerably greater soybean growth (11.94 and 10.9 per cent) compared to 50 per cent recommended fertilizer dosage.

During *Kharif*2005 in Maharashtra, India, Kadam *et al*., (2008) was carried out an experiment and found that applying 100 per cent N by poultry manure + foliar application by fulvic acid increased meaningfully plant height, number of leaves (30 and 60 days after sowing), seed and haulm yield of soybean.

Mahesh *et al*., (2008) conducted an experiment in Dharwad (Karnataka) and found that combining recommended fertilizers rates (40: 80: 25 N: P: K through urea, SSP and MOP, respectively) with recommended farm yard manure 5 t ha^{-1} resulted in the maximum grain yield and yield attributes.

According to Ramesh *et al*., (2008) poultry manure treatment resulted in the largest quantity of pods $plant^{-1}$ (38.7) when compared to chemical fertilizers (34.0) or other organic manure sources. The treatments had no effect on the number of seeds pod^{-1}, seed index, and HI of soybean. The poultry manure treatment produced the highest haulm yield (3438 kg ha^{-1}), whereas all other organic sources of nutrients produced almost equal haulm yields. Soybean yield in the control treatment were the lowest.

The use of vermicompost improved the grain yield and protein and sugar content in seed of black gram in mostly clay loam soils, according to Parthasarathi *et al.*, (2008). Plant height at 60 DAS, number of branches, protein content and protein production of black gram were all considerably greater under the incorporation of 5 t FYM ha^{-1} than under control, according to Kokani *et al.*, (2015).

In a research experiment carried by Ramesh *et al.*, (2009), the organic manure treatment produced significantly greater seed yield (10.6 and 11.1%) than chemical fertilizers. In both the years of the study, the grain yield of soybean was comparable when synthetic fertilizers and INM were used. In comparison to chemical fertilizers, organic manure treatment resulted in a much larger number of pods $plant^{-1}$ on average, although it was on par with integrated nutrient management. However, nitrogen management and cropping techniques had less effect on soybean seeds pod^{-1} and seed index.

Gunjal *et al.*, (2010), found that combined application of inorganic fertilizer with FYM enhanced yield attributing characteristics and yield. Increased levels of K_2O and FYM dramatically increased the highest seed yield parameters, such as pods count, weight pod^{-1}, number of seeds pod^{-1} and seed index.

The maximum plant height of 16.89 , 65.78 and 73.37 cm at 30, 60 and 90 DAS, the highest number of pods $plant^{-1}$ (80.40) and the highest test weight (17.02 g) were recorded in the treatment where (50%) recommended does of nitrogen applied through urea + (50%) N through FYM +PSB and the lowest of these were found in the treatment where (50%) recommended dose of nitrogen applied through urea + (50%) recommended dose of nitrogen (Koushal and Singh, 2011).

In comparison to the control, Rai *et al.*, (2012) found that combining poultry manure with NPK nutrients via fertilizers enhanced pods $plant^{-1}$andseed yield. During pooled data of both years, the seed production (28.95 q ha^{-1}) and haulm yield of soybean (45.69 q ha^{-1}) were significantly affected and registered maximum with (N15 P30 K45 + @ 5 t ha^{-1} poultry manure), while it was poorest with control (20.64 q ha^{-1}) and N15 P30 K45 + @ 5 t ha^{-1} poultry manure (37.30 q ha^{-1}).

Shirale *et al*., (2014) conducted a long-term fertilizers experiment in Parbhani and found that the 100 per cent NPK+ farm yard manure @10tonnes ha^{-1} produced the highest grain (26.44 q ha^{-1}) and halum yield (35.02 q ha^{-1}), while being statistically comparable to 150 per cent NPK and 100 per cent NPK+25 kg $ZnSO_4$ ha^{-1}.

Meena *et al*., (2014) carried a research experiment on cowpea and results revealed that seed bio inoculation with *Rhizobium* and PSB suggestively increased the number of pods $plant^{-1}$, number of seeds pod^{-1}, seed yield, halum yield and HI, as well as B:C, when compared to the other treatments Sushil *et al*., (2015) found that using (100%)recommended dose of fertilizer + vermicompost @ 1.25tones ha^{-1} + *Azotobacter* @ 375 ha^{-1} resulted in significantly higher growth and yield parameters.

Jha *et al*., (2015) split use of vermicompost 1.0 tonnes ha^{-1} at 30 days after sowing combined with farm yard manure 2.0 tonnes ha^{-1} (basal) resulted in a substantial improvement in black gram yield compared to vermicompost 1.0 t ha^{-1} (basal) + vermicompost 1.0 ton ha^{-1} at 30 days after sowing and control.

During *Kharif*, Potkile *et al*., (2017) evaluated the direct and residual effects of different organic manures and crop residues alone and in combination with jeevamrut on soybean – wheat cropping system productivity and economics. The combined findings of two years demonstrated that 100 per cent RDN through vermicompost + jeevamrut produced considerably better soybean grain equivalent yield (33.48 q ha $^{-1}$), system production efficiency (19.41 kg day^{-1}ha $^{-1}$) and maximum B-C ratio (2.21) than 100 per cent RDN *via* vermicompost.

In a study on land configuration and crop residue management and BBF on soybean (*Glycine max* (L.) Merrill.) Kinge *et al*., (2020) found that crop residue @2.5 $tonesha^{-1}$ + 10 kg ha^{-1} decomposing microorganism was significantly superior to the other treatments in terms of yield attributes, grain yield and haulm yield.

2.2 EFFECT OF CROP RESIDUE ON NUTRIENT CONTENT, UPTAKE AND QUALITY OF SOYBEAN

In a Typic Haplustert soil in Jabalpur, (M.P.) Dikshit and Khatik (2002) evaluated the effect of combining inorganic and organic fertilizer sources on soybean availability, absorption, seed quality and seed yield. They found that using 50 per cent of the RDF +10 tones farm yard manure ha^{-1} increased soybean protein and oil content as well as N, P and K absorption.

Singh *et al*., (2008) evaluated nutrient management packages on the quality of soybean seeds in the Bhopal area of Madhya Pradesh, India. Under treatment of 100 per cent RDF + farm yard manure at 2 $tonesha^{-1}$, the maximum oil (19.61 per cent), protein (37.09 per cent) and minerals (5.52 per cent), concentrations were reported.

In a soybean-maize cropping system, a research experiment was done to investigate the influence of various organic nitrogen sources combined with inorganic fertilizers on soybean quality and seed yield. Higher soybean yield of 13.3 qha^{-1} and 12.50 q ha^{-1}were obtained by applying 75 per cent of the required nitrogen and 100 per cent of the recommended PK using inorganic fertilizers, respectively, plus 25 per cent of the prescribed nitrogen by vermicompost (Reddy *et al*., 2010).

Gunjal *et al*., (2010) found that increasing levels of FYM dramatically boosted soybean absorption of N P and K. Over the control, application of the RDF with 5 t FYM ha^{-1} resulted in considerably increased total nitrogen, phosphorus, and potassium uptake (218, 28.48, and 125.51 kg ha^{-1}) and (135.84, 14.66 and 82.68 kg ha^{-1}) respectively.

Patil *et al*., (2012) found that the 100 per cent RDN through vermicompost + jeevamrut had the highest total uptake of N (119.11 kg ha^{-1}), P (19.95 kg ha^{-1}), K (61.72 kg ha^{-1}), oil content (20.10%) and protein (39.87%) in soybean seed and haulm.

Konthoujam *et al*., (2013), found that integrated nutrient management has a significant impact on the protein and oil content of soybean seed. Between the various treatments, 75 per cent RDF with VC @ (1 tonnes ha^{-1}) + PSB produced maximum protein and oil content of soybean grain and 75 per cent RDF + VC @ (1 t ha^{-1}) and 75 per cent RDF + VC @ (1 t ha^{-1}) + PSB produced maximum nitrogen, phosphorus, and potassium uptake.

The field experiment was conducted at KVK, Durg, Anjora (Chhatis Garh) Instructional Farm was cultivated soybean with 10 treatments containing 50,100 and 150 per cent of acceptable N, P, and K levels, as well as organic sources vermicompost @ 1 t ha^{-1}, vermicompost @ 2.5 t ha^{-1} and $ZnSO_4$ @ 10 kg ha^{-1}. The results revealed that treatment (100 per cent NPK+FYM) had the highest nitrogen and phosphorus absorption (Umesh *et al*., 2018).

2.3 EFFECT OF CROP RESIDUE ON SOIL HEALTH

Crop residues and organic manures have long been known to improve physical qualities of soil. According to Biswas *et al*., (1971), BD increased with the addition of chemical fertilizers but reduced by the addition of organic manures. The weakening of soil structure caused by the use of chemical N fertilizer was blamed for the higher bulk density. Continuous application of N fertilizer alone or in conjunction with P, according to Bhatia and Shukla (1982), increased BD (1.49 to 1.56 g cc^{-1}), however treatments with farm yard manure addition lowered BD (1.49 g cc^{-1}).

Bonde *et al*., (2004) found that crop residues incorporation reduced BD considerably when compared to the control. In a cotton-soybean cropping system, FYM reported higher N, P and K availability in soil than control and other treatments (pressmud compost and wheat straw treatments).

Pandey *et al*., (2006) found that manure application, regardless of source or rate, resulted in considerably greater soil organic carbon, accessible nitrogen, P_2O_5 and K_2O levels than control. Increased output of crop residues, as well as organic manure application, might explain the higher organic carbon concentration in soil.

Swetha (2007) found that after harvesting soybeans, soil characteristics such as organic carbon, accessible nitrogen, P_2O_5 and K_2O were considerably greater in treatments getting manures alone or with fermented organics than in treatments receiving fermented organics alone. Phosphorus adsorption on soil colloid increased the amount of phosphorus in the soil.

Shivakumar and Ahlawat (2008) found that farm yard manure (FYM) and 5 t ha^{-1} of crop residues (CR) as well as 5 kg Zn ha^{-1} of nutrient sources and 100 per cent RDF of fertilizer levels, resulted in higher OC, available N, P, K and Zn in soybean.

In comparison to other manures, vermicompost treatment raised the level of 0.57 per cent organic carbon, 178 kg ha^{-1} nitrogen and 314 kg ha^{-1}potassium, according to Sulochana Bhuyan and Gaur (2009). After harvest of the chickpea crop, Singh and Sharma (2011) discovered that the availability of N and P rose considerably with the use of a mixture of manure and fertilizer form of P, *Rhizobium* and PSB biofertilizer above control.

Chaturvedi *et al*., (2010) conducted a soybean experiment in Pantnagar (Uttrakhand) and found that using the prescribed dose of fertilizer (RDF) plus 10 t FYM ha^{-1} helped to sustain and improve soil fertility.

Vidyavathi *et al*., (2011) observed that combining organic manure and chemical fertilizers resulted in much greater accessible N, P, K and S than applying fertilizers alone in a field experiment at UAS, Dharwad (Karnataka). When compared to inorganic nutrient management, integrated nutrient management technique showed significantly greater nitrogen, phosphorus and potassium absorption.

Choudhary (2013) conducted a research experiment on greengram and discovered that applying different amounts of phosphorus boosted the activity of the dehydrogenase enzyme and alkaline phosphatase activity substantially over control over both years.

To investigate the impact of manures and PGPR on soil parameters, Ipsita Das and Singh (2014) carried out an experiment at the organic farming unit of the Institute of Agricultural Sciences, BHU, Varanasi (Uttar Pradesh). Among all the manures, FYM + PGPR was shown to be the most effective, with 339.71, 22.33, and 298.66 kg ha^{-1} of available N, P_2O_5, and K_2O following mung bean harvest, respectively.

Gharpinde *et al*., (2014) revealed the influence of INM on soil fertility, nutrient balance, seed yield and net returns and B:C of soybean produced in an Inceptisol under rainfed conditions in a field experiment in Akola, Maharashtra. The results showed that applying 100 per cent RDF, 25 kg K_2O ha^{-1} and biofertilizers to soybean planted in an Inceptisol under rainfed conditions resulted in increased production and economic returns, as well as improved soil fertility and nutrient balance.

Kokani *et al*., (2015) found that the inclusion of 5 t farm yard manure ha^{-1} resulted in considerably greater organic carbon content, accessible nitrogen and phosphorus status of soil in summer black gram than the control. According to Jha*et al*., (2015), vermicompost was applied split in split doses 1.0 tonne ha^{-1} at 30 days after sowing combined with farm yard manure 2.0 t ha^{-1} (basal) resulted in a substantial increase in net return of black gram when compared to vermicompost 1.0 t ha^{-1} (basal) + vermicompost 1.0 t ha^{-1} at 30 days after sowing and control.

According to Nagar *et al*., (2016), pigeon pea + black gram and pigeon pea + green gram intercropping had lower BD, pH, EC, higher OC and available nitrogen, phosphorus, potassium, and significantly higher soil microbial biomass carbon (SBMC) and microbial count (fungal, bacterial and actinomycetes) than sole pigeon pea system.

During *Kharif*, Potkile *et al*., (2017) evaluated the direct and residual effects of different organic manures and crop residues alone and in combination with jeevamrut on soybean – wheat cropping system productivity and economics. The combined findings of two years demonstrated that 100 per cent RDN through vermicompost + jeevamrut produced considerably better soybean grain equivalent yield (33.48 q ha^{-1}), system production efficiency (19.41 kg $day^{-1}ha^{-1}$) and maximum B-C ratio (2.21) than 100 per cent RDN *via* vermicompost.

Narolia *et al*., (2020) a research experiment was conducted at Kota, Rajasthan during 2015-16 to 2017-18, to study the effect of irrigation schedule, residue incorporation and nutrient management on system productivity and profitability of soybean–wheat cropping system in *Vertisols* of Rajasthan. Pooled data of 3 years revealed that application of crop residue with RDF significantly increased dry-matter production, unit-area efficiency, $branchesplant^{-1}$, $podsplant^{-1}$, $seedspod^{-1}$, seed index, seed and straw yields and net returns of soybean, grain soybean equivalent yield (SEY), profitability, production and economic-efficiency of system, available N, P and K status of soil after harvesting of wheat and soybean. However, available K status of soil after harvesting of soybean was found non-significant in relation to irrigation.

2.4 EFFECT OF CROP RESIDUE ON DIFFERENT CHEMICAL POOLS OF CARBON

Phalke *et al*., (2017) during the summer of 2011-12, a research experiment was conducted at MPKV Farm in Rahuri to assess the impact of incorporation of sugarcane crop residues and wastes of industries on soil organic carbon fractions such as microbial biomass C, labile carbon, particulate organic C, $KMnO_4$ extractable C and physically protected particulate organic matter carbon (POMC) and the results revealed a significantly improved water stable agreeability. When compared to burning residues, active carbon pools such as SMBC, WHC and AHC improved significantly in the treatment receiving 100 per cent of RDF plus incorporation of crop residues, press mud cake and methanated spent wash compost. When compared to burning sugarcane crop residues and removing stubbles following maize harvest, incorporation sugarcane residues with press mud integration preserved about (19.6, 38.8, and 33%) more total organic carbon (TOC), SMBC and AHC, respectively. In the treatment receiving *in-situ* residue decomposition of sugarcane crop residues in combination with equal proportions 50 per cent press mud cake and bio-methanated spent wash over the burning of sugarcane crop residues and removal of stubbles, the mean values of WSC (43 mg kg^{-1}) and physically protected carbon, *i.e.* POMC (2014 mg kg^{-1}) were greater by 47 per cent and 6.6 per cent, respectively. The treatment (*in-situ* breakdown of sugarcane crop wastes + 50% press-mud cake + 50% bio-methenated wasted wash) had the most recalcitrant fraction (humic acid) of carbon after maize harvest. This investigation clearly showed that where decomposed organic matter was treated on a regular basis, the resistant portion of carbon was stored greater. It was obvious that using *in-situ* decomposed industrial waste residues and by-products in conjunction with NPK increased biomass output, SOC stock and carbon pools below and above ground.

Kumar *et al*., (2018) the point of the study was to compare the effects of three tillage systems, namely conventional tillage (CT), reduced tillage (RT) and no-tillage (NT), as well as four cropping systems on soil living environments in terms of measuring dehydrogenase activity (DHA), fluorescein di (SOC). Soil samples were taken from the 0-15 cm depth layer at the conclusion of the third crop cycle. At the surface soil level, SOC were observed to be greater in RT (0.63 %) and NT (0.62 %) than in CT (0.57 per cent) within tillage regimes (0-15cm). When compared to CT, RT and NT had considerably greater SOC concentrations at 0-15cm depth (P0.05). The liable carbon (LC) concentration in surface soil (0-15 cm) followed the same patterns as SOC, with RT > NT > CT as the final step. Cropping systems (CS) also have a substantial impact on this carbon per centage at the surface layer. Furthermore, the enforced tillage techniques had a significant (P0.05) impact on soil enzymatic activity. The DHA levels in the NT (122.35 g TPF g^{-1} day^{-1}) system were considerably higher (P0.05) than in the RT (109.65 g TPF g^{-1} day^{-1}) and CT (77.07 μg TPF g^{-1} day^{-1}) systems. At 0- 15cm depth, the FDA was found to be considerably (P0.05) greater in RT (30.85μg fluorescein g^{-1} h^{-1}) than NT (27.95μg fluorescein g^{-1} h^{-1}) and CT (22.91μg fluorescein $g^{-1}h^{-1}$). Significant relationships between the soil organic carbon and soil biological parameters analyzed were found using Pearson correlation (r).

At 0-15 and 15-30 cm soil depths, Khan and Wani (2017) studied that a significant increase in soil organic carbon pools such as Walkley and Black organic carbon (WBC), total organic carbon (TOC), labile organic carbon pool (LBCP) and microbial biomass carbon (MBC) when farm yard manure and INM involving FYM and NPK were used in comparison to an unfertilized control plot. The application of NPK+ farm yard manure resulted in a large increase in soil organic matter. The author suggests that organic manure, such as FYM, is important for long-term crop productivity and soil quality and should be encouraged in the nutrient management of intensive cropping systems to improve soil fertility and biological characteristics.

Choudhary *et al*., (2018) studied that long-term (6 years) organic incorporation [(N100P16K28 + Moong), (N100P16K28 + GM before rice transplanting) and (N100P16K28 + FYM before rice transplanting)] sequestered 1.0 and 2.5 times more SOC than balanced inorganic (N180P39K63Zn5) and FP (N180P22K0Zn5) treatments. The relative susceptibility of SOC to oxidation is determined by how it is divided into active and passive pools. The lower active to passive ratio (1.63) in FYM-treated plots, as well as the possibility for enhanced soil organic carbon (SOC) sequestration.

Ghosh *et al*., (2018) found that INM practices (chemical fertilizers combined with various manures sources such as farmyard manure (FYM), vermicompost (VC), green manure (GM) and poultry manure (PM) improved soil aggregation when compared to only mineral fertilization (NPK). When compared to other treatments, plots with (50%) NPK+(50%) GM (1.8 t ha^{-1}) fertilizer exhibited substantially greater Walkley-Black carbon (WBC), total soil organic C (TOC), LOC, macroaggregate-associated C concentrations and soil aggregation. LOC was 16 per cent greater in the topsoil than in the subsurface soil in the NPK+FYM treatment. In comparison to solely mineral fertilization and unfertilized control plots, FYM and GM sources with mineral fertilization reduced soil degradation the most. FYM and GM sources were the best among all organic sources. With 50 per cent NPK+50 per cent FYM (6.0 tha^{-1}), the maximum wheat equivalent yield (WEY) was achieved, whereas similar WEY was achieved with the remaining 50 per cent organic sources. According to the relationships, the single value CMI may be used to estimate soil deterioration in sloping agriculture plots.

Ghosh *et al*., (2018) found that in the 0-90 cm soil layer, C accumulation and sequestration in the NPK+FYM treatment were 0.74 and 0.22 Mg C ha^{-1} $year^{-1}$, respectively, with >50 per cent of the deposited C in the deep soil layers (30-90 cm). Despite the fact that NPK+FYM and NPK plots had identical levels of soil macro aggregates in the 0-15 cm layer, NPK+FYM plots had 27 per cent more micro aggregates than NPK alone, resulting in improved aggregate stability. In bulk soils, NPK and NPK+FYM plots showed higher labile: recalcitrant C ratios than control, NP and N plots. Within macro and microaggregates, the NPK+FYM plots exhibited the most recalcitrant C pools. In both soil strata, glomalin was shown to be positively linked with all labile C pools. Furthermore, among bulk soils, mean weight diameter (MWD) was positively connected with aggregate-associated C and glomalin. Overall, NPK+FYM management approach exhibited stronger C accumulation and sequestration in surface and deep soils, as well as better aggregation and a 26 per cent higher CMI than NPK and so should be implemented.

Naresh *et al*., (2018), observed that the fraction of SMBC that is mineralizable C decreases with depth. The abundance of these four OOC fractions was in the sequence CNL (7.04 g kg^{-1}) >CL (2.02 g kg^{-1}) >CVL (1.35 g kg^{-1}) >CLL (1.35 g kg^{-1}) across soil depths and nutrient supply options (0.75 g kg^{-1}). In comparison to conventional tillage, zero tillage enhanced the organic carbon content and carbon store in wheat soils. In soils in the higher layers of depths, zero tillage increased dissolved organic carbon, microbial biomass carbon, light and heavy components of carbon.The carbon levels of the light and heavy fractions were found to be lower in lighter textured soil, but increased as the texture fineness increased. Tillage, cropping sequence and N fertiliser all had a significant impact on soil organic C (SOC). At 0-15, 15-30, 30-45 and 45-60 cm soil depths, the SOC stock ranged from 26.9 to 30.8, 17.7 to 21.2, 15.7 to 23.3 and 7.21 to 9.82 Mg ha^{-1}.For the CK, N, NP, FYM, NP+S and NP+FYM treatments, the topsoil (0–20 cm) exhibited the highest levels of cumulative SOC storage at the 1 m soil depth, accounting for 24 per cent, 23 per cent, 27 per cent, 30 per cent, 31 per cent, and 31 per cent, respectively. The SOC stocks of the NP, FYM, NP+S, and NP+FYM treatments were considerably greater than those of the CK at the 20-40 cm and 40-60 cm soil layers, respectively, by 17 per cent, 21 per cent, 25 per cent and 37 per cent and 5.3 per cent, 8.1 per cent, 7.3 per cent and 11 per cent. Regardless of treatment, the SOC stock declined significantly as the soil profile depth increased.

2.5 EFFECT OF NUTRIENT MANAGEMENT

2.5.1 Effect of Nutrient Management on Growth, Yield and Quality of Soybean

According to Imkongtoshi and Gohain (2009), the application of RDF resulted in the maximum plant height (63 cm) and the use of organic and inorganic nitrogen sources considerably boosted the fresh weight of soybean plants at all stages.

Lone *et al*., (2009), found that application of N 80, P_2O_5 120, and K_2O 30 kg ha^{-1} significantly enhanced plant height, number of nodules $plant^{-1}$, fresh nodule weight, and dry matter accumulation in soybean.Tomar and Khajanji (2009) reported that RDF (20 kg N + 60 kg P_2O_5 +20 kg K_2O ha^{-1}) recorded significantly higher plant height with profuse branching in soybean.

Mohod *et al*., (2010), indicated that the treatment 125 per cent RDF with 25 per cent N substituted through FYM resulted in maximum height $plant^{-1}$, number of compound leaves $plant^{-1}$, leaf area $plant^{-1}$, dry matter accumulation $plant^{-1}$, and number of root nodules $plant^{-1}$, while the treatment 100 per cent RDF with 25 per cent N substituted through FYM resulted in maximum height $plant^{-1}$, number of compound leaves $plant^{-1}$, leaf area $plant^{-1}$, dry matter accumulation $plant^{-1}$ and number of root. Thenua *et al*., (2010), found that the use of 40 kg nitrogen and 40 kg potassium hectare^{-1}year^{-1} resulted in greater soybean growth.

Ramesh *et al*., (2010), results revealed that the maximum soybean seed production (1069 kg ha^{-1}) was obtained with the treatment of 4 t ha^{-1}cowdung manure. According to Thenua *et al*., (2010), among the nitrogen and potassium levels used, 40 kg N and 40 kg K_2O ha^{-1} resulted in greater yield characteristics and grain yield in soybean.

Gajbhiye *et al*., (2011) found that applying 75 per cent nitrogen through RDF + 25 per cent nitrogen through FYM @ 5 t ha^{-1} at Kolhapur resulted in the highest grain yields of soybean (27.7 q ha^{-1}) and wheat (31.3 q ha^{-1}), with the sustainable yield index (SYI) ranging from 0.28 to 0.79 in soybean and 0.26 to 0.84 in wheat, respectively.

On the residual fertility status of soil, Koushal and Singh (2011) reported that in soybean, maximum plant heights of 16.89, 65.78 and 73.37 cm at 90 DAS, the highest pods plant^{-1} (80.40) and test weight (17.02 g) were recorded in application of 50% recommended N applied through urea + 50% recommended N applied through FYM + PSB.

In a research conducted in Ludhiana (Punjab), Saini and Chongtham (2011) discovered that the N50 + N50 FYM treatment produced comparable outcomes in terms of greater yield and yield attributing characters. Waghmare *et al*., (2012) found that using 75 per cent RDF in combination with *Rhizobium*, PSB and FYM @ of 5 t ha^{-1} increased pod yield plant^{-1}, seed yield plant^{-1}, 100 seed weight, seed yield, protein yield, and oil production in soybean.

During *Kharif* 2011, Awasarmal *et al*., (2013) observed that application of 100 per cent RDF+ *Rhizobium*+ PSB+ sulphur @ 25 kg ha^{-1}+vermicompost @ 3 t ha^{-1} resulted in the maximum seed, straw and biological yield in soybean.

Ravi *et al*., (2019) investigated how plant residues affected soybean growth, yield and economics in a rainfed environment in Northern Karnataka and discovered that applying RDF (40:80:25 NPK k ha^{-1} + 12 kg $ZnSO_4$ha^{-1} + 20 kg sulphur ha^{-1}) + plant residues at 3.0 tones ha^{-1} resulted in significantly higher haulm and seed yield (3007 and 2269 kg ha^{-1}, respectively). In contrast, the control treatment had much lower haulm and seed output.

2.5.2 Effect of Nutrient Management on Soil Health

Datt *et al*., (2013), found that the organic treatment FYM 10 t ha^{-1} + N F, phosphate solubilizer and chopped crop residues had the lowest BD and highest water retention capacity, whereas the control had the highest. Except for control, when it declined numerically (1.23 Mg m^{-3}) from its original value (1.24 Mg m^{-3}), the BD grew considerably in all treatments.

Raju *et al*., (2013) conducted a field experiment in Rajendranagar and revealed that during the flowering stage, the enzymes urease (31.54 g of $NH4^{+}$-N released g^{-1}soil h^{-1}), dehydrogenase (154.83 mg of TPF produced g^{-1}soil day^{-1}) and urease (6.97 g of $NH4^{+}$-N released g^{-1}soil h^{-1}) had the highest activity.

Nagar *et al*., (2016), found that organic manure, such as FYM + phosphocompost and pigeon pea stalk + phosphocompost, improved the physical, chemical and biological aspects of soil as compared to RDF application.

Souza *et al*., (2017) investigated the effect of enriched composts on soybean rhizosphere soil enzymatic activity in *Vertosol* at Research Farm, PDKV, Akola (Maharashtra) and found that the enzymatic activity, which included dehydrogenase (41.96 and 46.29 g TPF g^{-1} 24 hr^{-1}), alkaline phosphatase (161.34 and 163.09 g p-nitrophenol g^{-1} 24 hr^{-1}) When 100 per cent P was applied by nitro-phospho-sulpho compost followed by 100 per cent P through phospho-compost, flowering and pod development were greatest compared to all other treatments.

Aher *et al*., (2018) reveled that the organic treatment had the maximum number of microbial population (bacteria, fungus and actinomycetes), soil enzyme activities and soil microbial biomass carbon.

2.5.3 Effect of Nutrient Management on Carbon Dynamics

Khan *et al*., (2017) found that under FYM and integrated nutrient management using FYM and NPK in comparison to an unfertilized control plot in soil depths of 0-15 and 15-30 cm, significant increases in soil fertility in terms of alkaline $KMnO_4$-N, Olsen-P, NH_4Ac-K and $CaCl_2$-S, as well as SOC pools such as total organic carbon (TOC), Walkley and Black organic carbon (WBC), labile organic carbon (LBC) and microbial biomass carbon (MBC) were maintained. The application of NPK+ FYM increased soil organic matter and accessible water holding capacity while decreasing soil bulk density, resulting in a favorable soil environment for improved growth. The microbial community (bacteria, fungi and actinomycetes) was highly sensitive to the application of organic manure. Because the nutrient index, microbial index and crop index of soils increased as a result of the long-term application of organic manures in the rice-brown mustard cropping system, the index value rose. In the rice–brown mustard cropping system, however, merely using chemical fertilizers resulted in a low soil microbial index and a low crop index.

During *Kharif* 1999 in Junagadh, Gujarat, Karad *et al*., (2018) performed an experiment to examine the effect of integrated nutrient management on crop productivity and passive pools of soil organic carbon (SOC) under a *Haplustepts* groundnut-wheat cropping sequence. The application of 50 per cent NPK + FYM @ 10 t ha^{-1} to groundnut and 100 per cent NPK to wheat improved crop production, humic acid, fulvic acid and humin substantially. The passive pools of soil organic carbon were significantly affected by combining FYM with chemical fertilizers or using FYM alone. Crop yield was favorably and extremely substantially correlated between types.

According to Naresh *et al*., (2018), balanced fertilization and the application of chemical fertilizers and manure in combination enhanced SOC in all plots except the unfertilized control. Particulate organic carbon, carbon mineralization and microbial biomass carbon increased similarly in balanced fertilization (NPK) and integrated fertilization (NPK+FYM), but particulate organic nitrogen and microbial biomass nitrogen increased more in integrated fertilization (NPK+FYM) than in control treatment. Over the control, soil organic C and carbon stabilization stock increased in the fertilizer and manure treatments. The soil carbon in the control plot was 15.1 Mg ha^{-1} at the 0-15 cm depth, but increased to 19.5 Mg ha^{-1} in NPK+FYM. The SOC stock in the 0-15 cm depth rose under all fertilization treatments in the order: NPK+FYM> N+FYM> NPK> FYM> N> control, as compared to the original (13.7 Mg ha^{-1}). The rate of increase in SOC (carbon sequestration) owing to various land uses alone ranged from 57 to 89 kg $ha^{-1}yr^{-1}$, whereas the rate of increase owing to soil management *i.e.* FYM addition, ranged from 61 to 138 kg $ha^{-1}yr^{-1}$ with the greatest rate in NPK+FYM.

3. MATERIALS AND METHODS

A field trial entitled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** was performed for two consecutive seasons during the *Kharif* of 2019-20 and 2020-21. This chapter covers the specifics of the experimental methodology, materials employed, and treatment evaluation criteria employed throughout the experimentation.

3.1 EXPERIMENTAL SITE

The research experiment was carried out at the Agricultural Research Station, Ummedganj-Kota during both the years. The location was 25^{o}.133540' N latitude, 75^{o}.939756' E longitude and 258 m MSL. This region fall under agro-climatic zone V (Humid South Eastern Plain) of Rajasthan.

3.2 CLIMATE AND WEATHER CONDITIONS

The area is having local steppe climate with warm summers and heavy humidity, especially from mid-June to mid-September. The region's mean annual rainfall is 580-630 mm, with the S-W monsoon providing the majority of it from mid July to September. In the summer, the maximum temperature reaches as high as 44.0°C. The warmest months are May and June. Winters are usually dry with minimum temperature as low as 1.0°C in November to mid-January.

The meteorological observations documented at Meteorological Observatory, Agricultural Research Station, Kota through crop periods are presented in Table 3.1a and 3.1b and Fig. 3.1a and.3.1b. The conforming temperature fluctuations through year (2019-20 and 2020-21) of experimentation were 26.5 to 36.6 °C and 21.90 to 37.50 °C, respectively. Weekly mean max. and min. RH between 53.6 to 90.1 per cent and 22.4 to 82.9 per cent, respectively during 2019-20 and the corresponding values in the year 2020-21 were 62.6 to 92.1 per cent and 39.71 to 88.57 per cent. Total rainfall received during the crop growing period in 2019-20 and 2020-21 was 1413.1 mm and 547 mm, respectively.

3.3 PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF EXPERIMENTAL FIELD

To determine mechanical, physico-chemical and biological properties of the investigational field, sample of the soil (0-15 cm) depth from different spots of the field were drawn and a illustrative compound sample was prepared by mixing them, which was exposed to above mentioned analysis through standard procedures.

The experimental field was clay loam, neutral alkaline in reaction, low in available N and medium in available phosphorus and high in accessible potassium, according to the results of soil analysis (Table 3.2).

Table 3.2: Physico-chemical and biological properties of composite soil sample

Properties	2019-20	2020-21
A. Mechanical analysis		
Sand (%)	38.55	38.47
Silt (%)	26.68	26.46
Clay (%)	34.37	34.57
Textural class	Clay loam	Clay loam
B. Physical analysis		
Bulk density (Mg m^{-3})	1.35	1.31
Particle density (Mg m^{-3})	2.72	2.71
Porosity (%)	50.53	50.60
Water holding capacity (%)	40.42	42.20
C. Chemical analysis		
pH (1:2, soil : water)	7.75	7.71
EC (dSm^{-1}) (1:2, soil: water)	0.52	0.51
Organic carbon (%)	0.56	0.62
Available nitrogen (kg ha^{1})	253	255
Available phosphorus (kg ha^{-1})	22.00	24.67
Available potassium (kg ha^{-1})	342.56	345.12
Available Zn (mg kg^{-1})	0.63	0.65
Available Fe (mg kg^{-1})	3.72	3.75
Available Mn (mg kg^{-1})	3.51	3.55
Available Cu (mg kg^{-1})	2.38	2.33
D. Biological analysis		
Dehydrogenase activity (µgTPFg^{-1}soil)	16.81	17.95
Alkaline Phosphatase activity (µg g^{-1} h^{-1})	19.01	21.11

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

In the experimental field where the current study was conducted, the soybean – wheat crop sequence was followed for the last two years (Table 3.3).

Table 3.3: Previous history of experimental field

Year	*Kharif*	*Rabi*
2017-2018	Soybean	Wheat
2018-2019	Soybean	Wheat
2019-2020	Soybean*	-
2020-2021	Soybean*	-

* Experimental crop

3.5 EXPERIMENTAL DETAILS

According to Table 3.4, the experiment included sixteen treatments combinations with crop residue and nutrient management. The experiment was set up in a factorial RBD with 3 replications. Figure 3.2 depicts the layout plan and the following information is provided below:

Table 3.4: Details of treatments with their symbols

I.	Crop	Soybean
II.	Variety	RKS-45
III.	Initial year & Season	2019-20 &*Kharif*
IV.	Seed Rate	80 kg ha^{-1}
V.	Experimental design	Factorial RBD
VI.	Treatments	16
VII.	Replications	3
VIII.	Total number of plots	16 × 3 = 48
IX.	Plot size	(a) Gross size 5.0 × 3.6 m (b) Net size 4.0 m × 3.0 m
X.	Crop geometry	Soybean: (a) Row to row distance – 30 cm (b) Plant to plant distance – 10 cm
XI.	Location	Agricultural Research Station, Ummedganj-Kota

(A) Crop residue management

CR_1: Crop residue incorporation without irrigation

CR_2: Crop residue incorporation with irrigation

CR_3: Crop residue incorporation with irrigation and application of urea@ 25 kg ha^{-1}

CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ cellulolytic microbes @ 2.0 kg ha^{-1}

(B) Nutrient management

F_1: Control

F_2: 75% RDF

F_3: 100% RDF (20:40:40 NPK kg ha^{-1})

F_4:125% RDF

3.6 TREATMENT APPLICATION

As shown in Figure 3.2, the treatments were applied to soybean.

(a) Crop residue

The application of wheat straw as per the treatments applied each year. Nutrient composition of wheat straw applied in the experiment is given in Table 3.5.

Table 3.5: Nutrient composition of the wheat crop residue used in the experiment

Crop residue	N (%)	P_2O_5 (%)	K_2O (%)
Wheat Straw	0.44	0.14	0.49

(b) Fertilizers

The application of 20 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} are recommended dose of fertilizer for soybean.

3.7 VARIETAL CHARACTERS

Variety RKS-45 is having good germination, resistance to Alternaria leaf blight and tolerant to stem fly. Pods are resistance to shattering, flowers of purple colour, leaves dark green, seed yellow and round with black haulm containing 18-21 per cent oil and 40-41 per cent protein. It matures in 70-80 days, suitable for early sowing under rainfed and irrigated conditions.

3.8 DETAILS OF CROP RAISING

The calendar of various pre sowing and post sowing processes carried out during the crop season is given in Table 3.6 and details of crop raising are described as under:

3.8.1 Field Preparation

After harvesting the *Rabi* season crop, the trial field was prepared by cultivating with a tractor-drawn disc plough, cross harrowing and planking to bring the soil in to excellent tilth avoid disrupting the four contour lines after pre-sowing irrigation.

3.8.2 Seed and Sowing

A seed rate of 80 kg ha^{-1} was used. The seed were sown in opened furrows manually at a depth of 3-4 cm in rows spaced at 30 cm and plant x plant distance 10 cm apart. Fertilizers were placed beneath the seed, after placing the seed in furrows it was covered with soil for uniform germination and to protect from bird damage.

3.8.3 Treatment Application

3.8.3.1 Nitrogen

Urea was used to provide nitrogen to soybean according to the treatment plan. The first half of the nitrogen dose was supplied as a basal and the remaining half was delivered as a top dressing at the first and second irrigations.

3.8.3.2 Phosphors

Phosphorus was supplied to the furrows by SSP according to the sowing technique as a basal does.

3.8.3.3 Potassium

Potassium was applied as basal does in furrows using MOP as directed at the time of sowing.

3.8.3.4 Crop Residue

Crop residue was applied @ 5 t ha^{-1} through wheat straw in the soil as per treatment before one month of first ploughing.

3.8.4 Irrigation

During the cropping time, enough and evenly distributed rainfall was obtained, allowing the field to stay wet. During a dry time irrigations were applied.

3.8.5 Thinning, Hoeing and Weeding

Hoeing cum weeding was done for target population of plant was kept by thinning the crop at 25 days after sowing, keeping plant to plant spacing of 10 cm excess plants were thinned away in order to decrease plant competition. At 25 and 45 days after sowing, two hoeing and weeding sessions were done.

3.8.6 Harvesting

The crop was harvested when it had reached full maturity. Plants from the border region were picked and removed from each plot separately. The net area plot was harvested and the produce was tied and marked in bundles. The bundles were weighed after adequate drying to determine the biological yield by treatment.

3.8.7 Threshing and Winnowing

A power thresher was used to thresh the grain. To record seed production in each plot, the crop was winnowed, cleaned, sundried and weighed individually.

Table 3.6: Schedule of field operations during crop growth period

S. No.	Operations	Date	
		2019-20	2020-21
1.	Field preparation	28.06.2019	22.06.2020
2.	Layout, bunding and application of organic manures as per treatment	04.07.2019	02.07.2020
3.	Fertilizer application and sowing	15.07.2019	10.07.2020
4.	Irrigation		
	(a) Post sowing	-	-
	(b) 1st irrigation	-	16.09.2020
	(c) 2nd irrigation	27.09.2019	-
5.	Weeding and hoeing		
6.	Harvesting	25.10.2019	23.10.2020
7.	Threshing and winnowing	30.10.2019	29.10.2020

3.9 TREATMENT EVALUATION

The treatment effects were evaluated in terms of following parameters of soil and the crop.

3.9.1 Growth Parameters

3.9.1.1 Plant height at flowering stage (cm)

The plant height at flowering stage was measured using a scale from each plot five randomly selected plants.

3.9.1.2 Chlorophyll content (mg g^{-1})

The chorophyll concentration at flowering was determined using Arnon's (1949) technique, which involved obtaining 50 mg of fresh leaf material. The samples were homogenised in 80% acetone, centrifuged at 2000 rpm for 10 minutes and diluted to a final amount of 10 ml. Spectronic-20 was used to detect the absorbance of a clear supernatant solution at a wavelength of 652 nm.

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{\text{A(652)} \times 29 \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{Weight of samples}}$$

Where,

$\alpha$is the path length = 1 cm

A= Absorbance at desired wavelength

3.9.1.3 Number of total and effective root nodules plant^{-1}

The plants were carefully uprooted from the plot. The roots were washed and cleaned properly with water. The nodules were separated from the roots of each plant. They were counted and average numbers of the nodules plant^{-1} were recorded.

3.9.1.4 Leghemoglobin content (mg g^{-1})

Appleby *et al.*, (1986) and Bergerson (1986) assessed the leghaemoglobin concentration of root nodules as hemochrome (1982). Fresh nodules (100 mg) were macerated in 5m1 of 0.1 M potassium phosphate buffer (pH 7.4), filtered through a chase cloth and centrifuged for 30 minutes at 10,000 rpm. The alkaline pyridine reagent (4.2 M pyridine in 0.2 M NaOH) was added in an equal amount and stirred thoroughly. To half of the solution, add a few sodium dithionate crystals to lower the hemochrome, mix carefully to minimize modification and measure the colour intensity at 556 nm using a reagent blank as a control. A few crystals of potassium hexacynoferrate were added to the other half to oxidize the hemochrome and the intensity was measured at 539 nm. Leghaemoglobin concentration was estimated as follows:

$$\text{Lb (nm)} = \frac{\text{A559 } - \text{A539} \times 2\text{D}}{23.4}$$

D = initial dilution

3.9.1.5Fresh and dry weight of nodules (mg plant^{-1})

Each plot's effective root nodules were weighed using an electronic balance and the average was calculated and reported as the fresh weight of effective root nodules plant^{-1}. Total root nodules from the five plants in each plot were oven dried at 70° C until a consistent weight was achieved and then an average was calculated.

3.9.2 Yield Parameter

3.9.2.1 Pods per plant

The total number of pods on the five plants that had already been chosen was tallied and the mean number of pods plant^{-1}was computed.

3.9.2.2 Seed per pod

The number of seeds pod^{-1} was counted and a mean value for the number of seeds pod^{-1}was obtained after ten pods were randomly picked from each plot from previously selected plants.

3.9.2.3 Test weight (g)

Thousand seeds were counted and weighed using an electric balance from a seed sample collected from each plot's seed production. The weight was kept as the treatment's test weight.

3.9.2.4 Grain yield

Soybean plants were collected from each net plot and placed in gunny bags. These were threshed, winnowed and cleaned after sun drying. The seed weight of each plot was recorded after sun drying for 2-3 days and the final yield was expressed in kg ha^{-1}.

The cumulative biomass harvested from each net plot was threshed and the resulting winnowed, cleaned and dried soybean seed were weighed in kilograms plot^{-1} and then converted to kilograms ha^{-1}.

3.9.2.5 Haulm yield

Soybean haulm yield was computed by deducting seed yield from each treatment's respective biological yield and expressed in kg ha^{-1}.

3.9.2.6 Biological yield

The harvested bundles of each net plot were weighed for biological yield and converted to kg ha^{-1} after complete sun drying.

3.9.2.7 Harvest Index (%)

It's the relationship of economic yield (seed yield) to biological yield, calculated using a formula. This is presented in per cent.

$$\text{Harvest index }(\%) = \frac{\text{Seed yield }\left(\text{kg ha}^{-1}\right)}{\text{Biological yield }\left(\text{kg ha}^{-1}\right)} \times 100$$

3.9.3 QUALITY PARAMETERS

3.9.3.1 Protein Content

Protein content was calculated by multiplying the per cent nitrogen in a defatted seed sample by a factor of 6.25 (AOAC, 1975).

3.9.4 Chemical Analysis of Plant Sample

At the time of threshing, samples of seed and haulm of soybean were obtained for nitrogen, phosphorus and potassium measurement. For evaluating nutritional content in haulm, each dried haulm sample was crushed to a fine powder in a willey mill. Each sample was crushed in a mortar and pestle to determine the nutritional content.

For nitrogen analysis, the plant material was digested with H_2SO_4 and H_2O_2, and for P, K and micronutrient analysis, it was digested using a diacid combination (nitric acid and perchloric acid; 10:4). Standard techniques of analysis were used to examine the plant extracts for nitrogen, phosphorous, potassium and micronutrients, as shown in Table 3.7.

Table 3.7: Methods followed for plant analysis

Determination	Method used	Reference
1. Nitrogen Digestion with H_2SO_4-H_2O_2	Nessler's reagent, spectrophotometrically	Snell and Snell (1959)
2. Phosphorus Digestion with di-acid HNO_3 : $HClO_4$ (10 : 4)	Vanadomolybdate phosphoric acid yellow colour method	Jackson (1973)
3. Potassium	Flame photometer method	Jackson (1973)
4. Iron, Zinc, Copper and Manganese	Atomic absorption spectrophotometrically	Lindsay and Norvell (1978)

3.9.4.1 Nutrient uptake

The concentration of macronutrients was represented as a per centage, whereas their absorption was measured in kilograms hectare^{-1}year^{-1}. Micronutrient content was measured in mg kg^{-1} or ppm, whereas absorption was measured in g ha^{-1}.

The following formula was used to calculate nutrient uptake of N, P, K and micro nutrients using data on N, P, K and micronutrient content in seed and haulm:

For macronutrients

$$\text{Nutrient uptake}\left(\text{kg ha}^{-1}\right)=\frac{\text{Nutrient content }(\%)\times\text{Yield}\left(\text{kg ha}^{-1}\right)}{100}$$

For micronutrients

$$\text{Nutrient uptake}\left(\text{g ha}^{-1}\right)=\frac{\text{Nutrient content}\left(\text{mg kg}^{-1}\right)\times\text{Yield}\left(\text{kg ha}^{-1}\right)}{1000}$$

3.9.4.2 Total uptake

The sum of nutrient uptake by grain and haulm was used to calculate total N, P, K, S and micronutrients uptake at harvest.

3.9.5 Chemical Analysis of Soil Parameters

At soybean harvest, undisturbed soil samples from each plot were taken using an auger from 0-15 cm. These soil samples were treated and kept in plastic bags until they were subjected to different standard techniques of analysis were used to evaluate pH, EC, organic carbon, accessible N, P, K, micro nutrients, microbial biomass carbon, dehydrogenase activity, phosphate activity and urease activity, as shown in Table 3.8.

Microbial Biomass Carbon (MBC)

The microbial biomass carbon (MBC) in soil was measured using a fumigation extraction approach (Jenkinson and Powlson, 1976). 10.0 g of moist soil was fumigated with chloroform ($CHCl_3$) and extracted with 0.5M K_2SO_4 in a vacuum desiccator (soil: solution of 1:2.5). A duplicate soil sample (non-fumigated) was extracted in the same way with 0.5M K_2SO_4. Both non-fumigated and fumigated soil extracts were subjected to wet oxidation. Under refluxing conditions, 10 ml of the extract was digested for 30 minutes at 100 °C with 2 ml of 0.2 N $K_2Cr_2O_7$, 10 ml of conc. 5 ml H_3PO_4 and 5 ml H_2SO_4. Samples were chilled and titrated with a solution of 0.005N ferrous ammonium sulphate using diphenylamine as an indicator. The MBC was calculated by subtracting the quantity of organic carbon in fumigated soil from the amount of organic carbon in non-fumigated soil, and it was expressed on an oven dry weight basis. The following formula was used to calculate the quantity of MBC in soil:

$$\text{Microbial biomass carbon} = (OC_F - OC_{UF}) / K_{EC}$$

Where OC_F and OC_{UF} represent the organic carbon extracted from fumigated and non-fumigated soil, respectively (on an oven dry basis), and K_{EC} represents the extraction efficiency. For calculations, a value of 0.25 is utilized as a general K_{EC} value for microbial extraction efficiency.

Dissolved Organic Carbon (DOC)

Jones and Willett's technique was used to calculate dissolved organic carbon (DOC) (2006). In a nutshell, 5g of dry soil was extracted in a centrifuge tube with 25 ml ultra-pure water by shaking the mixture for 1 hour on a reciprocating shaker (200 rpm) and then centrifuged for 30 minutes at 4^{o}C at 13,000 rpm. A 0.45 m glass fibre filter was used to filter the supernatant. The $K_2Cr_2O_7$ titration technique was used to quantify the C concentration in the supernatant (Walkley and Black, 1934).

Particulate Organic Matter Carbon (POM−C)

The amount of particulate organic matter (POM) extracted from the soil was assessed using the Camberdella and Elliot technique (1992). On a shaker, a 10 g portion of 2 mm sieved air-dried soil sample was agitated for 15 hours with a 0.5 per cent sodium hexametaphosphate solution. The soil suspension was then pushed through a 0.053 mm sieve with a gentle water jet from the sieve's top. By washing with a jet of water, the solid part remained on the sieve was transferred to little pre-weighed plastic boats. It contains sand particles as well as particulate organic materials. The plastic boats were dried in a forced air oven at 50°C for 72 hours before their weights were recorded. The solid components in the boats were reduced to a fine powder with a pestle and mortar. Total organic carbon content in POM was assessed using a dry combustion technique in a CHNS analyzer after the materials were processed through a 0.2 mm filter (Euro Vector make, EuroEA3000 model).

Carbon mineralization (C_{min})

Carbon dioxide (CO_2) flow was measured as a measure of C mineralization in an incubation experiment using Parr and Smith's technique (1969). Twenty-six gram of fresh dry soil was taken and wetted to respective field capacity of soil, placed in a 50 ml beaker kept in a 500 ml capacity respiration jar with a vial containing. A 50 ml beaker was kept in a 500 ml capacity respiration jar with a vial containing 4 ml of 0.5M NaOH to trap the evolved CO_2 and the jar was closed with the help of a lid. The respiration jars were incubated at 37 ^{o}C for two months in a BOD incubator. The excess of NaOH was back-titrated with standard HCl to estimate C mineralization in soil (Zibilske, 1994). Alkali traps were replaced twice in the first two weeks, then once from the third week forward for the remainder of the study. During the sample day, the NaOH trap was removed from the jar and titrated with standard 0.5N HCl using phenolphthalein indicator.

Oxidizable Soil Organic Carbon and Its Fractions

The Walkley and Black (1934) approach, as modified by Chan et al., was used to estimate oxidizable organic carbon (OOC) and its various pools in the soil (2001). The whole SOC was separated into four pools, each with a lower oxidizability (Chan *et al*., 2001).

Pool1 (very labile OC; P_1): Organic C oxidizable with 12.0 mol L^{-1} H_2SO_4

Pool2 (labile OC; P_2):	Difference in OC oxidizable with 18.0 mol L^{-1} and that with 12.0 mol L^{-1} of H_2SO_4
Pool3 (less labile OC; P_3):	Difference in OC oxidizable with 24.0 mol L^{-1} and that with 18.0 mol L^{-1} of H_2SO_4 (24.0 mol L^{-1} H_2SO_4 is equivalent to the standard Walkley and Black method)
Pool4 (non-labile OC; P_4):	Residual organic C after oxidation with 24.0 mol L^{-1} H_2SO_4 when compared with TOC

Pools 1 and 2 together constitute the labile pool, while Pools 3 and 4 constitute together the recalcitrant pool.

Water Soluble Carbon

The amount of water soluble carbon (WSC) in bulk soil was calculated using the approach of McGill *et al.* (1986), and then Brar *et al.* (2013) using the following relationship:

$$\%WSC = (Blank – Sample)* 0.01*0.003* (100/10)$$

Where "Blank" refers to the number of milliliters of 0.01 N ferrous ammonium sulphate (FAS) consumed in the blank, and "Sample" refers to the number of milliliters of 0.01 N FAS consumed in the soil sample.

Total Carbohydrate Extraction

The total carbohydrate content of microaggregate and macroaggregate samples was determined using the Dubois *et al.*, phenol sulphuric acid technique (1956). A 0.5 g subsample of soil aggregates sections was treated for 2 hours with 4.0 ml of 12M H_2SO_4. 1 mL phenol solution and 5 mL concentrated H_2SO_4 were added and the solution. The tubes were then immersed in a water bath for 25 minutes at temperatures ranging from 25 to 300 degrees Celsius. In a spectrophotometer, the absorbance was measured at 490 nm. To evaluate carbohydrate content, a standard curve was created by diluting a stock glucose solution.

Table 3.8: Methods followed for soil analysis

S. No.	Properties	Procedure	Reference
1.	pH (1:2 soil water suspension)	Potentiometeric method using pH meter	Richards (1954)
2.	EC (1:2 soil water suspension)	Using solubridge method(Conductivity meter)	Richards (1954)
3.	Organic carbon (%)	Rapid titration method	Walkley and Black (1934)
4.	Available N	By alkaline $KMnO_4$ method	Subbiah and Asija (1956)
5.	Available P	Olsen's P, 0.5*M* $NaHCO_3$ method, pH 8.5	Olsen *et al.* (1954)
6.	Available K	Neutral normal ammonium acetate extraction and Flame photometry	Richards (1954)
7.	Available Zn, Fe, Cu & Mn (mg kg^{-1})	Extraction by 0.005*M* DTPA + 0.001*M* $CaCl_2$ + 0.1*M* triethanolamine at pH 7.3	Lindsay and Norvell (1978)
8.	Bulk Density	Core sampler method	Piper (1950)
9.	Porosity	Pycnometer	Bird *et al.*(1960)
11.	Water Holding Capacity	-	Veihmeyer and Hendrickson (1931)
12.	Dehydrogenase activity	TTC substrate method	Casida *et al.* (1964)
13.	Alkaline phosphatase avtivity	P-nitrophenol estimation method	Tabatabai and Bremner (1969)
14.	Microbial Population	Standard serial dilution and plate count method	Vance *et al.* (1987)

3.9.6 Statistical Analysis

The experimental data were statistically evaluated for analysis of variance using the methods outlined by Panse and Sukhatme for the experiment (1985). The 'F' test was used to interpret the data. The critical difference (CD) was calculated at a significance level of 5% for the comparison of means.

Summary tables, as well as SEm and CD were created and presented in the text of the chapter headed "Experimental Results" and their analysis of variance for various parameters is provided in the "Appendices" section at the conclusion. The approach proposed by Panse and Sukhatme was used to do a two-year pooled analysis of data (1985).

3.9.7 Economics of Treatments

The economics of treatment were calculated in terms of net returns (` ha^{-1}) and the Benefit Cost (BC) ratio in order to assess the economic viability of various treatments.

3.9.7.1 Net return (` ha^{-1})

To determine the profitability of various treatments, economists calculated net return (` $ha^{-1)}$ by deducting the cost of treatment and cultivation from the gross income gained. The cost of cultivation and net profit were computed using current product prices and input lobour rates.

3.9.7.2 Benefit-cost ratio

B:C was determined by the ratio of gross return (GR) with cost of cultivation (COC) for individual treatment in order to assess economic viability of experiment.

4. EXPERIMENTAL RESULTS

The results of a field experiment titled "**Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area**" was conducted at Agricultural Research Station, Ummedganj-Kota (Rajasthan) for two consecutive years, 2019 and 2020 are summarised under the following headings:

4.1 EFFECT OF CROP RESIDUE & NUTRIENT MANAGEMENT ON PLANT STUDIES OF SOYBEAN

4.1 Growth Parameters at Flowering

4.1.1 Plant height

Crop Residue management

The maximum plant height in the year 2019, 2020 and pooled basis was 44.92, 45.07 and 45.0 cm respectively recorded with the application of treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly superior over rest of the treatments *viz*., CR_1: Crop residue incorporation without irrigation, CR_2: Crop residue incorporation with irrigation and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during both the years of experimentation as well as on pooled basis. However, the minimum plant height 36.97 cm was recorded with CR_1: Crop residue incorporation without irrigation on pooled basis. The per cent increase in plant height with the application of crop residue with and without irrigation and urea treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation gave 21.69, 11.58 and 4.12 per cent tall plants respectively, on pooled basis as compared to CR_1: Crop residue incorporation without irrigation (Table 4.1).

Nutrient management

An examination of data (Table 4.1) indicates that the maximum plant height 46.35 and 46.79 cm during both the years of experimentation 2019 and 2020 respectively, was recorded with F_4:125% RDF, which was statistically at par with the treatment F_3:100% RDF in both the years of experimentation. On pooled basis the tallest plant (46.57 cm) was observed with the application of F_4:125% RDF, which was significantly superior over lower levels of nutrient management. The per cent increase in plant height with application of treatment F_4:125% RDF over F_1: Control was 40.29 per cent on pooled basis.

4.1.2 Chlorophyll Content

Crop residue management

Data presented in Table 4.1 clearly depicts that in the year 2019 and 2020 the maximum chlorophyll content of fresh leaves at flowering was 4.10 and 4.19 mg g^{-1} of fresh leave weight respectively, with treatment application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3.85 and 3.73 mg g^{-1} of fresh leave weight) and CR_2: Crop residue incorporation with irrigation (3.95 and 3.85 mg g^{-1} of fresh leave weight), whereas differing significantly with CR_1: Crop residue incorporation without irrigation (3.23 and 3.31 mg g^{-1} of fresh leave weight) respectively during 2019 and 2020. On pooled basis the maximum chlorophyll content of fresh leave at flowering was 4.14 mg g^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over rest of the levels of crop residue management. However, the minimum 3.27 mg g^{-1} was obtained with CR_1: Crop residue incorporation without irrigation.

Nutrient management

The scrutiny of data Table 4.1 indicates that in the year 2019 levels of nutrient management failed to show any significant effect on chlorophyll content of fresh leaves at flowering stage. In the 2020 the maximum chlorophyll content of fresh leaves at flowering was 4.13 mg g^{-1} of fresh leave weight with treatment application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (4.07 mg g^{-1} of fresh leave weight) and F_2:75% RDF (3.65 mg g^{-1} of fresh leave weight), whereas differing significantly with F_1: Control (3.44 mg g^{-1} of fresh leave weight). On pooled basis the maximum chlorophyll content of fresh leaves at flowering was 4.08 mg g^{-1} of fresh leave weight with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF.

4.1.3 Total Nodules

Crop residue management

Data (Table 4.2) depicts that the maximum number of total nodules 62.85, 64.41 and 63.63plant^{-1} with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (59.74, 61.13 and 6.44 total nodules plant^{-1}) respectively, during both the years of experimentation *viz*., 2019, 2020 and on pooled basis. However, the minimum was recorded with the application of CR_1: Crop residue incorporation without irrigation. On pooled basis the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} had increased the total number of nodules by 11.79 per cent with compare to CR_1: Crop residue incorporation without irrigation.

Nutrient management

An examination of data Table 4.2 clearly shows that the maximum number of total nodules plant^{-1} was 63.63 was recorded with treatment F_4:125% RDF, which was not differing significantly with F_3:100% RDF in the year of 2019. The total nodules in year 2020 was also recorded highest in treatment F_4:125% RDF (63.43) which was statistically at par with treatment F_3:100% RDF (62.31) and F_2:75% RDF (59.90), but differing significantly with F_1: Control (56.94). On pooled basis the maximum total number of nodules plant^{-1} was recorded with F_4:125% RDF (63.53), which was statistically at par with the F_3:100% RDF(62.33) but daggering significantly with F_2:75% RDF (59.01) and F_1: Control (54.75), which was 16.03 per cent lower than the F_4:125% RDF on pooled basis.

4.1.4 Effective Nodules

Crop residue management

An analysis of data (Table 4.2) clearly indicates that the maximum number of effective nodules 25.08, 25.54 and 25.31 was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} during both the years of experimentation as well as on pooled basis, respectively but was not differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (23.90 and 24.45) in case of 2019 and 2020 year of experimentation respectively, whereas it was statistically superior over rest of treatment on pooled basis. The lowest effective root nodules were recorded with CR_1: Crop residue incorporation without irrigation (23.27) on pooled basis.

Nutrient management

Data presented in Table 4.2 clearly specifies that the maximum number of effective nodules 24.62, 25.16 and 24.89 was recorded with F_4:125% RDF during both the years of experimentation as well as on pooled basis, respectively but was not differing significantly with F_3:100% RDF (24.62 and 25.05) and F_2:75% RDF (23.53 and 24.08) in case of 2019 and 2020 year of experimentation respectively, whereas it was statistically at par with only F_3:100% RDF(24.84) treatment on pooled basis. The lowest effective root nodules were recorded with F_1: Control (22.90) on pooled basis, which was 8.68 per cent lower than the F_4:125% RDF.

4.1.5 Leghemoglobin Content

Crop residue management

Root nodules were analysed in laboratory and results presented in Table 4.3 revealed that the significantly maximum concentration of leghemoglobin 2.31, 2.37 and 2.34 mg g^{-1} during both the years of experimentation an on pooled basis was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, respectively followed by CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (2.22, 2.26 and 2.4 mg g^{-1}), CR_2: Crop residue incorporation with irrigation (2.17, 2.22 and 2.19 mg g^{-1}) and CR_1: Crop residue incorporation without irrigation (2.13, 2.18 and 2.16 mg g^{-1}), which was recorded lowest during both the years of experimentation 2019, 2020 and on pooled basis. On pooled basis, the per cent increase in leghemoglobin content with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} was 8.52 per cent as compared to CR_1: Crop residue incorporation without irrigation (Table 4.3).

Nutrient management

Data shows that statically highest leghemoglobin content of nodules was recorded with the application of F_4:125% RDF (2.28 mg g^{-1}), which was not differing significantly with treatment F_3:100% RDF, followed by F_2:75% RDF (2.16 mg g^{-1}) on pooled basis. During both the years of research the maximum leghemoglobin content was obtained with F_4:125% RDF (2.26 and 2.31 mg g^{-1} respectively), which was statistically at par with the treatment F_3:100% RDF and F_2:75% RDF and the lowest was recorded under F_1: Control. Further analysis of data shows that on pooled basis with the increasing fertility levels the leghemoglobin content was increased from F_1: Control to F_4:125% RDF by 5.95 per cent (Table 4.3).

4.1.6 Fresh Weight of Nodules

Crop residue management

The mean comparison of two years data shows a significant difference in fresh weight of nodules plant^{-1}. Data shows that the significantly higher nodules' fresh weight 237.53, 242.73 and 240.13 mg plant^{-1}during both the years 2019, 2020 and pooled basis respectively, was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over rest of the treatments. However, the lowest fresh weight of nodules was recorded with CR_1: Crop residue incorporation without irrigation (218.88, 223.67 and 221.27 mg, respectively) (Table 4.3).

Nutrient management

Increasing levels of fertilizers significantly enhanced fresh nodule weight of soybean crop (Table 4.3). The maximum fresh weight of nodules plant^{-1} was obtained with F_4:125% RDF (231.81 and 236.88 mg plant^{-1}) which was statistically at par with the F_3:100% RDF (231.11 and 236.17 mg plant^{-1}) and F_2:75% RDF (224.71 and 229.63mg plant^{-1}) during both the years *viz*., 2019 and 2020 respectively. However, on pooled basis the maximum fresh weight of nodules was also recorded higher with F_4:125% RDF (234.34 mg plant^{-1}), which was statistically at par with the application of F_3:100% RDF (233.64 mg plant^{-1}) and differing significantly with F_2:75 % RDF (227.17 mg plant^{-1}) and F_1: Control (221.18 mg plant^{-1}). However, the lowest fresh weight of nodule was recorded with F_1: Control (221.18 mg plant^{-1}), which was 5.95 and 5.63 per cent less than the F_4:125% RDF (234.34 mg plant^{-1}) and F_3:100% RDF (233.64 mg plant^{-1}) respectively, on pooled basis.

4.1.7 Dry Weight of Nodules (mg)

Crop residue management

An analysis of two years data displays a noteworthy difference in dry weight of nodules plant^{-1}. Data shows that the significantly higher nodules' dry weight 71.07, 72.82 and 71.95 mg plant^{-1} during both the years 2019, 2020 and pooled basis respectively, was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over rest of the treatments. However, the lowest dry weight of nodules was recorded with CR_1: Crop residue incorporation without irrigation (65.49, 67.10 and 66.29 mg respectively) (Table 4.3).

Nutrient management

Increasing levels of fertilizers significantly enhanced fresh nodule weight of soybean crop. The maximum dry weight of nodules plant^{-1} was obtained with F_4:125% RDF (69.36 and 71.06 mg plant^{-1}) which was statistically at par with the F_3:100% RDF (69.15 and 70.85mg plant^{-1}) and F_2:75% RDF (67.24 and 68.89 mg plant^{-1}) during both the years *viz*., 2019 and 2020, respectively. However, on pooled basis the maximum dry weight of nodules was also recorded higher with F_4:125% RDF(70.21 mg plant^{-1}), which was statistically at par with the application of F_3:100% RDF (70.0 mg plant^{-1}) and differing significantly with F_2:75% RDF (68.06 mg plant^{-1}) and F_1: Control (66.27 mg plant^{-1}). However, the lowest fresh weight of nodule was recorded with F_1: Control (66.27 mg plant^{-1}) on pooled basis (Table 4.3).

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Pods Plant^{-1}

Crop residue management

Significantly higher pods plant^{-1} 73.77, 73.92 and 73.85 during 2019, 2020 and pooled basis, was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (66.88, 67.04 and 66.96), CR_2: Crop residue incorporation with irrigation (66.66, 66.81 and 66.73) and CR_1: Crop residue incorporation without irrigation (64.44, 64.65 and 64.54) respectively. The per cent increase in pods plant^{-1} with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} was 14.42 per cent with compared to CR_1: Crop residue incorporation without irrigation on pooled basis (Table 4.4).

Nutrient management

An application of F_4:125% RDF gave statistically higher number of pods plant^{-1} 73.52, 73.98 and 73.75 during 2019, 2020 and pooled basis correspondingly, which was not differing significantly with F_3:100% RDFduring both the years of experimentation as well as on pooled basis. However, the least number of pods plant^{-1} was obtained with F_1: Control and application of F_4:125% RDF has increased the number of pods by 25.82 per cent over the F_1: Control on pooled data (Table 4.4).

4.2.2 Seeds Pod^{-1}

Crop residue management

The results presented in Table 4.4 revealed that the crop residue management practices had significant effect on seeds pod^{-1}. Application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} gave significantly higher number of seeds pod^{-1} during 2019, 2020 and pooled basis was 3.76, 3.80 and 3.78 followed by CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3.60, 3.64 and 3.62 respectively). Further data depicts that the seeds pod^{-1} produced by CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (3.78), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3.62) and CR_2: Crop residue incorporation with irrigation (3.4) was 14.17, 9.26 and 2.52 per cent more than CR_1: Crop residue incorporation without irrigation (3.31) on pooled basis.

Nutrient management

Significantly higher number of seeds pod^{-1} during 2019, 2020 and pooled basis was 3.73, 3.77 and 3.75 produced by application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (3.59, 3.63 and 3.61) respectively. Data further indicates that the application of F_4:125% RDF had increased the seeds pod^{-1} by 10.12 per cent as compared to F_1: Control on pooled basis (Table 4.4).

4.2.3 Test Weight

Crop residue management

Scrutiny of data (Table 4.4) indicates that the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} gave highest test weight 112.31, 112.23 and 112.27 g during 2019, 2020 and pooled basis, which was statistically at par with treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (110.91 g) in 2019, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (106.31 g) and CR_2: Crop residue incorporation with irrigation (110.40 g) in 2020 and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (110.65 g) on pooled basis. However, the minimum test weight 102.85, 103.40 and 103.12 g in 2019, 2020 and pooled basis respectively was recorded with CR_1: Crop residue incorporation without irrigation.

Nutrient management

The results revealed that the maximum test weight 113.44, 113.17 and 113.30 g was recorded with the treatment F_4:125% RDF, which was statistically at par with F_3:100% RDF (111.42, 111.42 and 111.42 g) in the year 2019, 2020 and on pooled basis respectively. Whereas, the minimum test weight was recorded with F_1: Control (102.53 g), which was 10.50 per cent less than the application of F_4:125% RDF (113.30 g) on mean basis of both the years of experimentation (Table 4.4).

4.2.4 Grain Yield

Crop residue management

Results presented in Table 4.5 revealed that in 2019 and 2020 year of experimentation the maximum grain yield 1758.27 and 1790.76 kg ha^{-1} was produced by CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (1673.99 and 1688.60 kg ha^{-1}) during both the years respectively. However, the lowest grain yield during 2019 and 2020 year of research was recorded with CR_1: Crop residue incorporation without irrigation (1200.42 and 1263.68 kg ha^{-1}) respectively. On pooled basis, the significantly superior grain yield was produced with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (1774.52 kg ha^{-1}), followed by CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (1681.29 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation (1232.05 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (1596.83 kg ha^{-1}). However, with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation the grain yield of soybean has been increased by 44.03, 36.46 and 29.61 per cent as compared to CR_1: Crop residue incorporation without irrigation.

Nutrient management

An examination of data presented (Table 4.5) shows that the maximum grain yield 1771.43, 1807.23 and 1789.33 kg ha^{-1} was obtained with the application of F_4:125% RDF, which was statistically at par with treatment F_3:100% RDF (1726.73, 1766.68 and 1746.71kg ha^{-1}) during both the years of research as well as on pooled basis respectively. Further, data shows that the grain yield 1468.66 kg ha^{-1} was recorded with F_3:100% RDF, which differ significantly with rest of levels of nutrient management, whereas, the minimum grain yield 1280.0 kg ha^{-1} was attained with F_1: Control, which was 39.79 and 36.46 per cent less than the F_4:125% RDF and F_3:100% RDF on mean basis of both the years, respectively.

Interaction effect

Data presented in Table 4.5.1 clearly shows that application of crop residue and nutrient management significantly influenced the grain yield of soybean crop during both the years of investigations. The maximum grain yield 1884.0 and 1941.3 kg ha^{-1} was produced under combined application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} + F_4:125% RDF, followed by CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} + F_3:100%

RDF (1878.8 and 1940.1 kg ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + F_4:125% RDF (1839.2 and 1858.8 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_2:75% RDF (1784.4 and 1795.3 kg ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (1781.3 + 1858.8 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_3:100% RDF (1726.5 and 1738.0 kg ha^{-1}) and CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} + F_2:75% RDF (1716.1 and 1748.2 kg ha^{-1}) during the year 2019 and 2020 respectively. Further, on analysis of pooled data depicts that the maximum grain yield 1912.6 kg ha^{-1} was recorded with combined application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (1909.4 kg ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (1849.0 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_4:125% RDF (1789.8 kg ha^{-1}), and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (1780.5 kg ha^{-1}). However, the lowest grain yield 804.5, 875.5 and 840.0 kg ha^{-1} was recorded with CR_1: Crop residue incorporation without irrigation + F_1: Control during both the years of investigations as well as on pooled basis respectively.

4.2.5 Haulm Yield

Crop residue management

The scrutiny of data (Table 4.5) shows that the maximum haulm yield 3437.54 kg ha^{-1} was produced with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3299.33 kg ha^{-1}) and CR_2: Crop residue incorporation with irrigation (3181.63 kg ha^{-1}) during the year 2019 of trail. The same trend was also followed in the year 2020. On the basis of means of treatments of both the years the maximum haulm yield 3465.81 kg ha^{-1} was also recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3330.73 kg ha^{-1}), whereas, the lowest haulm yield was recorded with CR_1: Crop residue incorporation without irrigation (2797.43 kg ha^{-1}) on pooled basis. The application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} had increased the haulm yield of soybean by 23.89 per cent with compared to CR_1: Crop residue incorporation without irrigation on the collective basis of 2019 and 2020.

Nutrient management

The scrutiny of data (Table 4.5) shows that the maximum haulm yields 3510.44, 3520.40 and 3515.42 kg $ha^{-1}$was produced with F_4:125% RDF, which was not differing significantly with the treatment F_3:100% RDF (3413.37, 3449.30 and 3431.33 kg ha^{-1}) during the year 2019, 2020 and on pooled basis respectively. Whereas, the lowest haulm yield was recorded with F_1: Control (2835.38 kg ha^{-1}) on pooled basis. The application of F_4:125% RDF had increased the haulm yield of soybean by 23.98 per cent with compared to F_1: Control on the pooled basis of both the years.

Interaction effect

An examination of data (Table 4.5.2) indicated that the combined application of crop residues along with nutrient management practices have significantly affected the haulm yield of soybean crop during both the years and pooled basis data. The maximum haulm yield 3723.4 and 3667.2 kg ha-1 was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} along with F_4:125% RDF during the year 2019 and 2020 of investigation respectively. Pooled dada indicated that significantly higher haulm yield 3695.3 kg ha^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} + F_4:125% RDF, which was at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF, CR_2: Crop residue incorporation with irrigation + F_4:125% RDF, CR_1: Crop residue incorporation without irrigation + F_4:125% RDF, CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100%

RDF and CR_2: Crop residue incorporation with irrigation + F_3:100% RDF. However, the lowest haulm yield 1835.10 kg ha^{-1} was recorded with the application of CR_1: Crop residue incorporation without irrigation + F_1: Control.

4.2.6 Biological Yield

Crop residue management

The maximum biological yield 5195.81 kg ha^{-1} was produced with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (4973.32 kg ha^{-1}) during the year 2019 of trail. The same trend was also followed in the year 2020 but biological yield produced in the year 2020 was also higher than 2019. On the basis of pooled data of both the years the maximum biological yield 5240.33 kg ha^{-1} was also recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over remaining levels of crop residue management practices, whereas, the lowest biological yield was recorded with CR_1: Crop residue incorporation without irrigation (4029.49 kg ha^{-1}) on pooled basis. The application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} had increased the biological yield of soybean by 30.05 per cent with compared to CR_1: Crop residue incorporation without irrigation on the pooled basis of 2019 and 2020 (Table 4.6).

Nutrient management

An examination of data presented in (Table 4.6) shows that the extreme biological yields 5281.87, 5327.63 and 5304.75kg $ha^{-1}$was produced with F_4:125% RDF, which was not differing significantly with the treatment F_3:100% RDF (5140.10, 5215.98 and 5178.04 kg ha^{-1}) during the year 2019, 2020 and on pooled basis respectively. On pooled basis the lowest biological yield was recorded with F_1: Control (4115.38 kg ha^{-1}). The application of F_4:125% RDF had increased the biological yield of soybean by 28.90 per cent with compared to F_1: Control on the pooled basis of both the years.

Interaction effect

A perusal of data Table 4.6.1 depicts that application of crop residue along with various nutrient management activities significantly affected the biological yield of soybean crop during both the years of investigation as well as on pooled basis. The pooled data show that uppermost biological yield 5607.9 kg ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically similar to that produced with application of treatment combinations *viz*., CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (5526.6 kg ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (5426.3 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_4:125% RDF (5222.5 kg ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (5271.7 kg ha^{-1}). The minimum biological yield 2675.1 kg ha^{-1} was recorded with the application of CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis, which was 109.63 per cent lower as compared to the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF.

4.2.7 Harvest Index

Crop residue management

The highest harvest index 33.98 per cent was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (33.65%) and CR_2: Crop residue incorporation with irrigation (32.68%) but differing significantly with CR_1: Crop residue incorporation without irrigation (29.61%), which was lowest among the treatment means during the year 2019. In year 2020 of experimentation, various levels of crop residue management did not show any significant effect on harvest index. However, on pooled basis the maximum harvest index 33.98 per cent was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (33.56%) and CR_2: Crop residue incorporation with irrigation (32.84%) but differing significantly with CR_1: Crop residue incorporation without irrigation (30.33%), which was lowest on pooled basis (Table 4.6).

Nutrient management

The results revealed that application of various fertility levels failed to show any significant effect on harvest index during 2019 and 2020. On pooled basis the maximum harvest index 33.80 per cent was attained with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (33.75%). With application of F_2:75% RDF harvest index was 31.96 per cent and differing significantly with F_1: Control (31.13%), which was lowest on pooled basis (Table 4.6).

4.3 NUTRIENT CONTENT

4.3.1 Nitrogen Content

4.3.1.1 Grain

Crop residue management

An analysis of data Table 4.7 clearly shows that the application of various crop residue management failed to show any significant effect on nitrogen content of grain in 2019, 2020 and on pooled basis.

Nutrient management

An investigation of data Table 4.7 shows that the application of various fertility levels did not show any momentous outcome on nitrogen content of grain in 2019, 2020 and on pooled basis.

4.3.1.2 Haulm

Crop residue management

Plant samples were analysed in laboratory and data presented in Table 4.7 indicated that the maximum nitrogen content of haulm 2.17 and 2.20 per cent was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (2.11 and 2.14%) and CR_2: Crop residue incorporation with irrigation (2.08 and 2.10%), whereas the lowest concentration of nitrogen in haulm was in CR_1: Crop residue incorporation without irrigation (1.88 and 1.92%) during both the years of experimentation *viz*., 2019 and 2020 respectively. On mean basis the maximum nitrogen content of haulm 2.19 per cent was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (2.13%) but differing significantly with CR_2: Crop residue incorporation with irrigation (2.09%) and CR_1: Crop residue incorporation without irrigation (1.90%), which was 9.73, 11.83 and 14.85 per cent lower than CR_2: Crop residue incorporation with irrigation, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} respectively, on pooled basis.

Nutrient management

Data presented in Table 4.7 indicated that the maximum nitrogen content of haulm 2.22 and 2.24 per cent was recorded with the application of F_4:125% RDF, which was statistically at par with the treatment F_3:100% RDF (2.12 and 2.20%) and F_2:75% RDF (2.01 and 2.04 %), whereas the lowest concentration of nitrogen in haulm was in F_1: Control (1.89 and 1.88%) during both the years of experimentation *viz*., 2019 and 2020 respectively. On mean basis the maximum nitrogen content of haulm 2.23 per cent was obtained with F4, which was significantly superior, followed by F_3:100% RDF (2.16%), F2 and F_1: Control (1.89%), which was 7.55, 14.58 and 18.29 per cent lower than F_2:75% RDF, F_3:100% RDF and F_4:125% RDF respectively, on pooled basis.

4.3.2 Phosphorus Content

4.3.2.1 Grain

Crop residue management

The crop residue management practices failed to show any significant effect on phosphorus content in the grain of soyabean during both the years of experimentation *viz*., 2019 and 2020. On the basis of means of two-year data the maximum phosphorus content of grain 0.25 per cent was obtained with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.245%). The phosphorus content of grain with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} was 0.241 per cent, followed by CR_1: Crop residue incorporation without irrigation (0.230%), which was 8.26 per cent lower than the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} on pooled basis (Table 4.8).

Nutrient management

Results revealed that the phosphorus content in grain was not affected by nutrient management practices in 2019 year of experimentation. In 2020 and on pooled basis the application of various fertility levels significantly affected the phosphorus content of grain. The maximum P content of grain 0.255 per cent in 2020 was recorded with F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (0.249%) and F_2:75% RDF (0.244%) but differing significantly with F_1: Control (0.226%). On pooled basis the maximum P content was also obtained with F_4:125% RDF (0.252%), which was at par with F_3:100% RDF (0.247%) and differing significantly with F_2:75% RDF (0.239%) and F_1: Control (0.227%). With increasing levels of RDFs the per cent increase in P content of grain was 5.26, 8.86 and 10.79 with application of F_2:75% RDF, F_3:100% RDF and F_4:125% RDF as compared to F_1: Control on pooled basis (Table 4.8).

4.3.2.2 Haulm

Crop residue management

A close examination of data Table 4.8 demonstrate that the crop residue management practices did not show any significant effect on phosphorus content in the haulm of soyabean during both the years of experimentation *viz*., 2019 and 2020. On the basis of means of two-year data the maximum phosphorus content of haulm 0.13 per cent was obtained with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.128%). The phosphorus content of haulm with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} was 0.125 per cent, followed by CR_1: Crop residue incorporation without irrigation (0.122%), which was 6.66 per cent lower than the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} on pooled basis.

Nutrient management

Scrutiny of data Table 4.8 clearly directs that during both the years of experimentation various fertility levels did not shows any significant effect on P content in haulm of soybean. However, on pooled basis the highest P content of haulm 0.131 per cent was obtained with F_4:125% RDF, which was statistically at par with F_3:100% RDF (0.129%). Further data shows that P content of haulm with F_2:75% RDF was 0.125 per cent which was significantly higher than F_1: Control (0.120%), which was lowest among various fertility levels on pooled basis.

4.3.3 Potassium Content

4.3.3.1 Grain

Crop residue management

Analysis of grain samples was done in laboratory and data presented in Table 4.9 clearly depicts that the maximum K content of grain 1.06 per cent was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation, but the lowest K concentration 0.94 per cent was analysed in CR_1: Crop residue incorporation without irrigation in the year 2019. The same trend was also followed in the year 2020 of experimentation. On the basis of pooled data, the significantly superior K content of grain 1.07 per cent was recorded with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, followed by CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (1.01%) and CR_2: Crop residue incorporation with irrigation (0.97%) and CR_1: Crop residue incorporation without irrigation (0.95%), which was lowest on pooled basis.

Nutrient management

An examination data samples presented in Table 4.9 evidently illustrates that the maximum K content of grain 1.05 per cent was recorded with F_4:125% RDF, which was statistically at par with the treatment F_3:100% RDF (1.01%) and F_2:75% RDF (0.96%), but the lowest K concentration 0.92 per cent was recorded in F_1: Control in the year 2019. The same trend was also followed in the year 2020 of experimentation. On the basis of pooled data, the maximum K content of grain 1.07 per cent was recorded with the F_4:125% RDF, which was statistically superior and differing significantly with F_3:100% RDF (1.03%), F_2:75% RDF (0.98%) and F_1: Control (0.92%), which was lowest on pooled basis. The per cent increase in the grain K content with application of F_4:125% RDF was 16.50 per cent more than the application of F_1: Control on pooled basis.

4.3.3.2 Haulm

Crop residue management

An evident from data Table 4.9 indicates that the crop residue management practices did not influenced the K content of haulm of soybean crop during both the years of experimentation. The maximum K content of haulm on pooled basis 2.74 per cent was observed with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior and differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (2.65%), CR_2: Crop residue incorporation with irrigation (2.57%) and CR_1: Crop residue incorporation without irrigation (2.54%), which were also differing significantly with each other treatment means. The per cent increase in the concentration of K in haulm of soybean with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} was 16.50 per cent as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

Results revealed that the levels of nutrient management *viz*., F_1: Control, F_2:75% RDF, F_3:100% RDF and F_4:125% RDF did not show any significant effect on K content in haulm during the year 2019 of research work. In 2020, the maximum k concentration in haulm was recorded with the application of F_4:125% RDF (2.76%), which was statistically at par with F_3:100% RDF (2.73%) and F_2:75% RDF (2.59%), but differing significantly with F_1: Control (2.46%), which was having lowest K content in haulm. On the basis of mean data of both the years of experimentation the maximum K content of haulm was also recorded with application of F_4:125% RDF (2.75%), which was statistically at par with the application of F_3:100% RDF (2.71%) but differing significantly with F_2:75 % RDF (2.57%) and F_1: Control (2.48%). However, the minimum K content of haulm was recorded with F_1: Control (2.48%), which was 10.89 per cent lower than the application of F_4:125% RDF on pooled basis (Table 4.9).

4.3.4 Sulphur Content

4.3.4.1 Grain

Crop residue management

Data Table 4.10 depicted that the sulphur content of soybean grain was maximum 0.43 and 0.44 per cent with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.40 and 0.42%) and CR_2: Crop residue incorporation with irrigation (0.38 and 0.40%) but differing significantly with CR_1: Crop residue incorporation without irrigation (0.36 and 0.37%) during both the years of experimentation *viz.*, 2019 and 2020 respectively. Further, data indicated that on pooled basis the maximum sulphur content of grain was significantly superior with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (0.43%), followed by CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.41%), CR_2: Crop residue incorporation with irrigation (0.39%) and CR_1: Crop residue incorporation without irrigation (0.36%). With application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} the sulphur content of grain was increased significantly by 20.25 per cent as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

Increasing levels of nutrient management had significantly improved the concentration of sulphur in grains of soybean during both the years of experimentation as well as on pooled basis (Table 4.10). In 2020, the highest concentration of sulphur 0.44 per cent was recorded with F_4:125% RDF, which was statistically at par with the F_3:100% RDF (0.42%) and F_2:75% RDF (0.41%) but differing significantly with F_1: Control (0.35%). The same trend was also followed during previous year of experimentation. Whereas, on pooled basis the significantly superior concentration of sulphur 0.44 per cent was obtained with application of F_4:125% RDF, which was differing significantly with rest of levels of RDFs. However, the per cent increase in the S content of grain with increasing level of nutrient as compared to F_1: Control was 16.19, 19.14 and 26.50 per cent with application of F_2:75 % RDF, F_3:100% RDF and F_4:125% RDF respectively on pooled basis.

4.3.4.2 Haulm

Crop residue management

The study of various crop residue management treatment revealed that the maximum S content of haulm was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (0.32 and 0.33%), which was statistically at par with CR_2: Crop residue incorporation with irrigation (0.29 and 0.29%) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.30 and 0.31%), but differing significantly with CR_1: Crop residue incorporation without irrigation (0.26 and 0.27%) during both the years of experimentation *viz*., 2019 and 2020, respectively. Data indicates that the maximum S content of haulm on pooled basis was 0.32 per cent with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior and differing significantly with rest of the levels of crop residue management. However, the lowest S content of haulm was 0.26 per cent recorded with CR_1: Crop residue incorporation without irrigation on pooled basis (Table 4.10).

Nutrient management

Nutrient management practices had remarkable effect on sulphur content of haulm on pooled basis (Table 4.10). However, during both the years of experimentation various fertility levels failed to show any significant effect on sulphur content of haulm of soybean. On pooled data basis, the highest S content of haulm 0.32 per cent was noted with F_4:125% RDF, which was significantly superior. Further data depicted that with application of F_3:100% RDF, F_2:75% RDF and F_1: Control the S content of haulm was 0.30, 0.29 and 0.27 per cent was recorded respectively. However, the per cent increase in the S concentration with application of F_4:125% RDF was 17.98 per cent as compared to F_1: Control on pooled basis.

4.3.5 Zinc Content

4.3.5.1 Grain

Crop residue management

A perusal of data displayed in Table 4.11 shows that different practices of crop residue management has significantly influenced the zinc content of soybean grain during both the years of research and on pooled analysis. In 2019, crop applied wit CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} resulted in maximum zinc content in grain 23.13 ppm, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation. This trend was also followed in 2020 year of experimentation. On the basis of pooled data results revealed that the significantly highest Zn content of grain was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (23.30 ppm), which was differing significantly with rest of the treatment and 16.12 per cent more than the application of CR_1: Crop residue incorporation without irrigation.

Nutrient management

An evident from data exhibited in Table 4.11 that different nutrient management levels has significantly inclined the zinc content of soybean grain during both the years of research and on pooled analysis. In 2019 and 2020 crop supplied with F_4:125% RDF resulted in maximum zinc content in grain 22.88 and 23.33 ppm, which was statistically at par with F_3:100% RDF (22.55 and 22.92 ppm) and F_2:75% RDF (20.82 and 21.26 ppm) respectively. On the basis of pooled analysis of data results revealed that the significantly highest Zn content of grain was recorded with

F_4:125% RDF (23.11 ppm), which was statistically at par with F_3:100% RDF (22.74 ppm) and differing significantly with rest of the treatment *viz.*, F_2:75 % RDF (21.04 ppm) and F_1: Control (20.13 ppm). The lowest zinc content of grain 20.04, 20.21 and 20.13 per cent was recorded with F_1: Control during 2019, 2020 and on pooled basis respectively.

4.3.5.2 Haulm

Crop residue management

During both the years of experimentation the application of crop residues failed to show any significant effect on zinc content of haulm of soybean (Table 4.11). The use of crop residues significantly increased the Zn content of haulm of soybean crop on pooled basis. Data further indicates that on pooled analysis the highest concentration of zinc 14.11 ppm was found in application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (13.84 ppm) and differing significantly with rest of the treatments. With application of CR_2: Crop residue incorporation with irrigation the zinc content of haulm was 13.47 ppm, which differing significantly with CR_1: Crop residue incorporation without irrigation (13.14 ppm).

Nutrient management

Plant samples were analysed in the laboratory during both the years of research and data presented in Table 4.11 revealed that application of fertility levels failed to show any significant effect on zinc content of haulm of soybean. The nutrient management practices have significantly increased the Zn content of haulm of soybean crop on basis of pooled analysis of data. The highest concentration of zinc 14.22 ppm was found in application of F_4:125% RDF, which was statistically superior over rest of levels of nutrient management and differing significantly with rest of the treatments *viz.*, F_3:100% RDF (13.79 ppm), F_2:75% RDF (13.57 ppm) and F_1: Control (12.97 ppm), which was minimum and 9.60 per cent lower than that application of F_4:125% RDF on pooled basis.

4.3.6 Iron Content

4.3.6.1 Grain

Crop residue management

Scrutiny of data of both the years of experimentation indicates that crop residues management practices failed to show any significant effect on iron content of soybean grain (Table 4.12). Whereas, practice of crop residues significantly increased the Fe content of grain on pooled basis. Data further indicates that on pooled analysis the highest concentration of iron in grain 44.44 ppm was found in application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (43.52 ppm) and differing significantly with rest of the treatments. The minimum iron content of grain 41.37 ppm was obtained with CR_1: Crop residue incorporation without irrigation, which was also not differing significantly with CR_2: Crop residue incorporation with irrigation (42.18 ppm) and lowest among various means of levels of crop residue management.

Nutrient management

Data of both the years of experimentation indicates that nutrient management practices failed to show any significant effect on iron content of soybean grain. Whereas, Fe content of grain was increased significantly on pooled basis. Data further specifies that on pooled analysis the highest concentration of iron in grain 43.76 ppm was found with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (43.17 ppm) and differing significantly with rest of the treatments. The minimum iron content of grain 41.85 ppm was obtained with F_1: Control, which was also not differing significantly with F_2:75% RDF (42.71 ppm) and lowest among various means of levels of nutrient management (Table 4.12).

4.3.6.2 Haulm

Crop residue management

The study of iron content of haulm indicated that in both the years of experimentation crop residue management practices did not show any significant effect on iron content in haulm of soybean crop but differed significantly on the basis of pooled analysis (Table 4.12). Further, data Table shows that on pooled basis the maximum concentration of iron in haulm 80.49 ppm was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing statistically with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (79.57 ppm) but significantly superior over CR_2: Crop residue incorporation with irrigation (78.51 ppm) and CR_1: Crop residue incorporation without irrigation (76.69 ppm).

Nutrient management

A perusal of data (Table 4.12) directed that in both the years of experimentation nutrient management practices failed to express any substantial effect on iron content of soybean haulm but diverged significantly on the basis of pooled analysis. Further, data shows that on the basis of pooled analysis the maximum concentration of iron in haulm 80.54 ppm was recorded with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (79.47 ppm) but significantly superior over F_2:75% RDF (78.58 ppm) and F_1: Control (76.67 ppm).

4.3.7 Manganese Content

4.3.7.1 Grain

Crop residue management

On pooled basis the maximum concentration of Mn in grain of soybean was 64.43 ppm recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing statistically with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (63.58 ppm) and CR_2: Crop residue incorporation with irrigation (63.37 ppm) but significantly superior over and CR_1: Crop residue incorporation without irrigation (59.25 ppm), which was recorded lowest among various treatment means. Further, study of Mn content of grain indicated that in both the years of investigation crop residue managing practices did not show any significant consequence on Mn content in grain of soybean (Table 4.13).

Nutrient management

The maximum concentration of Mn in grain of soybean was 64.53 ppm recorded with application of F_4:125% RDF, which was not differing statistically with

F_3:100% RDF (64.27 ppm) and F_2:75 % RDF (63.10 ppm) but pointedly higher over and F_1: Control (58.72 ppm), which was recorded lowest among various treatment means. Supplementary study of Mn content of grain (Table 4.13) indicated that in both the years of investigation *viz*., 2019 and 2020; the application of fertility levels was not successful to demonstrate any noteworthy value on Mn content in grain of soybean.

4.3.7.2 Haulm

Crop residue management

An evident from data Table 4.13 clearly depicts that the maximum concentration of Mn in haulm of soybean was 50.92 ppm recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (50.17 ppm) and CR_2: Crop residue incorporation with irrigation (49.92 ppm) but significantly superior over CR_1: Crop residue incorporation without irrigation (46.47 ppm), which was recorded lowest among various treatment means. Further, study of Mn content of haulm specified that in both the years of investigation crop residue managing practices did not show any significant results on Mn content in haulm of soybean.

Nutrient management

The maximum concentration of Mn in haulm of soybean was 51.00 ppm recorded with application of F_4:125% RDF, which was not differing statistically with F_3:100% RDF (50.64 ppm) but pointedly higher over F_2:75 % RDF (49.75 ppm) and F_1: Control (46.08 ppm), which was recorded lowest among various treatment means. Additional study of Mn content of haulm showed that in both the years of investigation *viz*., 2019 and 2020; the application of fertility levels failed to demonstrate any remarkable change in Mn content in haulm of soybean. However, the per cent increase in Mn content of haulm with application of F_4:125% RDF was 9.64 per cent as compared to F_1: Control (Table 4.13).

4.3.8 Copper Content

4.3.8.1 Grain

Crop residue management

Results of data Table 4.14 revealed that the highest Cu content of grain of soybean 12.60 ppm was obtained with CR_1: Crop residue incorporation without irrigation, which was statistically at par with the application of CR_2: Crop residue incorporation with irrigation and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, but differing significantly with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (10.75 ppm), which was lowest in the year 2019. In the year 2020 of investigation the maximum Cu content of grain 12.85 ppm was also observed under the application of CR_1: Crop residue incorporation without irrigation, which was not differing significantly with CR_2: Crop residue incorporation with irrigation (12.24 ppm) and significantly superior over rest of the treatment means. Data further shows that the significantly highest copper content of grain 12.73 ppm was recorded with CR_1: Crop residue incorporation without irrigation on pooled basis, followed by CR_2: Crop residue incorporation with irrigation (12.14 ppm), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} 11.48 ppm) and CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (10.83 ppm). However, the lowest copper content of grain was 10.75, 10.90 and 10.83 ppm were recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} in 2019, 2020 and on pooled basis analysis respectively.

Nutrient management

An evident from data Table 4.14 clearly illustrates that the maximum concentration of Cu in grain of soybean was 13.03 ppm recorded with application of F_4:125% RDF, which was significantly superior over rest of the treatment and F_1: Control (9.61 ppm) was recorded lowest among various treatment means on pooled basis. During the year 2019 and 2020 of investigation the maximum Cu content of grain was 12.99 and 13.08 ppm was recorded with F_4:125% RDF, which was at par with the application of F_3:100% RDF and F_2:75% RDF respectively. However, the treatment F_1: Control was lowest in the concentration of Cu in grains of soybean crop during both the years of experimentation.

4.3.8.2 Haulm

Crop residue management

An analysis of data (Table 4.14) clearly shows that the maximum Cu content of haulm in the year 2019, 2020 and on pooled basis was maximum in CR_2: Crop residue incorporation with irrigation 8.61, 8.62 and 8.61 ppm, respectively. Further, data indicate that the Cu content of haulm with application of CR_2: Crop residue incorporation with irrigation was statistically at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (8.14 and 8.24 ppm) and CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (7.92 and 7.85 ppm) and differing significantly with rest of treatment CR_1: Crop residue incorporation without irrigation (7.49 ppm) during both the years of investigation. However, the lowest Cu content of haulm in 2019, 2020 and pooled basis was 7.49, 7.55 and 7.52 ppm were under CR_1: Crop residue incorporation without irrigation respectively.

Nutrient management

An analysis of data (Table 4.14) shows that the highest Cu content of haulm of soybean was 9.23 and 9.26 ppm with the application of F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (8.43 and 8.65 ppm) in 2019 and 2020 year of investigations respectively. On pooled basis analysis of data demonstrate that the highest Cu content of soybean haulm was 9.25 ppm in application of F_4:125% RDF, which was significantly superior over rest of the treatments means. However, the lowest concentration of copper in haulm was 6.43, 6.30 and 6.36 ppm recorded with application of F_1: Control in both the years of research and on pooled basis respectively.

4.4 NUTRIENT UPTAKE

4.4.1 Nitrogen Uptake

4.4.1.1 Grain

Crop residue management

An analysis of data Table 4.15 clearly shows that the application of various crop residue management significantly increased nitrogen uptake by grain in 2019, 2020 as well as on pooled basis. In year 2019 and 2020 the highest nitrogen uptake by grain was 107.32 and 109.42 kg ha^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (101.74 and 102.80 kg ha^{-1}) respectively. The means of both the years demonstrated that the maximum nitrogen uptake by grain 108.37 kg ha^{-1} was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (102.27 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation (96.72 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (74.78 kg ha^{-1}), which was lowest among various treatment means on pooled basis. Data further shows that the nitrogen uptake by soybean grain was 44.91 per cent higher with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

It is an evident from data Table 4.15 the application of several nutrient management practices significantly increased nitrogen uptake by grain in 2019, 2020 as well as on pooled basis. In year 2019 and 2020 the highest nitrogen uptake by grain was 108.04 and 110.67 kg ha^{-1} was recorded with F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (104.99 and 107.70 kg ha^{-1}) respectively. The treatment means on pooled basis proved that the maximum nitrogen uptake by grain 109.35 kg ha^{-1} was obtained with F_4:125% RDF, which was at par with F_3:100% RDF (106.35 kg ha^{-1}) however, differing significantly with F_2:75%

RDF (89.08 kg ha^{-1}) and F_1: Control (77.37 kg ha^{-1}), which was lowest among various treatment means on pooled basis. Figures further confirm that the nitrogen uptake by soybean grain was 41.34 per cent higher with application of F_4:125% RDF as compared to F_1: Control on pooled basis.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the nitrogen uptake by grain of soybean during 2019 year of experimentation and pooled data basis (Table 4.15.1). The data indicated that maximum nitrogen uptake by grain in 2019 was 115.55 kg ha^{-1} with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF, CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_2:75% RDF, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF, CR_2: Crop residue incorporation with irrigation + F_4:125% RDF and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF. On pooled basis results revealed that the maximum nitrogen uptake by grain 117.37 kg ha^{-1} was calculated with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF, CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_2:75 % RDF, CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF. However, the least nitrogen uptake by grain 50.68 kg ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data (Table 4.15.1)

4.4.1.2 Haulm

Crop residue management

Plant samples were analysed in laboratory and data presented in Table 4 indicated that during the year 2019 and 2020 the highest nitrogen uptake by haulm was 74.98 and 77.03 kg ha^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (70.07 and 72.35 kg ha^{-1}) respectively. The pooled data of both the years confirmed that the maximum nitrogen uptake by haulm 76.0 kg ha^{-1} was attained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (71.21 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation (68.05 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (53.96 kg ha^{-1}), which was lowest among various treatment means on pooled basis. Data further shows that the nitrogen uptake by soybean haulm was 40.85 per cent higher with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

Data presented in Table 4 indicated that the maximum nitrogen uptake by haulm in the year 2019 and 2020 was 78.08 and 78.96 kg ha^{-1} was obtained in F_4:125% RDF, which was statistically similar to the treatment application of F_3:100% RDF and F_2:75% RDF in 2019 and only with F_3:100% RDF in the year 2020. The analysis of pooled data shows that the significantly higher nitrogen uptake by haulm 78.52 kg $ha^{-1}$was recorded with F_4:125% RDF, which was differing significantly with rest of treatment means. The N uptake by haulm with application of F_3:100% RDF was 74.23 kg ha^{-1} also differs significantly with F_2:75% RDF and F_3:100% RDF on pooled data basis. However, the lowest N uptake was observed with F_1: Control.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the nitrogen uptake by haulm of soybean on pooled data basis

(Table 4.15.1). The data indicated that maximum nitrogen uptake by haulm on pooled basis 86.44 kg ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF. However, the least nitrogen uptake by haulm 31.48 kg ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.2 Phosphorus Uptake

4.4.2.1 Grain

Crop residue management

The crop residue management practices showed significant effect on phosphorus uptake by grain of soyabean during both the years of experimentation *viz*., 2019 and 2020 as well on pooled data basis (Table 4.16). On the basis of means of two-year data the maximum phosphorus uptake by grain 4.44 kg ha^{-1} was obtained with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher and differing with rest of treatments on pooled basis. The per cent increase in the uptake of phosphorus with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} over CR_1: Crop residue incorporation without irrigation was 55.32 per cent.

Nutrient management

Results revealed that the increasing levels of RDFs significantly increased the P uptake by grains of soybean crop. The maximum phosphorus consumption by grains 4.41 and 4.62 kg ha^{-1} was recorded with the application of treatment F_4:125% RDF, which was not differing significantly with F_3:100% RDF in the year 2019 and 2020 respectively. The significantly higher P uptake by soybean grain 4.52 kg ha^{-1} was in F_4:125% RDF, which differs significantly with rest of levels of nutrient management on the basis of pooled data. The minimum uptake of phosphorus by grain was 2.93 kg ha^{-1} was recorded with F_1: Control, which was 54.24 per cent lower than that consumed by F_4:125% RDF on pooled basis (Table 4.16).

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the P uptake by seed of soybean on pooled data basis (Table 4.16.1). The data indicated that maximum P uptake by seed on pooled basis 4.97 kg ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (4.88 kg ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (4.73 kg ha^{-1}). However, the least P uptake by seed 1.82 kg ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.2.2 Haulm

Crop residue management

The crop residue management practices showed significant effect on phosphorus uptake by haulm of soyabean during both the years of experimentation *viz*., 2019 and 2020 as well on pooled data basis. In the year 2019 and 2020 of investigation the highest P uptake by haulm 4.45 and 4.56 kg ha^{-1} was observed with treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (4.20 and 4.30 kg ha^{-1}) and CR_2: Crop residue incorporation with irrigation (3.98 and 4.18 kg ha^{-1}) during both the years, respectively. On the basis of pooled data, the maximum phosphorus uptake by haulm 4.50 kg ha^{-1} was recorded with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly supreme and deviating with rest of treatments on pooled basis. The per cent increase in the uptake of phosphorus by haulm with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} over CR_1: Crop residue incorporation without irrigation was 31.99 per cent (Table 4.16).

Nutrient management

The nutrient management practices showed significant effect on phosphorus uptake by haulm of soyabean during both the years of experimentation *viz*., 2019 and 2020 as well on pooled data basis (Table 4.16). In the year 2019 and 2020 of investigation the highest P uptake by haulm 4.55 and 4.61 kg ha^{-1} was observed with treatment F_4:125% RDF, which was statistically at par with F_3:100% RDF (4.37 and 4.46 kg ha^{-1}) and F_2:75% RDF (3.80 and 3.89 kg ha^{-1}) during both the years, respectively. On the basis of pooled data, the maximum phosphorus uptake by haulm 4.58 kg ha^{-1}was recorded with the F_4:125% RDF, which was significantly higher and deviating with rest of treatments on pooled basis. The per cent increase in the uptake of phosphorus by haulm with application of F_4:125% RDF over F_1: Control was 34.41 per cent.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the P uptake by haulm of soybean on pooled data basis (Table 4.16.1). The data indicated that maximum P uptake by haulm on pooled basis 4.95 kg ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (4.79 kg ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (4.72 kg ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (4.53 kg ha^{-1}). However, the least P uptake by haulm 2.13 kg ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.3 Potassium Uptake

4.4.3.1 Grain

Crop residue management

The maximum K uptake by grain 18.65 kg ha^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the treatment

CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (16.60 kg ha^{-1}), but the lowest K uptake 11.48 kg ha^{-1} was calculated in CR_1: Crop residue incorporation without irrigation in the year 2019. The maximum K uptake by grain 19.50 kg ha^{-1} was noted with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (16.60 kg ha^{-1}) and CR_2: Crop residue incorporation with irrigation (16.12 kg ha^{-1}), but the lowest K uptake 12.41 kg ha^{-1} was obtained in CR_1: Crop residue incorporation without irrigation in the year 2020. On the basis of pooled data, the significantly superior K uptake by grain 19.07 kg ha^{-1} was recorded with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (17.11 kg ha^{-1}) and CR_2: Crop residue incorporation with irrigation (15.59 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (11.94 kg ha^{-1}), which was lowest on pooled basis (Table 4.17).

Nutrient management

An examination data samples presented in Table 4.17 evidently illustrates that the maximum K uptake by grain 18.69 kg ha^{-1} was recorded with F_4:125% RDF, which was statistically at par with the treatment F_3:100% RDF (17.48 kg ha^{-1}), however, the lowest K uptake by grain of soybean 11.64 kg ha^{-1} was recorded in F_1: Control in the year 2019. The same trend was also followed in the year 2020 of experimentation. On the basis of pooled data, the maximum K uptake by grain 19.26 kg ha^{-1} was recorded with the F_4:125% RDF, which was significantly superior and differing statistically with F_3:100% RDF (18.09 kg ha^{-1}), F_2:75% RDF (14.49 kg ha^{-1}) and F_1: Control (11.89 kg ha^{-1}), which was lowest on pooled basis. The per cent increase in the grain K uptake with application of F_4:125% RDF was 62.06 per cent more than the application of F_1: Control on pooled basis.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the potassium uptake by grain of soybean on pooled data basis (Table 4.16.2). The data indicated that maximum K uptake by seed on pooled basis 21.85 kg ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (21.03 kg ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (20.07 kg ha^{-1}). However, the least K uptake by grain 7.32 kg ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.3.2 Haulm

Crop residue management

An evident from data Table 4.17 indicates that the crop residue management practices did not influenced the K uptake by haulm of soybean crop during 2019 year of experimentation. The maximum K uptake by haulm on pooled basis 95.31 kg ha^{-1} was observed with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior and differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (88.43 kg ha^{-1}), CR_2: Crop residue incorporation with irrigation (83.70 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (71.60 kg ha^{-1}), which were also differing significantly with each other treatment means. The per cent increase in the uptake of K through haulm of soybean with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} was 33.12 per cent as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

Results revealed that the levels of nutrient management significantly influenced K uptake by haulm during both the years of research work. The maximum k uptake by haulm was recorded with the application of F_4:125% RDF (96.04 and 97.36 kg ha^{-1}), which was statistically at par with F_3:100% RDF (91.62 and 94.33 kg ha^{-1}) and F_2:75% RDF (77.58 and 80.20 kg ha^{-1}), but differing significantly with F_1: Control (69.32 and 71.62 kg ha^{-1}), which was having lowest K uptake by haulm in 2019 and 2020 year of research respectively. On the basis of mean data of both the years of experimentation the maximum K uptake by haulm was also recorded with application of F_4:125% RDF (96.70 kg ha^{-1}), which was statistically at par with the application of F_3:100% RDF (92.98 kg ha^{-1}) but differing significantly with F_2:75 % RDF (78.89 kg ha^{-1}) and F_1: Control (70.47 kg ha^{-1}). However, the minimum K uptake by haulm was recorded with F_1: Control (70.47 kg ha^{-1}), which was 37.22 per cent lower than the application of F_4:125% RDF on pooled basis.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the K uptake by haulm of soybean on pooled data basis (Table 4.16.2). The data indicated that maximum K uptake by haulm on pooled basis 105.93 kg ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (102.2 kg ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (99.36 kg ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (95.21 kg ha^{-1}). However, the least K uptake by haulm 43.77 kg ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.4 Sulphur Uptake

4.4.4.1 Grain

Crop residue management

Data Table 4.18 depicted that the maximum sulphur uptake by soybean grain was 7.55 and 7.97 g ha^{-1} with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (6.78 and 7.06 g ha^{-1}) and CR_2: Crop residue incorporation with irrigation (6.07 and 6.50 g ha^{-1}) but differing significantly with CR_1: Crop residue incorporation without irrigation (4.37 and 4.72 g ha^{-1}) during both the years of experimentation *viz*., 2019 and 2020 respectively. Further, pooled data indicated that the maximum sulphur uptake by grain was significantly superior with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (7.76 g ha^{-1}), which differing significantly with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (6.92 g ha^{-1}), CR_2: Crop residue incorporation with irrigation (6.28 g ha^{-1}) and CR_1: Crop residue incorporation without irrigation (4.54 g ha^{-1}). With application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} the sulphur uptake by grain was increased significantly by 70.80 per cent as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

Increasing levels of nutrient management had significantly improved the sulphur uptake by grains of soybean during both the years of experimentation as well as on pooled basis. In 2020, the highest sulphur uptake 8.05 g ha^{-1} was recorded with F_4:125% RDF, which was statistically at par with the F_3:100% RDF (7.41 g ha^{-1}), but differing significantly with F_2:75 % RDF (6.13 g ha^{-1}) and F_1: Control (4.67 g ha^{-1}). The same trend was also followed during previous year of experimentation. Whereas, on pooled basis the significantly higher uptake of sulphur 7.84 g ha^{-1} was obtained with the application of F_4:125% RDF, which was differing significantly with rest of levels of RDFs. However, the per cent increase in the S uptake by grain with increasing level of nutrient as compared to F_1: Control was 32.65, 60.67 and 74.63 per cent with application of F_2:75% RDF, F_3:100% RDF and F_4:125% RDF respectively on pooled basis (Table 4.18).

4.4.4.2 Haulm

Crop residue management

Data Table 4.18 depicted that the maximum sulphur uptake by soybean haulm was 10.89 and 11.42 g ha^{-1} with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (9.95 and 10.41 g ha^{-1}) and CR_2: Crop residue incorporation with irrigation (9.10 and 9.81 g ha^{-1}) but differing significantly with CR_1: Crop residue incorporation without irrigation (7.47 and 7.54 g ha^{-1}) during both the years of experimentation *viz*., 2019 and 2020 respectively. Further, pooled data indicated that the maximum sulphur uptake by haulm was significantly higher with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (11.16 g ha^{-1}), which differing significantly with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (10.18 g ha^{-1}), CR_2: Crop residue incorporation with irrigation (9.46 g ha^{-1}) and CR_1: Crop residue incorporation without irrigation (7.50 g ha^{-1}). With application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} the sulphur uptake by haulm was increased significantly by 48.76 per cent as compared to CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

Nutrient management practices had remarkable effect on sulphur uptake by haulm in both the years and on pooled basis. In 2019 & 2020, the highest sulphur uptake 11.11 and 11.46 g ha^{-1} was recorded with F_4:125% RDF, which was statistically at par with the F_3:100% RDF (10.11 and 10.52 g ha^{-1}) and F_2:75% RDF(8.70 and 9.14 g ha^{-1}) but differing significantly with F_1: Control (7.49 and 8.06 g ha^{-1}). On pooled data basis, the highest S uptake by haulm 11.28 g ha^{-1} was noted with F_4:125% RDF, which was significantly superior. Further data depicted that with application of F_3:100% RDF, F_2:75 % RDF and F_1: Control the S uptake by haulm was 10.31, 8.92 and 7.78 g ha^{-1} was recorded respectively. However, the per cent increase in the uptake of sulphur by haulm with application of F_4:125% RDF was 45.09 per cent as compared to F_1: Control on pooled basis (Table 4.18).

4.4.5 Zinc Uptake

4.4.5.1 Grain

Crop residue management

A perusal of data displayed in Table 4.19 shows that different practices of crop residue management has significantly influenced the zinc uptake by soybean grain during both the years of research and on pooled analysis. In 2019, crop applied wit CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} resulted in maximum zinc uptake by grain 40.83 g ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (37.57 g ha^{-1}). On the basis of pooled data results revealed that the significantly highest Zn uptake by grain was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (41.52 g ha^{-1}), which was differing significantly with rest of the treatment and 65.03 per cent more than the application of CR_1: Crop residue incorporation without irrigation.

Nutrient management

An evident from data exhibited in Table 4.19 that different nutrient management levels has significantly inclined the zinc uptake by soybean grain during both the years of research and on pooled analysis. In 2019 and 2020 crop supplied with F_4:125% RDF resulted in maximum zinc uptake by grain 40.67 and 42.34 g ha^{-1}, which was statistically at par with F_3:100% RDF (39.09 and 40.72 g ha^{-1}) in the year 2019 and 2020 and with F_2:75% RDF (32.01 g ha^{-1}) in 2020, respectively. On the basis of pooled analysis of data results revealed that the significantly highest Zn uptake by grain was recorded with F_4:125% RDF (41.50 g ha^{-1}), which was statistically at par with F_3:100% RDF (39.90 g ha^{-1}) and differing significantly with rest of the treatment *viz*., F_2:75% RDF (31.25) and F_1: Control (26.10 g ha^{-1}). The lowest zinc uptake by soybean grain 25.37, 26.83 and 26.10 g ha^{-1} was recorded with F_1: Control during 2019, 2020 and on pooled basis respectively. The zinc uptake was 59.03 per cent higher with application of F_4:125% RDF as compared to F_1: Control on pooled basis.

4.4.5.2 Haulm

Crop residue management

During 2019 year of experimentation the application of crop residues failed to show any significant effect on zinc uptake by haulm of soybean. The use of crop residues significantly increased the Zn uptake by soybean haulm in 2020 and pooled basis. Data further indicates that on pooled basis analysis the highest uptake of zinc by haulm 48.94 g ha^{-1} was found in application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing statistically with rest of treatment levels mean. With application of CR_2: Crop residue incorporation with irrigation the zinc uptake by haulm was 43.88 g ha^{-1}, which differing significantly with CR_1: Crop residue incorporation without irrigation (37.03 g ha^{-1}). The lowest zinc uptake by soybean haulm was 37.22, 36.84 and 37.03 g ha^{-1} was recorded with the application of CR_1: Crop residue incorporation without irrigation in 2019, 2020 and pooled basis data, respectively (Table 4.19).

Nutrient management

The nutrient management practices have significantly increased the Zn uptake though haulm of soybean crop on basis of pooled analysis of data. The highest uptake of zinc 49.98 g ha^{-1} was found in application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (47.40 g ha^{-1}) and superior over rest of levels of nutrient management and differing significantly with rest of the treatments *viz.*, F_2:75 % RDF (41.71 g ha^{-1}) and F_1: Control (36.92 g ha^{-1}), which was minimum and 35.37 per cent lower than that application of F_4:125% RDF on pooled basis (Table 4.19).

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the zinc uptake by haulm of soybean on pooled data basis (Table 4.22.1). The data showed that maximum zinc uptake by haulm on pooled basis 54.16 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (51.58 g ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (51.49 g ha^{-1}). However, the least zinc uptake by haulm 22.91 g ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.6 Iron Uptake

4.4.6.1 Grain

Crop residue management

Scrutiny of data of both the years of experimentation indicates that crop residues management practices significantly increased iron uptake by soybean grain. Data further indicates that on pooled analysis the highest uptake of iron by soybean grain 78.95 g ha^{-1} was found with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior and differing significantly with rest of the treatments. The minimum iron uptake by grain 51.30 g ha^{-1} was attained with CR_1: Crop residue incorporation without irrigation, which was lowest among various means of levels of crop residue management (Table 4.20).

Nutrient management

Data (Table 4.20) of both the years of experimentation indicates that nutrient management practices significant increased iron uptake by soybean grain. The maximum uptake of iron by grain 77.38 and 79.41 g ha^{-1} was recorded with F_4:125% RDF, which was statistically similar to the uptake recorded under F_3:100% RDF (74.43 and 76.70 g ha^{-1}) and F_2:75% RDF (62.04 and 64.11 g ha^{-1}) in 2019 and 2020 respectively. Data further specifies that on the basis of pooled analysis the highest uptake of iron by grain 78.40 g ha^{-1} was found with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (75.57 g ha^{-1}) and differing significantly with rest of the treatments. The minimum iron uptake by grain 53.84 g ha^{-1} was obtained with F_1: Control, which was also differing significantly with F_2:75% RDF (63.07 g ha^{-1}) and lowest among various means of levels of nutrient management.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the iron uptake by seed of soybean on pooled data basis (Table 4.16.2). The data showed that maximum iron uptake by seed on pooled basis 85.29 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (85.29 g ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (81.97 g ha^{-1}). However, the least iron uptake by seed 33.78 g ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.6.2 Haulm

Crop residue management

The study of iron content of haulm indicated that in the year 2019 of experimentation crop residue management practices did not show any significant effect on iron uptake by haulm of soybean crop but differed significantly in 2020 and on the basis of pooled analysis. Further, data Table shows that on pooled basis the maximum uptake of iron by haulm 279.25 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing statistically with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (265.29 g ha^{-1}) but significantly superior over CR_2: Crop residue incorporation with irrigation (255.67 g ha^{-1}) and CR_1: Crop residue incorporation without irrigation (215.37 g ha^{-1}). The minimum uptake of iron by haulm of soybean crop was 217.35, 213.40 and 215.37 g ha^{-1} was recorded with application of CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled basis data respectively.

Nutrient management

A perusal of data Table directed that in the 2020 year of experimentation nutrient management practices failed to express any substantial effect on iron uptake by soybean haulm but diverged significantly in 2019 and on the basis of pooled analysis. Further, data shows that on the basis of pooled analysis the maximum uptake of iron through haulm 283.36 g ha^{-1} was recorded with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (272.84 g ha^{-1}) but significantly superior over F_2:75% RDF (241.30 g ha^{-1}) and F_1: Control (218.08 g ha^{-1}). The minimum uptake of iron by haulm of soybean crop 213.33, 22.83 and 218.08 g ha^{-1} was recorded with application of F_1: Control during 2019, 2020 and on pooled basis data respectively.

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the iron uptake by haulm of soybean on pooled data basis (Table 4.16.2). The data indicated that maximum iron uptake by haulm on pooled basis 303.96 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (293.4 g ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (290.99 g ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (280.26 g ha^{-1}) and CR_2: Crop residue incorporation with irrigation + F_4:125% RDF (275.61 g ha^{-1}) However, the least iron uptake by haulm 136.72 g ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.7 Manganese Uptake

4.4.7.1 Grain

Crop residue management

Study of Mn uptake by soybean grain indicated that in both the years of investigation and on pooled basis crop residue managing practices show significant consequence on Mn uptake by grain of soybean (Table 4.21). The maximum Mn uptake by grain of soybean crop was 113.18 and 116.01 g ha^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation in the year 2019 and 2020 respectively. On pooled basis the maximum Mn uptake by grain of soybean was 114.60 g ha^{-1} recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (107.20 g ha^{-1}), CR_2: Crop residue incorporation with irrigation (101.67 g ha^{-1}) and CR_1: Crop residue incorporation without irrigation (132.26 g ha^{-}1). However, the lowest uptake of Mn by grain among various treatment means was recorded with CR_1: Crop residue incorporation without irrigation.

Nutrient management

The maximum uptake of Mn through grain of soybean was 115.59 g ha^{-1} recorded with application of F_4:125% RDF, which was not differing significantly with

F_3:100% RDF (112.57 g ha^{-1}) but pointedly higher over F_2:75 % RDF (93.18 g ha^{-1}) and F_1: Control (75.68 g ha^{-1}), which was recorded lowest among various treatment means on pooled basis. Supplementary study of Mn uptake by grain indicated that in both the years of investigation *viz*., 2019 and 2020, the maximum Mn uptake by grain 113.92 and 117.26 g ha^{-1} was also obtained with F_4:125% RDF, which was at par with F_3:100% RDF (110.89 g ha^{-1}) in case of 2019, but during the year of 2020 it was statistically at par with F_3:100% RDF (114.26 g ha^{-1}) and F_2:75 % RDF (94.69 g ha^{-1}) respectively (Table 4.21).

Interaction effect

The combined application of crop residue and nutrient management significantly influenced the Mn uptake by seed of soybean on pooled data basis (Table 4.22.1). The data showed that maximum Mn uptake by seed on pooled basis 126.53 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (126.18 g ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (120.97 g ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_4:125% RDF (116.78 g ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (116.23 g ha^{-1}). However, the least Mn uptake by seed 46.48 g ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.7.2 Haulm

Crop residue management

An evident from data (Table 4.21) clearly depicts that the maximum Mn uptake by haulm of soybean 176.93 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (167.19 g ha^{-1}) but significantly superior over CR_2: Crop residue incorporation with irrigation (162.50 g ha^{-1}) and CR_1: Crop residue incorporation without irrigation (132.06 g ha^{-1}), which was recorded lowest among various treatment means on pooled basis. Further, study of Mn uptake by haulm specified that in year 2019 of investigation crop residue managing practices did not show any significant results on Mn uptake by haulm of soybean. However, in 2020, the maximum Mn uptake by haulm 178.80 g ha^{-1} was again obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} which was statistically similar to the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation.

Nutrient management

The statistically higher uptake of Mn by haulm of soybean 178.51, 180.60 and 179.56 g ha^{-1} was recorded with application of F_4:125% RDF, which was not differing statistically with F_3:100% RDF (172.03, 175.43 and 173.73 g ha^{-1}) in 2019, 2020 and on pooled basis respectively. However, in 2019 and 2020 F_4:125% RDF was also at par with F_2:75% RDF (151.13 and 154.46 g ha^{-1}) respectively. Data further shows that minimum Mn uptake by haulm 127.96, 135.23 and 131.59 g ha^{-1} was recorded with F_1: Control during both the years and on pooled analysis (Table 4.21).

4.4.8 Copper Uptake

4.4.8.1 Grain

Crop residue management

Results of data (Table 4.22) revealed that the highest Cu uptake by grain of soybean 19.67 g ha^{-1} was attained with CR_2: Crop residue incorporation with irrigation, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (19.50 g ha^{-1}) and CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (19.41 g ha^{-1}), but differing significantly with CR_1: Crop residue incorporation without irrigation (16.09 g ha^{-1}), which was lowest on the basis of pooled data analysis. An additional examination of data shows that the crop residue management practices did not show any significant effect on copper uptake by grain of soybean during both the years of investigation *viz*., 2019 and 2020.

Nutrient management

An evident from data Table 4.22 clearly illustrates that the maximum uptake of Cu though grain of soybean was 23.24 g ha^{-1} recorded with application of F_4:125% RDF, which was significantly superior over rest of the treatment, whereas, application of F_1: Control (12.13 g ha^{-1}) was recorded lowest among various treatment means on pooled basis. During the year 2019 and 2020 of investigation the maximum Cu uptake by grain was 22.93 and 23.55 g ha^{-1} was recorded with F_4:125% RDF, which was at par with the application of F_3:100% RDF (21.57 and 22.30 g ha^{-1}) respectively. However, the treatment F_1: Control was lowest in the uptake of Cu by grains of soybean crop during both the years of experimentation as well as on pooled basis.

Interaction effect

The combined application of crop residue and nutrient management significantly inclined the copper uptake by seed of soybean on pooled data basis (Table 4.22.1). The data showed that extreme copper uptake by seed on pooled basis 23.06 g ha^{-1} was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (22.23 g ha^{-1}), CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_4:125% RDF (23.53 g ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_4:125% RDF (23.95 g ha^{-1}), CR_1: Crop residue incorporation without irrigation + F_4:125% RDF (22.43 g ha^{-1}), CR_2: Crop residue incorporation with irrigation + F_3:100% RDF (22.39 g ha^{-1}) and CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ F_3:100% RDF (21.88 g ha^{-1}). However, the least copper uptake by seed 8.86 g ha^{-1} was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control on pooled basis data.

4.4.8.2 Haulm

Crop residue management

An analysis of data (Table 4.22) clearly shows that the maximum Cu uptake by haulm in the year 2020 and on pooled basis was maximum in CR_2: Crop residue incorporation with irrigation 28.67 and 28.11 g ha^{-1}, which was at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (27.93 and

27.49 g ha^{-1}) and CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (27.58 and 27.47 g ha^{-1}) respectively. Further, data revealed that the crop residue management practices failed to show any significant effect on copper uptake by haulm of soybean in the year 2019. The lowest uptake of copper by haulm 21.53 and 21.67 g ha^{-1} was recorded with CR_1: Crop residue incorporation without irrigation during 2020 and pooled basis respectively.

Nutrient management

An analysis of data (Table 4.22) shows that the highest Cu uptake by haulm of soybean 32.40 and 32.64 g ha^{-1} was recorded with the application of F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (28.78 and 29.81 g ha^{-1}) in 2019 and 2020 year of investigations respectively. On pooled basis analysis of data demonstrate that the highest Cu uptake by soybean haulm was 32.52 g ha^{-1} in application of F_4:125% RDF, which was significantly superior over rest of the treatments means. However, the lowest uptake of copper by haulm 17.99, 18.41 and 18.20 g ha^{-1} was recorded with application of F_1: Control in both the years of research and on pooled basis, respectively.

4.5 PHYSIO-CHEMICAL PROPERTIES

4.5.1 pH

Crop residue management

Data presented in the (Table 4.23) clearly shows that application of crop residues management practices significantly lowered the soil pH at the time of harvest during both the years of investigation as well as on pooled basis. The soil pH was decreased in the year 2020 as compared to the 2019. The lowest soil pH 7.45, 7.43 and 7.44 was recorded with the application of CR_4, which was significantly lowest among the various treatment of crop residue management in the both years and pooled basis, respectively. The maximum soil pH 7.97 was observed with the CR_1 on pooled basis.

Nutrient management

Data presented in the (Table 4.23) clearly shows that application of nutrient management practices significantly increased the soil pH at the time of harvest during both the years of investigation as well as on pooled basis. The maximum soil pH 7.84 was recorded with the application of 125% RDF, which was statistically similar to the application of 50 and 100 per cent RDF on pooled basis. However, the lowest soil pH was recorded with the control.

4.5.2 EC

Crop residue management

Data presented in the (Table 4.23) clearly shows that application of crop residues management practices significantly decreased the soil EC at the time of harvest during both the years of investigation as well as on pooled basis. The lowest soil electrical conductivity (0.301, 0.285 and 0.293 dSm^{-1}) was recorded with the application of CR_4, which was significantly lowest in the year 2019, 2020 and pooled basis, respectively. However, the highest electrical conductively was recorded with CR_1.

Nutrient management

Data presented in the (Table 4.23) clearly shows that application of nutrient management practices significantly altered the soil EC at the time of harvest during both the years of investigation as well as on pooled basis. The statistically maximum EC (0.350, 0.336 and 0.343 dSm^{-1} was recorded with 125 per cent RDF, which was at par with F3 during both the years but significantly higher on pooled basis respectively. However, the lowest EC was recorded with control treatment.

4.5.3 Organic Carbon

Crop residue management

Data Table 4.24 depicts that the application of various crop residue management practices failed to show any significant effect on organic carbon status of soil after crop harvest during both the years of experimentations. Further, the pooled data shows that maximum organic carbon 0.69 (%) was recorded with treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.67%) and differing significantly with CR_2: Crop residue incorporation with irrigation (0.65%) and CR_1: Crop residue incorporation without irrigation (0.63%), which was minimum among various levels of crop residue management and 9.67 per cent lower than that application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.

Nutrient management

An examination of data (Table 4.24) indicated that the application of nutrient management practices did not show a little significant effect on organic carbon status of soil after crop harvest during both the years of experimentations *viz.*, 2019 and 2020. Further, the pooled data revealed that maximum organic carbon 0.68 (%) was recorded with treatment F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (0.67%) and differing significantly with F_2:75 % RDF (0.65 %) and F_1: Control (0.63%), which was minimum among various levels of crop residue management and 7.39 per cent lower than that application of F_4:125% RDF.

4.5.4 Cation Exchange Capacity

Crop residue management

The analysis of soil samples was done and data clearly shows that crop residue management practices significantly influenced the CEC of soil during both the years of experimentation. Results revealed that the maximum CEC 25.0 and 25.99 C mol (P^+) kg^{-1} was recorded from the plot supplied with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (23.94 and 24.73 C mol (P^+) kg^{-1}) and CR_2: Crop residue incorporation with irrigation (23.02 and 23.61 C mol (P^+) kg^{-1}) during both the years 2019 and 2020 of experimentation respectively. On pooled basis data indicated that the significantly highest CEC of soil 25.50 C mol (P^+) kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing statistically with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (24.33 C mol (P^+) kg^{-1}), CR_2: Crop residue incorporation with irrigation (23.32 C mol (P^+) kg^{-1}) and CR_1: Crop residue incorporation without irrigation (22.39 C mol (P^+) kg^{-1}). However, the least CEC 22.12, 22.66 and 22.39 C mol (P^+) kg^{-1} was analysed with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled data analysis, respectively (Table 4.24).

Nutrient management

The analysis of soil samples was done and data presented in Table 4.24 clearly shows that crop nutrient management practices pointedly inclined the CEC of soil during both the years of experimentation. Results revealed that the maximum CEC 25.27 and 26.17 C mol (P^+) kg^{-1} was recorded from the plot supplied with F_4:125% RDF, which was statistically at par with the treatment F_3:100% RDF (24.22 and 25.16 C mol (P^+) kg^{-1}) during both the years 2019 and 2020 of experimentation respectively. On pooled basis data specified that the suggestively maximum CEC of soil 25.72 C mol (P^+) kg^{-1} was recorded with F_4:125% RDF, which was differing statistically with F_3:100% RDF (24.69 C mol (P^+) kg^{-1}), F_2:75 % RDF (22.76 C mol (P^+) kg^{-1}) and F_1: Control (22.37 C mol (P^+) kg^{-1}). However, the least CEC 22.30, 22.44 and 22.37 C mol (P^+) kg^{-1} was analysed with F_1: Control during 2019, 2020 and on pooled data analysis, respectively.

4.5.5 Bulk Density

Crop residue management

An analysis of soil samples was done in the laboratory and data presented in the Table clearly shows that increasing application of crop residue significantly increased the bulk density of soil at the time of harvest during both the years of investigation as well as on pooled basis (Table 4.25). The significantly minimum bulk density (1.27, 1.24 and 1.25 Mg m^{-3}) was observed with application of CR_4. However, the highest bulk density was recorded with the application of CR_1 in both the years of experimentation as well as on pooled basis.

Nutrient management

Data presented in the (Table 4.25) clearly shows that increasing dose of RDFs significantly effect on the bulk density of soil at the time of harvest during both the years of investigation as well as on pooled basis. The minimum bulk density (1.296, 1.261 and 1.278 mg m^{-3}) was recorded with control in 2019, 2020 and pooled basis respectively.

4.5.6 Particle Density

Crop residue management

An evident from data (Table 4.25) depicts that crop residue management activities did not show any significant effect on particle density of soil at harvest during both the years of experimentation *viz*., 2019, 2020 as well as on pooled basis.

Nutrient management

An evident from data (Table 4.25) illustrates that nutrient management levels failed to show any noteworthy effect on particle density of soil at harvest during both the years of experimentation during *Kharif* season of 2019 and 2020 as well as on pooled basis.

4.5.7 Porosity (%)

Crop residue management

Application of crop residue management show significant effect on porosity of soil during both the years of experimentation as well on pooled data analysis. This might be because of no significant effect of crop residues on bulk density (Table 4.26). The maximum porosity (53.15, 54.32 and 53.73%) was recorded with the application of CR_4 during 2019, 2020 and pooled basis. However, the lowest porosity was recorded with CR_1.

Nutrient management

The data shows that application of nutrient management activities had significant effect on porosity of soil during both the years of experimentation as well on pooled data analysis because of significant effect of RDFs on bulk density (Table 4.26). The increasing levels of RDFs had increased the BD of soil. The maximum porosity (52.19, 53.48 and 52.83 %) was recorded with control. Whereas, the lowest porosity was obtained in 125% RDF.

4.5.8 Water Holding Capacity

Crop residue management

In soybean use of crop residues had shown remarkable effect on water holding capacity of soil in the Chambal command area. The results shows that maximum water holding capacity of soil 49.41 per cent was recorded with the application of

CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (48.11%) and CR_2: Crop residue incorporation with irrigation during the year 2020 of investigations. However, water holding capacity was not influenced with the application of crop residues in the year 2019. On pooled basis data analysis results shows that the significantly higher water holding capacity was observed with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of treatments of crop residues. The minimum water holding capacity of soil was recorded with CR_1: Crop residue incorporation without irrigation (42.87%) which was 11.69 per cent less than the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (Table 4.26).

Nutrient management

Data (Table 4.26) indicates that the nutrient management practices had failed to show any significant effect on water holding capacity of soil. Further, on the basis of pooled analysed data depicts that the maximum water holding capacity 46.65 per cent was recorded with the application of F_4:125% RDF, which was at par with the F_3:100% RDF (46.11%). However, the minimum water holding capacity of soil was recorded with F_1: Control (44.31%) on pooled basis.

4.5.9 Soil Available Macro Nutrients

4.5.9.1 Available nitrogen

Crop residue management

The presented (Table 4.27) results revealed that crop residue management practices didn’t show any significant effect on available nitrogen in the soil at harvest of crop during both the years of experimentations. An additional study of pooled analysed data illustrates that the maximum soil available nitrogen 275.65 kg ha^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher and differing with rest of levels of crop residue management. The available nitrogen 267.05 kg ha^{-1} was analysed with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which also differing significantly with CR_2: Crop residue incorporation with irrigation (257.02 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (251.22 kg ha^{-1}). However, the minimum available nitrogen in the soil was recorded with CR_1: Crop residue incorporation without irrigation (251.22 kg ha^{-1}), which was statistically similar to the CR_2: Crop residue incorporation with irrigation (257.02 kg ha^{-1}) on pooled basis.

Nutrient management

Data (Table 4.27) specifies that the nutrient management practices had failed to show any significant effect on soil available nitrogen during both the years of experimentations. Further, on the basis of pooled analysed data illustrates that the maximum soil available nitrogen 271.70 kg ha^{-1} was recorded with the application of F_4:125% RDF, which was at par with the F_3:100% RDF (267.07 kg ha^{-1}). However, the minimum available nitrogen of soil was recorded with F_1: Control (254.05 kg ha^{-1}) on pooled basis. The application of increasing levels of RDFs from F_1: Control to F_4:125% RDF had significantly increased the soil available nitrogen by 6.95 per cent over the application of F_1: Control.

4.5.9.2 Available phosphorus

Crop residue management

The presented results (Table 4.27) revealed that crop residue management practices didn’t show any significant effect on available phosphorus in the soil at harvest of crop during both the years of experimentations. Further, on the basis of pooled analysed data illustrates that the maximum soil available phosphorus 27.16 kg ha^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher and differing with rest of levels of crop residue management. The available phosphorus 26.31 kg ha^{-1} was analysed with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which also differing significantly with CR_2: Crop residue incorporation with irrigation (25.32 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (24.75 kg ha^{-1}). However, the minimum available P in the soil was recorded with CR_1: Crop residue incorporation without irrigation (24.75 kg ha^{-1}), which was statistically dissimilar to the CR_2: Crop residue incorporation with irrigation (25.32 kg ha^{-1}) on pooled basis.

Nutrient management

The study of available phosphorus stipulates that the nutrient management practices had failed to show any significant effect on soil available phosphorus during both the years of experimentations. Further, on the basis of pooled analysed data illustrates that the maximum soil available phosphorus 26.77 kg $ha^{-1}$was recorded with the application of F_4:125% RDF, which was at par with the F_3:100% RDF (26.31 kg ha^{-1}). However, the minimum available phosphorus of soil was recorded with F_1: Control (25.03 kg ha^{-1}) on pooled basis. The application of increasing levels of RDFs from F_1: Control to F_4:125% RDF had significantly increased the soil available phosphorus by 6.95 per cent over the application of F_1: Control (Table 4.27).

4.5.9.3 Available potassium

Crop residue management

The presented results revealed that crop residue management practices didn't show any significant effect on available potassium in the soil at harvest of crop during both the years of experimentations. Further, on the basis of pooled analysed data demonstrates that the maximum soil available potassium 365.79 kg ha^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (357.64 kg ha^{-1}) and CR_1: Crop residue incorporation without irrigation (357.40 kg ha^{-1}) but differing with CR_2: Crop residue incorporation with irrigation (346.79 kg ha^{-1}) levels of crop residue management. However, the minimum available potassium in the soil was recorded with CR_2: Crop residue incorporation with irrigation (346.79 kg ha^{-1}), which was statistically dissimilar to the rest of the levels of crop residue management on pooled basis (Table 4.28).

Nutrient management

The study of application of nutrient management practices had failed to show any significant effect on soil available potassium during both the years of experimentations. Further, on the basis of pooled analysed data illustrates that the maximum soil available potassium366.42 kg $ha^{-1}$was recorded with the application of F_4:125% RDF, which was statistically at par with the F_3:100% RDF (359.61 kg ha^{-1}). However, the minimum available potassium of soil was recorded with F_1: Control

(346.91 kg ha^{-1}) on pooled basis. The application of F_4:125% RDF had significantly increased the soil available potassium by 5.63 per cent over the application of F_1: Control (Table 4.28).

4.6 SOIL AVAILABLE DTPA-EXTRACTABLE MICRONUTRIENTS

4.6.1 DTPA-extractable Zinc (Zn)

Crop residue management

Results revealed that the maximum available zinc in the soil at harvest 0.72 ppm was recorded with application of CR_2: Crop residue incorporation with irrigation, which was significantly higher over rest of the levels on pooled basis. However, the lowest available zinc content of soil 0.64 ppm was observed with application of CR_1: Crop residue incorporation without irrigation (0.64 ppm). The same trend was also observed in the year 2020 of investigation. Data further shows that during the 2019 year of experimentation, crop residues did not show any significant effect on soil available zinc concentration (Table 4.28).

Nutrient management

The scrutiny of data Table 4.28 shows that application of nutrient management practices had failed to show any significant effect on soil available zinc during both the years of experimentations. Further, on the basis of pooled analysed data proves that the thoroughgoing soil available zinc 0.71 ppm was recorded with the application of F_4:125% RDF, which was statistically at par with the F_3:100% RDF (0.70 ppm). However, the minimum available zinc in the soil was recorded with F_1: Control (0.65 ppm) on pooled basis. The application of F_4:125% RDF had significantly increased the soil available zinc by 5.63 per cent over the application of F_1: Control.

4.6.2 DTPA-extractable Iron (Fe)

Crop residue management

The analysis of data Table 4.29 shows that application of crop residue management practices had shown significant effect on soil available iron during both the years of experimentations. The maximum available iron in the soil 4.18 and 4.24 ppm was found with the supplementations of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically similar with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation in both the years of experiments. However, on the basis of pooled analysed data proves that the maximum soil available iron 4.21 ppm was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically higher over rest of the levels of crop residues management. Whereas, the minimum available iron in the soil was recorded with CR_1: Crop residue incorporation without irrigation (3.76 ppm) on pooled basis. The soil available iron with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} was 4.05 ppm, which was at par with the CR_2: Crop residue incorporation with irrigation (3.96 ppm). The per cent increase in the soil available iron with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} was 12.03 per cent as compared to CR_1: Crop residue incorporation without irrigation.

Nutrient management

The scrutiny of data Table 4.29 shows that application of nutrient management practices had failed to show any significant effect on soil available iron during 2019 year of experimentations. In the year 2020, the maximum soil available iron 4.22 ppm was recorded with F_4:125% RDF, which was statistically similar to the application of F_3:100% RDF and F_2:75 % RDF. Further, on the basis of pooled analysed data proves that the maximum soil available iron 4.19 ppm was recorded with the application of F_4:125% RDF, which was statistically at par with the F_3:100% RDF (4.15 ppm). However, the minimum available iron in the soil was recorded with F_1: Control (3.75 ppm) on pooled basis. The application of F_4:125% RDF had significantly increased the soil available iron by 11.82 per cent over the application of F_1: Control.

4.6.3 DTPA-extractable Manganese (Mn)

Crop residue management

An investigation of data Table 4.29 depicts that the maximum soil available Mn 3.95 and 4.02 ppm was observed with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3.82 and

3.86 ppm) and CR_2: Crop residue incorporation with irrigation (3.75 and 3.79 ppm) during the year 2019 and 2020 of investigations. Further analysis of data revealed that on pooled basis the maximum soil available Mn 3.98 ppm was also recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly superior over rest of the treatments. The soil available Mn 3.84 ppm was recorded with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} on pooled basis, which was statistically at par with the application of CR_2: Crop residue incorporation with irrigation. However, the minimum soil Mn was 3.53, 3.56 and 3.55 ppm was obtained with CR_1: Crop residue incorporation without irrigation in 2019, 2020 and on pooled data basis respectively.

Nutrient management

An inquiry of data Table 4.29 describes that the maximum soil available Mn 3.97 and 4.03 ppm was observed with the application of F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (3.91 and 3.97 ppm) and F_2:75 % RDF (3.64 and 3.68 ppm) during the year 2019 and 2020 of investigations. Further analysis of data revealed that on pooled basis the maximum soil available Mn 4.0 ppm was also recorded with F_4:125% RDF, which was statistically at par with F_3:100% RDF treatments. The soil available Mn 3.66 ppm was recorded with F_2:75% RDF on pooled basis. However, the minimum soil Mn was 3.54 ppm was obtained with F_1: Control in 2019, 2020 and on pooled data basis.

4.6.4 DTPA-extractable Copper (Cu)

Crop residue management

An examination of data Table 4.30 clearly shows that crop residue management practices did not show any significant effect on soil available copper at harvest of the soybean crop during the entire period of investigations.

Nutrient management

Data Table 4.30 depicts that nutrient management practices failed to show any significant influence on soil available copper concentration during 2019 and 2020 year of investigation but found significant effect on the pooled basis data analysis of the above-mentioned years. Pooled results revealed that the maximum soil available copper 2.44 ppm was recorded with the F_4:125% RDF, which was statistically similar with treatment F_3:100% RDF (2.41 ppm) but differing significantly with treatment F_2:75% RDF and F_1: Control. The minimum soil available copper was analysed in the treatment F_1: Control (2.27 ppm), which also differing significantly with F_2:75% RDF (2.34 ppm). The per cent increase in the soil available copper with the increasing levels of RDFs was 2.75, 6.16 and 7.25 per cent with the application of F_2:75 % RDF, F_3:100% RDF and F_4:125% RDF as compared to the F_1: Control on pooled basis.

4.7 BIOLOGICAL PROPERTIES

4.7.1 Alkaline Phosphatase Activity

Crop residue management

Data presented in Table 4.31 indicates that the statistically higher alkaline phosphatase activity 24.61 and 25.64 µg*p*-nitrophenol g^{-1} soilh^{-1} was observed with the treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (22.95 and 24.43 µg*p*-nitrophenol g^{-1} soilh^{-1}) and CR_2: Crop residue incorporation with irrigation (22.31 and 23.13 µg*p*-nitrophenol g^{-1} soilh^{-1}) during the year 2019 and 2020 of investigation. Further, analysis of pooled data shows that the maximum alkaline phosphatase activity 25.13 µg*p*-nitrophenol g^{-1} soilh^{-1} was also observed with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of crop residue management practices in the soybean crop. The activity of alkaline phosphatase with treatment application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, CR_2: Crop residue incorporation with irrigation and CR_1: Crop residue incorporation without irrigation on pooled basis was 23.69, 22.72 and 20.42 µg*p*-nitrophenol g^{-1} soilh^{-1} respectively was recorded, which were differing statistically with each other. However, the lowest alkaline phosphatase activity 19.57, 21.28 and 20.42 µg*p*-nitrophenol g^{-1} soilh^{-1} was observed with CR_1: Crop residue incorporation without irrigation during 2019, 2020 as well as on pooled basis data analysis, respectively.

Nutrient management

Application of various levels of nutrients showed remarkable effect on alkaline phosphatase activity during both the years as well as pooled data analysis.

Data presented in Table indicates that the statistically higher alkaline phosphatase activity 24.57 and 25.68 μg*p*-nitrophenol g^{-1} soilh^{-1} was detected with the treatment F_4:125% RDF, which was not differing significantly with F_3:100% RDF (23.09 and 24.48 μg*p*-nitrophenol g^{-1} soilh^{-1}) during the year 2019 and 2020 of investigation. Further, analysis of pooled data expressed that the maximum alkaline phosphatase activity 25.13 μg*p*-nitrophenol g^{-1} soilh^{-1} was also observed with F_4:125% RDF, which was differing significantly with rest of nutrient management practices in the soybean crop. However, the lowest alkaline phosphatase activity 20.57, 21.86 and 21.22 μg*p*-nitrophenol g^{-1} soilh^{-1} was observed with F_1: Control during 2019, 2020 as well as on pooled basis data analysis, respectively (Table 4.31).

4.7.2 Dehydrogenase Activity

Crop residue management

The statistically higher dehydrogenase activity 22.87 and 23.50 μg TPF g^{-1} 24 hr^{-1} was observed with the treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (20.65 μg TPF g^{-1} 24 hr^{-1}) during the year 2019 and differing significantly with rest of treatment means in the year 2020 of investigation. Further, analysis of pooled data shows that the maximum dehydrogenase activity 23.19 μg TPF g^{-1} 24 $hr^{-1}$was also detected with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of crop residue management practices in the soybean crop. The activity of dehydrogenase with treatment application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, CR_2: Crop residue incorporation with irrigation and CR_1: Crop residue incorporation without irrigation on pooled basis was 20.91, 19.32 and 17.82 μg TPF g^{-1} 24 hr^{-1} respectively was recorded, which were differing statistically with each other. However, the lowest dehydrogenase activity 17.54, 18.11 and 17.82 μg TPF g^{-1} 24 hr^{-1} was observed with CR_1: Crop residue incorporation without irrigation during 2019, 2020 as well as on pooled basis data analysis, respectively (Table 4.31).

Nutrient management

The study of soil biological properties indicated that the maximum dehydrogenase activity 22.30 and 22.81 µg TPF g^{-1} 24 hr^{-1} was observed with the treatment F_4:125% RDF, which was not differing significantly with F_3:100% RDF (20.72 and 21.21 µg TPF g^{-1} 24 hr^{-1}) during the year 2019 and 2020 respectively. Supplementary study of pooled data shows that the maximum dehydrogenase activity 22.56 µg TPF g^{-1} 24 $hr^{-1}$was also detected with F_4:125% RDF, which was differing significantly with rest of nutrient management practices in the soybean crop. However, the lowest dehydrogenase activity 17.80, 18.26 and 20.97 µg TPF g^{-1} 24 hr^{-1} was observed with F_1: Control during 2019, 2020 as well as on pooled basis data analysis, respectively (Table 4.31).

4.7.3 Soil Microbial Population

Crop residue management

The presented (Table 4.32) results revealed that use of crop residues in crop production had remarkable effect on soil microbial population. The statistically maximum soil microbial population 33.35, 34.21 and 33.78 cfu g^{-1} was observed with the treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was at par with the treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (33.0, 33.96 and 33.48 cfu g^{-1}) during 2019, 2020 and pooled data basis respectively. However, the minimum colony forming units 25.80, 26.46 and 26.13 cfu g^{-1} was obtained with CR_1: Crop residue incorporation without irrigation during both the years of investigation as well as on pooled data basis.

Nutrient management

The results revealed that use of nutrient management activities in crop production had remarkable effect on soil microbial population (Table 4.32). The statistically maximum soil microbial population 32.98 and 33.67 cfu g^{-1} was observed with the treatment F_4:125% RDF, which was at par with the treatment F_3:100% RDF (31.95 and 32.92 cfu g^{-1}) and F_2:75 % RDF (30.04 and 30.64 cfu g^{-1}) during 2019 and 2020 year of experimentation, respectively. However, the minimum colony forming units 25.92, 26.92 and 26.42 cfu g^{-1} was obtained with F_1: Control during both the years of investigation as well as on pooled data basis. An analysis of pooled data demonstrated that statistically maximum populations of microbes 33.32 cfu $g^{-1}$was again found with application of F_4:125% RDF, which was differing significantly with rest of levels of nutrient management. The increasing levels of nutrients had significantly increased the microbial population of soil by 26.13 per cent with application of F_4:125% RDF as compared to F_1: Control on pooled basis.

4.7.4 Soil Microbial Biomass Carbon

Crop residue management

Results revealed that the statistically highest soil microbial biomass carbon 186.22 mg kg^{-1} was analysed with treatment application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (183.40 mg kg^{-1}) on pooled data basis (Table 4.32). Data further indicated that the various levels of crop residue management failed to show any significant effect on soil microbial biomass carbon during both the years on investigations. However, the least biomass carbon was produced with CR_1: Crop residue incorporation without irrigation (173.54 mg kg^{-1}) on pooled data basis.

Nutrient management

Results revealed that the statistically highest soil microbial biomass carbon 188.47 mg kg^{-1} was assessed with treatment application of F_4:125% RDF, which was not differing significantly with the application of F_3:100% RDF (184.93 mg kg^{-1}) on pooled data basis. Data further indicated that the various levels of nutrient management did not show any significant effect on soil microbial biomass carbon during both the years on investigations. However, the least biomass carbon was produced with F_1: Control (172.20 mg kg^{-1}) on pooled data basis (Table 4.32).

4.8 DIFFERENT CHEMICAL POOLS OF CARBON

4.8.1 Total Organic Carbon

Crop residue management

An analysis of data (Table 4.33) pertaining to total organic carbon in the soil at harvest with application of crop residue management activity in soybean crop shows significant influence. The maximum total organic carbon 9.0 and 10.12 g kg^{-1}

was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically similar to that obtained with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (8.83 and 9.90 g kg^{-1}) and CR_2: Crop residue incorporation with irrigation (8.22 and 9.26 g kg^{-1}) during the year 2019 and 2020 respectively. An additional study of data Table shows that on pooled basis the maximum total organic carbon 9.56 g kg^{-1} was obtained in the plot supplied with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}. The application of CR_2: Crop residue incorporation with irrigation left 8.74 g kg^{-1} total organic carbon, which was differing significantly with CR_1: Crop residue incorporation without irrigation (8.13 g kg^{-1}). However, the lowest total organic carbon 7.67, 8.59 and 8.13 g kg^{-1} was observed with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled basis data analysis, respectively.

Nutrient management

A close examination of data (Table 4.33) depicts that nutrient management practices significantly influenced total organic carbon in the soil at harvest in soybean crop. The maximum total organic carbon 9.14 and 10.26 g kg^{-1} was recorded with the application of F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (8.57 and 9.65 g kg^{-1}) and F_2:75% RDF (8.26 and 9.35 g kg^{-1}) during the year 2019 and 2020 respectively. An additional analysis shows that on pooled basis the maximum total organic carbon 9.70 g kg^{-1} was obtained in the plot supplied with F_4:125% RDF, which was statistically superior and differing significantly with rest of levels of nutrient management. However, the lowest total organic carbon 7.76, 8.62 and 8.19 g kg^{-1} was observed with F_1: Control during 2019, 2020 and on pooled basis data analysis, respectively.

4.8.2 Dissolved Organic Carbon

Crop residue management

The maximum dissolved organic carbon 223.74 and 234.79 mg kg^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (219.10 and 231.29 mg kg^{-1}) and CR_2: Crop residue incorporation with irrigation (215.89 and 228.33 mg kg^{-1}) during the year 2019 and 2020 respectively. Further pooled basis data shows that the maximum dissolved organic carbon 229.26 mg kg^{-1} was obtained in the plot supplied with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher than other levels of crop residue management. The application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} left 225.20 mg kg^{-1} dissolved organic carbon, which was statistically similar with CR_2: Crop residue incorporation with irrigation (222.11 mg kg^{-1}). However, the lowest dissolved organic carbon 207.41, 219.03 and 213.22 mg kg^{-1} was observed with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled basis data analysis, respectively. On pooled basis the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} had significantly increased the dissolved organic carbon by 7.52 per cent as compared to the CR_1: Crop residue incorporation without irrigation application (Table 4.34).

Nutrient management

Data (Table 4.34) indicates that the maximum dissolved organic carbon 226.36 and 236.81 mg kg^{-1} was recorded with the application of F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (222.67 and 2333.04 mg kg^{-1}) in the year 2019 and 2020 and F_2:75 % RDF (227.61 mg kg^{-1}) during the year 2020 respectively. Further pooled basis data shows that the maximum dissolved organic carbon 231.59 mg $kg^{-1}$was obtained with F_4:125% RDF, which was significantly higher than other levels of nutrient management. The application of F_3:100% RDF left 227.86 mg kg^{-1} dissolved organic carbon, which was statistically higher over F_2:75% RDF (219.31 mg kg^{-1}) and F_1: Control (211.04 mg kg^{-1}). However, the lowest dissolved organic carbon 206.11, 215.97 and 211.04 mg kg^{-1} was observed with F_1: Control during 2019, 2020 and on pooled basis data analysis, respectively. On pooled basis the application of F_4:125% RDF had significantly increased the dissolved organic carbon by 9.74 per cent as compared to the F_1: Control application.

4.8.3 Hot Water Extractable Carbon

Crop residue management

Data on hot water exchangeable carbon under the influence of crop residue management are presented in the Table 4.34. The results revealed that the significantly higher hot water exchangeable carbon 0.70, 0.73 and 0.72 mg kg^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of treatments of crop residue management during both the years of experimentation and pooled basis. Data further indicated that 0.55 mg kg^{-1} hot water exchangeable carbon was recorded with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was also differing significantly with CR_2: Crop residue incorporation with irrigation (0.46 mg kg^{-1}) and CR_1: Crop residue incorporation without irrigation (0.39 mg kg^{-1}) on pooled basis of both the years of data. The minimum hot water exchangeable carbon was obtained with CR_1: Crop residue incorporation without irrigation during 2019, 2020 as well as on pooled analysis.

Nutrient management

Data (Table 4.34) revealed that nutrient management practices have significantly affected hot water exchangeable carbon of the soil at harvest of soybean crop. The results revealed that the significantly higher hot water exchangeable carbon 0.68, 0.72 and 0.70 mg $kg^{-1}$was recorded with the application of F_4:125% RDF, which was differing significantly with rest of treatments of nutrient management during both the years of experimentation and pooled basis. Data further indicated that 0.55 mg kg^{-1} hot water exchangeable carbon was recorded with F_3:100% RDF, which was also differing significantly with F_2:75% RDF (0.48 mg kg^{-1}) and F_1: Control (0.39 mg kg^{-1}) on pooled basis of both the years of data. The minimum hot water exchangeable carbon was obtained with F_1: Control during 2019, 2020 as well as on pooled analysis.

4.8.4 Particulate Organic Matter Carbon

Crop residue management

The perusal of data (Table 4.35) on particulate organic matter carbon under the influence of crop residue management are presented in the Table. The results revealed that the significantly higher particulate organic matter carbon 8.52, 8.74 and 8.63 g kg^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of treatments of crop residue management during both the years of experimentation and pooled basis. Data further indicated that 8.02 g kg^{-1} particulate organic matter carbon was recorded with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was also differing significantly with CR_2: Crop residue incorporation with irrigation (6.41 g kg^{-1}) and CR_1: Crop residue incorporation without irrigation (5.31 g kg^{-1}) on pooled basis of both the years of data. The minimum particulate organic matter carbon was obtained with CR_1: Crop residue incorporation without irrigation during 2019, 2020 as well as on pooled analysis.

Nutrient management

Data (Table 4.35) revealed that nutrient management practices have significantly affected particulate organic matter carbon of the soil at harvest of soybean crop. The results revealed that the significantly higher particulate organic matter carbon 8.18, 8.47 and 8.32 g kg^{-1} was recorded with the application of F_4:125% RDF, which was differing significantly with rest of treatments of nutrient management during both the years of experimentation and pooled basis. Data further indicated that particulate organic matter carbon 7.80 g kg^{-1} was recorded with F_3:100% RDF, which was also differing significantly with F_2:75% RDF (6.95 g kg^{-1}) and F_1: Control (5.28 g kg^{-1}) on pooled basis of both the years of data. The minimum particulate organic matter carbon 5.19, 5.38 and 5.28 g kg^{-1} was obtained with F_1: Control during 2019, 2020 as well as on pooled analysis.

4.8.5 Particulate Organic Matter Nitrogen

Crop residue management

The scrutiny of data (Table 4.35) on particulate organic matter nitrogen under the influence of crop residue management are presented in the Table. The results shows that the significantly maximum particulate organic matter nitrogen 0.53, 0.55 and 0.54 g $kg^{-1}$was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of treatments of crop residue management during both the years of experimentation and pooled basis. Data further specified that 0.46 g kg^{-1} particulate organic matter nitrogen was recorded with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was also differing significantly with CR_2: Crop residue incorporation with irrigation (0.42 g kg^{-1}) and CR_1: Crop residue incorporation without irrigation (0.37 g kg^{-1}) on pooled basis of both the years of data. The minimum particulate organic matter nitrogen was obtained with CR_1: Crop residue incorporation without irrigation during 2019, 2020 as well as on pooled analysis. The application of increasing crop residues with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} had increased the particulate organic matter nitrogen by 45.12 per cent as compared to CR_1: Crop residue incorporation without irrigation on average of both the years of experimentation.

Nutrient management

An inspection of data (Table 4.35) on particulate organic matter nitrogen under the influence of nutrient management practices are presented in the Table. The results discovered that the significantly maximum particulate organic matter nitrogen 0.49, 0.53 and 0.51 g $kg^{-1}$was recorded with the application of F_4:125% RDF, which was differing suggestively with rest of treatments of nutrient management during both the years of experimentation and pooled basis. Data additionally specified that 0.48 g kg^{-1} particulate organic matter nitrogen was recorded with F_3:100% RDF, which was also differing significantly with F_2:75% RDF (0.42 g kg^{-1}) and F_1: Control (0.38 g kg^{-1}) on pooled data of both the years of data. The minimum particulate organic matter nitrogen 0.37, 0.39 and 0.38 g kg^{-1} was obtained with F_1: Control during 2019, 2020 as well as on pooled analysis of data respectively. The application of increasing RDF had increased the particulate organic matter nitrogen by 35.70 per cent with F_4:125% RDF as compared to F_1: Control on pooled data of both the years of research.

4.8.6 Chan Pools

4.8.6.1 Very labile

Crop residue management

An evident from data Table 4.36 show that the application of crop residues had significant effect on very labile chan pools. The maximum very labile carbon 3.17, 3.38 and 3.27 g kg^{-1} was observed with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically similar to the very labile carbon with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3.13, 3.31 and 3.22 g kg^{-1}) during both the years and pooled analysis, respectively. However, the least very labile carbon 2.38, 2.53 and 2.45 g kg^{-1} was obtained with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled data basis.

Nutrient management

An apparent as of data Table 4.36 demonstrate that the application of nutrient management practices showed important consequences on very labile Chan pools. The maximum very labile carbon 3.29 and 3.48 g kg^{-1} was observed with the application of F_4:125% RDF, which was statistically similar to the very labile carbon with F_3:100% RDF (3.06 and 3.27 g kg^{-1}) during both the years *viz.*, 2019 and 2020, respectively. The analysis of pooled data shows that maximum very labile carbon 3.39 g kg^{-1} was observed with F_4:125% RDF, which was differing significantly with rest of treatment means followed by 3.17 g kg^{-1} was recorded with F_3:100% RDF, F_2:75% RDF (2.94 g kg^{-1}) and F_1: Control (2.30 g kg^{-1}). However, the least very labile carbon 2.25, 2.35 and 2.30 g kg^{-1} was obtained with F_1: Control during 2019, 2020 and on pooled data basis, respectively.

4.8.6.2 Labile

Crop residue management

An examination of data Table 4.36 show that the application of crop residues showed significant effect on labile Chan pools. The maximum labile carbon 1.30, 1.33 and 1.31 g kg^{-1}was detected with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg

ha^{-1}, which was statistically superior over rest of treatments during both the years and pooled analysis, respectively. However, the least labile carbon 0.87, 0.84 and 0.86 g kg^{-1} was obtained with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled data basis.

Nutrient management

The data demonstrated in Table 4.36 depicts that the application of nutrient management practices showed important significances on labile carbon Chan pools. The maximum labile carbon 1.14 and 1.13 g kg^{-1} was observed with the application of F_4:125% RDF, which was statistically similar to the F_3:100% RDF (1.07 g kg^{-1}) during 2019 and at par with F_3:100% RDF (1.10 g kg^{-1}) and F_1: Control (1.04 g kg^{-1}) in 2020 year of investigation, respectively. The analysis of pooled data shows that maximum labile carbon 1.14 g $kg^{-1}$was observed with F_4:125% RDF, which was differing significantly with rest of treatment means followed by 1.08 g kg^{-1} was recorded with F_3:100% RDF, F_1: Control (1.00 g kg^{-1}) and F_2:75% RDF (0.98 g kg^{-1}). However, the least labile Chan pool carbon 0.98 g kg^{-1} was obtained with F_1: Control on pooled data basis.

Interaction effect

The data Table 4.36.1 clearly depicts that the use of crop residue with nutrient management practices has significant effected labile Chan pool carbon in 2019, 2020 as well as on pooled data analysis. The results revealed that maximum labile carbon 1.43, 1.56 and 1.5 g kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_1: Control, which was significantly higher over rest of treatment combinations during both the years of experimentations and pooled data respectively.

4.8.6.3 Less labile

Crop residue management

It is clear from data Table 4.37 that maximum less labile carbon 2.23, 2.77 and 2.50 g $kg^{-1}$was observed with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over less labile carbon Chan pool recorded with rest of the treatment means of crop residue management during both the years and pooled analysis, respectively. However, the least labile carbon 1.30, 1.69 and 1.50 g kg^{-1} was obtained with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled data basis.

Nutrient management

The data (Table 4.37) on less labile carbon Chan pool presented in the Table shows that the maximum less labile carbon 2.12, 2.89 and 2.50 g kg^{-1} was detected with the application of F_4:125% RDF, which was statistically superior over less labile carbon Chan pool recorded with rest of the treatment means of nutrient management during both the years and pooled analysis, respectively. On pooled basis, data indicates that under the application of F_3:100% RDF less labile carbon 1.98 g kg^{-1} was observed, which was statistically superior over the F_2:75% RDF (1.76 g kg^{-1}) and F_1: Control (1.71 g kg^{-1}). However, the least labile carbon 1.30, 1.69 and 1.50 g kg^{-1} was obtained with F_1: Control during 2019, 2020 and on pooled data basis. The per cent increase in the less labile carbon Chan pool with application of F_4:125% RDF was 46.58 per cent with compared to F_1: Control.

Interaction effect

The data Table 4.37.1 clearly depicts that the use of crop residue with nutrient management practices has significant effected less-labile Chan pool carbon in 2019, 2020 as well as on pooled data analysis. The results revealed that maximum less labile carbon 2.66, 3.30 and 2.98 g kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_1: Control, which was significantly higher over rest of treatment combinations during both the years of experimentations and pooled data respectively. However, the minimum less labile Chan pool carbon 1.06, 1.29 and 1.18 was recorded with combined application of CR_1: Crop residue incorporation without irrigation + F_2:75 % RDF, CR_1: Crop residue incorporation without irrigation + F_1: Control and CR_1: Crop residue incorporation without irrigation + F_2:75% RDF during 2019, 2020 and pooled data, respectively.

4.8.6.4 Non-labile

Crop residue management

An analysis of data (Table 4.37) shows that the minimum non labile carbon Chan pool 2.30, 2.65 and 2.48 g $kg^{-1}$was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically lowest and differing significantly with rest of treatment means during both the years of experimentation as well as on pooled data analysis respectively. Further results revealed that the maximum non labile Chan pool carbon 3.11, 3.54 and 3.33 g kg^{-1} was noted with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and on pooled basis data respectively. The application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} has reduced the non-labile carbon by 25.56 per cent as compared to CR_1: Crop residue incorporation without irrigation on pooled data basis.

Nutrient management

The minimum non labile carbon Chan pool 2.59, 2.76 and 2.48 g kg^{-1} was recorded with F_4:125% RDF, which was statistically at par with F_3:100% RDF (2.72 and 3.04 g kg^{-1}) during both the years of experimentation whereas differing significantly with rest of levels of nutrient management on pooled basis data analysis respectively. Further results revealed that the maximum non labile Chan pool carbon 3.03, 3.33 and 3.18 g kg^{-1} was noted with F_1: Control during 2019, 2020 and on pooled basis data respectively. The application of F_4:125% RDF has reduced the non-labile Chan pool carbon by 15.91 per cent as compared to F_1: Control on pooled data basis (Table 4.37).

Interaction effect

The data Table 4.37.2 clearly depicts that the use of crop residue with nutrient management practices has significant effected non-labile Chan pool carbon in 2020 as well as on pooled data analysis. The results revealed that maximum non labile carbon 3.97 and 3.64 g kg^{-1} was recorded with CR_1: Crop residue incorporation without irrigation + F_2:75 % RDF, which was statistically at par with CR_1: Crop residue incorporation without irrigation + F_1: Control (3.80 and 3.54 g kg^{-1}) and significantly higher over rest of treatment combinations during 2020 and pooled data, respectively.

4.8.7 Carbon Mineralization

4.8.7.1 At 15 DAS

Crop residue management

Under crop residue management practices maximum carbon mineralization 0.200 (mg CO_2 100 g^{-1}) soil at 15 DAS was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 (mg CO_2 100 g^{-1}), which was significantly higher over rest of the levels of crop residue management treatments during both the years as well as on pooled basis data. Data further indicates that the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} mineralized 0.153 (mg CO_2 100 g^{-1}) carbon at 15 DAS, which was differing significantly with CR_2: Crop residue incorporation with irrigation (0.127 mg CO_2 100 g^{-1}) and CR_1: Crop residue incorporation without irrigation (0.118 mg CO_2 100 g^{-1}) during all the time of research. However, the lowest carbon mineralization 0.118 (mg CO_2 100 g^{-1}) was observed with CR_1: Crop residue incorporation without irrigation, which was statistically similar to the CR_2: Crop residue incorporation with irrigation (0.127 mg CO_2 100 g^{-1}). The use of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} has increased the mineralization of carbon by 69.99 per cent as compared to the CR_1: Crop residue incorporation without irrigation at 15 DAS on pooled basis (Table 4.38).

Nutrient management

The maximum carbon mineralization 0.174 and 0.177 (mg CO_2 100 g^{-1}) at 15 DAS was recorded with F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (0.160 and 0.162 mg CO_2 100 g^{-1}) during both the years of investigation. Data further indicates that the application of F_4:125% RDF mineralized 0.176 (mg CO_2 100 g^{-1}) carbon at 15 DAS on pooled basis, which was differing significantly with F_3:100% RDF, F_2:75% RDF and F_1: Control. However, the lowest carbon mineralization 0.123 (mg CO_2 100 g^{-1}) was observed with F_1: Control during both the years of investigation as well as on pooled basis data. The practice of F_4:125% RDF has increased the mineralization of carbon by 43.39 per cent as compared to the F_1: Control at 15 DAS on pooled basis (Table 4.38).

4.8.7.2 At 30 DAS

Crop residue management

The perusal of data (Table 4.38) clearly shows that crop residue management practices have significantly influenced carbon mineralization. The maximum carbon mineralization 0.390 (mg CO_2 100 g^{-1}) at 30 DAS was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher over rest of the levels of crop residue management treatments during both the years as well as on pooled basis data. Data further indicates that the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} mineralized (0.284 mg CO_2 100 g^{-1}) carbon at 30 DAS, which was differing significantly with CR_2: Crop residue incorporation with irrigation (0.239 mg CO_2 100 g^{-1}) and CR_1: Crop residue incorporation without irrigation (0.221 mg CO_2 100 g^{-1}) on the basis of pooled data. However, the lowest carbon mineralization 0.221 (mg CO_2 100 g^{-1}) was observed with CR_1: Crop residue incorporation without irrigation, which was statistically similar to the CR_2: Crop residue incorporation with irrigation (0.239 mg CO_2 100 g^{-1}) in the year 2019 and 2020 but differing significantly on pooled basis. The use of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} has increased the mineralization of carbon by 76.41 per cent as compared to the CR_1: Crop residue incorporation without irrigation at 30 DAS on pooled basis.

Nutrient management

The maximum carbon mineralization 0.333 and 335 (mg CO_2 100 g^{-1}) at 30 DAS was recorded with F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (0.302 and 0.307 mg CO_2 100 g^{-1}) during both the years of investigation respectively. Data further indicates that the application of F_4:125% RDF mineralized 0.335 (mg CO_2 100 g^{-1}) carbon at 30 DAS on pooled basis, which was differing significantly with F_3:100% RDF, F_2:75% RDF and F_1: Control. However, the lowest carbon mineralization 0.229, 0.235 and 0.232 (mg CO_2 100 g^{-1}) was observed with F_1: Control during both the years of investigation as well as on pooled basis data respectively. The practice of F_4:125% RDF has increased the mineralization of carbon by 44.52 per cent as compared to the F_1: Control at 30 DAS on pooled basis (Table 4.38).

Interaction effect

The data Table 4.38.1 clearly depicts that the application of crop residue with nutrient management practices has significant effected carbon mineralization at 30 DAS on pooled data analysis. The results revealed that maximum carbon mineralization 0.438 (mg CO_2 100 g^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was significantly higher over rest of treatment combinations on pooled data basis, followed by CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (0.419 g kg^{-1}) also differing significantly superior over rest of the combinations. However, the lowest carbon mineralization 0.178 (mg CO_2 100 g^{-1}) was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control combination of treatment at 30 DAS on pooled basis.

4.8.7.3 At 60 DAS

Crop residue management

The scrutiny of data Table 4.39 clearly shows that crop residue management practices have significantly influenced carbon mineralization. The maximum carbon mineralization 0.608 (mg CO_2 100 g^{-1}) at 60 DAS was logged with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher over rest of the levels of crop residue management treatments during both the years as well as on pooled basis data. Data further indicates that the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} mineralized 0.462 (mg CO_2 100 g^{-1}) carbon at 60 DAS, which was differing significantly with CR_2: Crop residue incorporation with irrigation (0.404 mg CO_2 100 g^{-1}) and CR_1: Crop residue incorporation without irrigation (0.372 mg CO_2 100 g^{-1}) on the basis of pooled data. However, the lowest carbon mineralization 0.372 (mg CO_2 100 g^{-1}) was observed with CR_1: Crop residue incorporation without irrigation, which was statistically differing to the CR_2: Crop residue incorporation with irrigation (0.404 mg CO_2 100 g^{-1}) on pooled basis. The use of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} has increased the mineralization of carbon by 63.66 per cent as compared to the CR_1: Crop residue incorporation without irrigation at 60 DAS on pooled basis.

Nutrient management

The maximum carbon mineralization 0.542 and 0.542 (mg CO_2 100 g^{-1}) at 60 DAS was recorded with F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (0.492 and 0.500 mg CO_2 100 g^{-1}) during both the years of investigation respectively. Data further indicates that the application of F_4:125% RDF mineralized 0.542 mg CO_2 100 g^{-1} carbon at 60 DAS on pooled basis, which was differing significantly with F_3:100% RDF, F_2:75% RDF and F_1: Control. However, the lowest carbon mineralization 0.379 (mg CO_2 100 g^{-1}) was observed with F_1: Control during both the years of investigation as well as on pooled basis data respectively. The application of F_4:125% RDF has increased the mineralization of carbon by 42.87 per cent as compared to the F_1: Control at 60 DAS on pooled basis (Table 4.39).

Interaction effect

The data Table 4.38.1 clearly depicts that the application of crop residue with nutrient management practices has significant effected carbon mineralization at 60 DAS on pooled data analysis. The results revealed that maximum carbon moralization 0.677 (mg CO_2 100 g^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was significantly higher over rest of treatment combinations on pooled data basis, followed by CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (mg CO_2 100 g^{-1}) also differing significantly superior over rest of the combinations. However, the lowest carbon mineralization 0.297 (mg CO_2 100 g^{-1}) was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control combination, which was 127.95 per cent lower than the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF treatment combination at 60 DAS on pooled basis.

4.8.7.4 At 90 DAS

Crop residue management

An analysis of data Table 4.39 clearly indicates that crop residue management practices have significantly inclined carbon mineralization. The maximum carbon mineralization 0.816 (mg CO_2 100 g^{-1}) at 90 DAS was logged with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was suggestively superior over rest of the levels of crop residue management treatments on pooled basis data. Data further indicates that the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} mineralized 0.625 (mg CO_2 100 g^{-1}) carbon at 90 DAS, which was differing significantly with CR_2: Crop residue incorporation with irrigation (0.551 mg CO_2 100 g^{-1}) and CR_1: Crop residue incorporation without irrigation (0.505 mg CO_2 100 g^{-1}) on the basis of pooled data. However, the lowest carbon mineralization 0.505 (mg CO_2 100 g^{-1}) was observed with CR_1: Crop residue incorporation without irrigation, which was statistically differing to the CR_2: Crop residue incorporation with irrigation (0.551 mg CO_2 100 g^{-1}) on pooled basis. The use of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} has increased the mineralization of carbon by 61.59 per cent as compared to the CR_1: Crop residue incorporation without irrigation at 90 DAS on pooled basis.

Nutrient management

An examination of data Table 4.39 depicts that the maximum carbon mineralization 0.724 and 0.744 (mg CO_2 100 g^{-1}) at 90 DAS was recorded with F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (0.664 and 0.675 mg CO_2 100 g^{-1}) during both the years of investigation respectively. Data further indicates that the application of F_4:125% RDF mineralized 0.734 (mg CO_2 100 g^{-1}) carbon at 90 DAS on pooled basis, which was differing significantly with F_3:100% RDF, F_2:75% RDF and F_1: Control. However, the lowest carbon mineralization 0.509, 0.521 and 0.515 (mg CO_2 100 g^{-1}) was observed with F_1: Control during both the years of investigation as well as on pooled basis data respectively. The application of F_4:125% RDF has increased the mineralization of carbon by 42.42 per cent as compared to the F_1: Control at 60 DAS on pooled basis.

Interaction effect

The data Table 4.38.1 clearly depicts that the application of crop residue with nutrient management practices has significant effected carbon mineralization at 90 DAS on pooled data analysis. The results revealed that maximum carbon moralization 0.907 (mg CO_2 100 g^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF, which was significantly higher over rest of treatment combinations on pooled data basis, followed by CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_3:100% RDF (0.851 mg CO_2 100 g^{-1}) also differing significantly superior over rest of the combinations. However, the lowest carbon mineralization 0.403 (mg CO_2 100 g^{-1}) was obtained with CR_1: Crop residue incorporation without irrigation + F_1: Control combination, which was 125.06 per cent lower than the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4:125% RDF treatment combination at 60 DAS on pooled basis.

4.8.8 Water Soluble Carbon

Crop residue management

An analysis of data Table 4.40 clearly indicates that crop residue management practices have significantly inclined water-soluble carbon. The maximum water-soluble carbon 67.71, 69.41 and 68.56 mg kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was suggestively superior over rest of the levels of crop residue management treatments during both the years and pooled basis data respectively. Data further indicates that 58.94 mg kg^{-1} water soluble carbon was recorded with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was differing significantly with CR_2: Crop residue incorporation with irrigation (53.48 mg kg^{-1}) and CR_1: Crop residue incorporation without irrigation (50.22 mg kg^{-1}) on the basis of pooled data. However, the lowest water-soluble carbon 50.22 mg kg^{-1} was observed with CR_1: Crop residue incorporation without irrigation, which was differing significantly with the CR_2: Crop residue incorporation with irrigation (53.48 mg kg^{-1}) on pooled basis. The use of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} has increased the water-soluble carbon by 36.52 per cent as compared to the CR_1: Crop residue incorporation without irrigation on pooled basis.

Nutrient management

The study of effect of nutrient management on water soluble carbon shows that the maximum water-soluble carbon 67.26, 69.47 and 68.37 mg kg^{-1} was recorded with F_4:125% RDF, which was enticingly superior over rest of the levels of nutrient management during both the years and pooled basis data respectively. Data further indicates that 59.08 mg kg^{-1} water soluble carbon was recorded with application of F_3:100% RDF, which was differing significantly with F_2:75% RDF (53.98 mg kg^{-1}) and F_1: Control (49.76 mg kg^{-1}) on the basis of pooled data. However, the lowest water-soluble carbon 49.76 mg kg^{-1} was observed with F_1: Control, which was differing significantly with the F_2:75% RDF (53.98 mg kg^{-1}) on pooled basis. The application of F_4:125% RDF has increased the water-soluble carbon by 37.39 per cent as compared to the F_1: Control on pooled basis (Table 4.40).

4.8.9 Water Soluble Carbohydrates

Crop residue management

The scrutiny of data (Table 4.40) evidently specifies that crop residue management practices have significantly inclined water-soluble carbohydrates. The maximum water-soluble carbohydrates 4.40, 4.51 and 4.46 mg kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was encouragingly higher over rest of the levels of crop residue management throughout both the years of research and pooled basis data respectively. Data further indicates that 4.19 mg kg^{-1} water soluble carbohydrates was recorded with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was differing significantly with CR_2: Crop residue incorporation with irrigation and CR_1: Crop residue incorporation without irrigation on the basis of pooled data. However, the lowest water-soluble carbohydrates 3.29 mg kg^{-1} was observed with CR_1: Crop residue incorporation without irrigation, which was differing significantly with the CR_2: Crop residue incorporation with irrigation (3.65 mg kg^{-1}) on pooled basis.

Nutrient management

The study of effect of nutrient management on water soluble carbohydrates shows that the maximum water-soluble carbohydrates 4.41, 4.56 and 4.48 mg kg^{-1} were recorded with F_4:125% RDF, which was enticingly higher over rest of the echelons of nutrient management during both the years and pooled basis data respectively. Data further indicates that 4.07 mg kg^{-1} water soluble carbohydrates were recorded with application of F_3:100% RDF, which was differing significantly with F_2:75% RDF (3.64 mg kg^{-1}) and F_1: Control (3.39 mg kg^{-1}) on the basis of pooled data. However, the lowest water-soluble carbohydrates 3.39 mg kg^{-1} was observed with F_1: Control, which was differing significantly with the F_2:75% RDF on pooled basis. The application of F_4:125% RDF has increased the water-soluble carbohydrates by 32.14 per cent as compared to the F_1: Control on pooled basis (Table 4.40).

4.9 ECONOMICS

4.9.1 Net Return

Crop residue management

The statistically higher net return ` 51976 and 53379 ha^{-1} was gained with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was at par with the net return gained with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (48403 and 49165 ` ha$^{-1}$) during the year 2019 and 2020 of experimentation respectively. On pooled basis data analysis, the significantly higher net return ` 52678 ha^{-1} was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly over rest of the treatments of crop residue management. A net return of `48784 ha$^{-1}$ was recorded with treatment $CR_3$: Crop residue incorporation with irrigation and application of urea @ 25 kg ha$^{-1}$, which was also significantly higher over $CR_2$: Crop residue incorporation with irrigation (` 45493 ha^{-1}) and CR_1: Crop residue incorporation without irrigation (` 31363 ha$^{-1}$) on pooled basis data. However, the lowest net return ` 31363 ha^{-1} was recorded with CR_1: Crop residue incorporation without irrigation, which was 67.96 per cent lower than the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} on the basis of means of both the years of experimentations (Table 4.41).

Nutrient management

The statistically higher net return ` 51309, 52672 and 51991 ha$^{-1}$ was gained with the application of $F_4$:125% RDF, which was at par with the net return gained with $F_3$:100% RDF (50236, 51844 and 51040 ` ha^{-1}) during the year 2019, 2020 and pooled basis respectively. On pooled basis data analysis, treatment F_2:75 % RDF net return of ` 40157 ha$^{-1}$, which was statistically at par with $F_1$: Control (` 35129 ha^{-1}) However, the lowest net return ` 33747, 36512 and 35129 ha^{-1} was recorded with F_1: Control during both the years of experimentation and on pooled data basis respectively (Table 4.41).

4.9.2 B:C Ratio

Crop residue management

The statistically higher BC ratio 2.05 and 2.11 was obtained with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (1.91 and 1.94) during the year 2019 and 2020 of experimentation respectively. On pooled basis data analysis, the pointedly higher benefit cost ratio 2.08 was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly over rest of the treatments of crop residue management. A BC ratio of 1.93 was recorded with treatment CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was also significantly higher over CR_2: Crop residue incorporation with irrigation (1.80) and CR_1: Crop residue incorporation without irrigation (1.27) on pooled basis data. However, the lowest BC ratio 1.23, 1.32 and 1.27 was recorded with CR_1: Crop residue incorporation without irrigation during 2019, 2020 and pooled basis, respectively (Table 4.41).

Nutrient management

The statistically higher benefit-cost ratio 1.95, 2.01 and 1.98 was recorded with the application of F_3:100% RDF, which was at par with the F_4:125% RDF (1.92, 1.97 and 1.95) during the year 2019, 2020 and pooled basis respectively. On pooled basis data analysis, 1.59 B-C ratio was obtained with treatment F_2:75% RDF, which was statistically at par with F_1: Control (1.57). However, the lowest BC ratio 1.50, 1.62 and 1.57 was recorded with F_1: Control, F_2:75% RDF and F_1: Control during 2019, 2020 year of experimentation and on pooled data basis, respectively (Table 4.41).

5. DISCUSSION

Substantial changes were documented for a number of parameter studies for treatment evaluation during the presentation of the findings of the experiment entitled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area"** in the preceding chapter. In this chapter, an attempt is made to discuss the important results acquired and reconcile them into some concrete idea in order to explain the treatment differences in terms of test crop growth and production. Experimental findings and observation of other workers have been cited to support the result of present investigation. The entire discussion has been confined as following:

5.1 EFFECT OF CROP RESIDUES MANAGEMENT

5.1.1 Effect of Crop Residues Management on Growth

Results revealed that application of crop residue incorporation with or without irrigation, urea and cellulolytic microbes significantly increased soybean growth attributes *viz*., plant height, chlorophyll content, number of total and effective root nodules, fresh and dry weight of nodules and leghaemoglobin content in the root nodules during both the years of investigation as well as pooled data basis. The maximum plant height (44.92, 45.07 and 45.0 cm), total nodules plant^{-1} (62.85, 64.41 and 63.63), effective nodules plant^{-1} (25.08, 25.54 and 25.31), nodules fresh weight (273.53, 248.73 and 240.13 mg plant^{-1}), nodules dry weight (71.07, 72.82 and 71.95 mg plant^{-1}), leghaemoglobin content (2.31, 2.37 and 2.34mg g^{-1}) and chlorophyll content (4.10, 4.19 and 4.14 mg g^{-1}) was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher over rest of the treatment means of crop residue management but statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} in case of total nodules plant^{-1}(59.74, 61.13 and 60.44) in the years 2019, 2020 and on pooled basis data analysis. Increase in growth attributes of soybean is due to decomposition of crop residues, which can enhance soil structure, supply plant nutrients, reduce soil erosion, increase organic matter content in the soil, act as mulch and decrease evaporation, modify soil temperature and reduce weed growth and help to fix CO_2 in the soil, which might have resulted in better root growth, higher uptake of nutrients and ultimately increased the plant height of soybean. Crop residue mulch increases soil aeration by facilitating free exchange of gases between the soil and the atmosphere, which might have encouraged by rise of structural stability, porosity, less surface crusting and by improving the overall soil drainage. Increased plant growth parameters as a result of crop residue integration may be due to the addition of nutrients or an increase in nutrient availability due to the complexing properties of crop residues. Which have increased the total and effective nodules, chlorophyll content of leaves resulting increased accumulation of photosynthates, which have increased the growth attributes of soybean crop. These results are closely in conformity with findings of Meena *et al*. (2011) and Ravi *et al*. (2019).

5.1.2 Effect of Crop Residues Management on Yield Attributes and Yield

Application crop residues with urea and cellulolytic bacteria significantly increased the yield attributes and yield of soybean crop. It was observed that the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} produced significantly higher pods $plant^{-1}$, seeds pod^{-1} and test weight during the period of investigation. It was reported that the maximum pods $plant^{-1}$ (73.77, 73.92 and 73.85) was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher over rest or levels of crop residue management. The maximum number of seed pod^{-1} (3.76, 3.8 and 3.78) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3.6, 3.64 and 3.62). Statistically maximum test weight was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (112.31, 112.23 and 112.27 g), which was also at par with the supply of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (110.91, 110.40 and 110.65 g). Further, results revealed that the maximum seed yield (1758.27, 1790.76 and 1774.52 kg ha^{-1}), haulm yield (3437.54, 3494.09 and 3465.81 kg ha^{-1}) and biological yield (5195.81, 5284.85 and 5240.33 kg ha^{-1}) was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea

@ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}. Use of crop residue with cellulolytic bacteria and urea might have slowly decomposed the crop residues applied in the field. Which have resulted in the slow release and made availability of plant nutrients in the soil to plants. Crop residue also reduced the evaporation of soil moisture, maintained soil temperature and soil structure, which have increased the emergence (Singh, 2009) of seeds and optimum for plant growth and development. Ravi *et al.*, (2019) also found that application of crop residues along with RDFs significantly increased branches per plant, pods per plant, seed index, haulm and seed yield of soybean. Crop residue management is a well-known and generally recognized method of managing the physical, chemical, and biological functions of soil. Crop residues returns the fertility of soil by releasing the essential plant nutrients, increasing soil organic matter, aeration and porosity, decreasing soil bulk density and keeping the soil moist, which will be favourable for bumper growth resulting in increased photosynthesis, more accumulation of photosynthates in the sink and producing a greater number of branches, pods per plants, seeds per pod, weight of seeds consequently increased seed and haulm yield. A highly significant correlation among yield, growth and yield attributes were observed (Table 5.1). A highly significant and positive correlation between yield and plant height (r = 0.876**), effective nodules (r= 0.854**), nodules fresh weight (r = 0.823**), pods $plant^{-1}$ (r = 0.844**), seeds pod^{-1} (r =0.797**) and test weight (r = 0.915**) affirms the role of growth and yield characters in the increasing the grain yield and 90.20 per cent of variation can be explained together by these independent variables. The increased soil available nutrients, soil microbial population and soil organic carbon, increased nitrogen fixation and soil biological property are favourable for better plant growth and development, which results in increased seed and straw yield of soybean crop. These results are closely related to the findings of Singh, (2009) and Ravi *et al.* (2019).

5.1.3 Effect of Crop Residues Management on Nutrient Content and Uptake by Seed and Haulm of Soybean Crop

The analysis of plant samples revealed that application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} have maximum nitrogen content of haulm (2.17, 2.20 and 2.19%), phosphorus content of seed (0.246, 0.253 and 0.249%) and haulm (0.129, 0.130 and 0.130%) and potassium content of seed (1.06, 1.08 and 1.07%) and haulm (2.72, 2.76 and 2.74%) which were remained at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during both the years of experimentation as well as on pooled analysis. Further the crop supplied with aforesaid crop residue management practices accumulated significantly higher micro nutrients *viz*., Fe, Zn, S, Cu, Mn in both seed and haulm during both the years of carrying out tests as well as on pooled analysis. Crop residue is well-known and generally accepted method of managing the physical, chemical, and biological functions of soil. Crop residues influence soil water flow, drainage, and infiltration by incorporating a significant amount of nutrients in the soil for crop production. According to reports, various vital inorganic nutrient for plant growth is released by soil, air, and water, all of which have a great deal of contact with plants. Plant availability of NPK nutrients from crop residues mostly depends on different soil physical, chemical, and biological processes. Hence, application of crop residues with proper irrigation, cellulolytic bacteria and application of urea significantly improved the soil available plant nutrient by the recycling and decomposing the crop residues, which have increased the uptake of plant nutrient by seed and haulm of crop. Moharana *et al.* (2014) reported the matured rock phosphate enriched compost contained higher bioavailable P as well as total P content. Meena and Biswas (2014) found that application of enriched compost along with recommended rate of inorganic fertilizer had increased concentrations of saloid P, iron (Fe) P, aluminum (Al) P, Ca-P, occluded P, water-soluble K, exchangeable K, and nonexchangeable K over the control. Furthermore, data revealed that uptake of nitrogen, phosphorus, potassium and micronutrients such as zinc, iron, sulphur, copper, and manganese at harvest was significantly increased with application of various crop residue management practices. The application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} gave highest uptake of nitrogen by seed (107.32, 109.42 and 108.37 kg ha^{-1}) and haulm (74.98, 77.03 and 76.00 kg ha^{-1}), phosphorus by seed (4.34, 4.54 and 4.44 kg ha^{-1}) and haulm (4.45, 4.56 and 4.50 kg ha^{-1}), potassium uptake by seed (18.65, 19.50 and 19.07 kg ha^{-1}) during both the years of research and pooled analysis, which were remained statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during both the years of experimentations. This might be due to the increased plant nutrient content in the seed and haulm of soybean crop, optimum available soil moisture throughout the cropping period due to crop residues and growth of plants leads to maximum uptake of macro and micro nutrients.

5.1.4 Effect of Crop Residues Management on Physico-Chemical Properties of Soil

The use of crop residues significantly maintained the soil health by building up organic matter in the soil and maintaining optimum soil moisture. Crop residues with or without irrigation and urea application significantly affected the physical and chemical properties of the soil. Application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} significantly increased the soil organic carbon (0.69 g kg^{-1}), which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} on pooled basis. The statistically higher CEC was also recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}{25.50 mol (P^+) kg^{-1}}. However, the minimum soil pH (7.45, 7.44 and 7.43), EC (0.301, 0.285 and 0.293 dSm^{-1}) bulk density (1.27, 1.24 and 1.25 Mg m^{-3}) and maximum porosity (53.15, 54.32 and 55.73%) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} but remained unaffected with the application of various crop residue management practices. Applications of crop residues recover soil exposure to air by promoting free exchange of gases between soil and atmosphere. This is facilitated by improvement of structural stability, porosity, and decrease of surface crusting and by improving the overall soil drainage. The maximum water holding capacity (46.36, 49.41 and 47.88%) was obtained with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which remained at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} and CR_2: Crop residue incorporation with irrigation during both the years but significantly higher over rest of treatments on pooled data basis. Crop residues reduce the evaporation and loss of moisture, which consequently increases the water holding capacity of soil. Choudhury *et al.* (2018) observed that long-term (6 years) incorporation of organics sequestered 1.5- and 2.0-times higher soil organic carbon as compared to the balanced inorganic. Similarly, Ghosh *et al.* (2018) also found that application of mineral fertilizers with different organic sources like FYM, vermi-compost, green manure and poultry manure had enhanced soil aggregation and had significantly higher Walkley-Black carbon (WBC), total soil organic C (TOC), LOC, macroaggregate- associated C concentrations, and soil aggregation compared to other treatments. Further, results revealed that the maximum soil available nutrients were affected significantly with the application of crop residues with irrigation and urea. The significantly maximum available nitrogen (275.65 kg ha^{-1}), phosphorus (27.16 kg ha^{-1}), potassium (365.60 kg ha^{-1}) was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}. The significantly maximum DTPA extractable zinc (0.72 mg kg^{-1}) was recorded with the supply of CR_2: Crop residue incorporation with irrigation. The higher DTPA extractable Mn (3.98 mg kg^{-1}) was also recorded higher with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}. However, application of various crop residue management practices did not show any significant effect on DTPA extractable copper at the harvest. The application of residue reduces the detachment of soil particle by the force of wind and water, which reduces the soil erosion and protects the soil from losses. The decaying crop residues in the soil also release the organic matter and nutrients, which might have increased the soil nutrient status and resulted in the higher availability of soil nutrients. Application of crop residue with urea resulted in significant improvement in the build-up of the available nutrients of subsurface soil. So, it is clear that application of crop residues with urea and cellulolytic bacteria increased the available nutrients in soil is attributed to the increase in total organic carbon that might have been partially due to a slow release of plant nutrients from crop residues and fertilizers. Verma and Goyal (2018) also found that the organic carbon, available N, P, K, micronutrients, microbial biomass carbon, microbial biomass nitrogen, microbial biomass phosphorus and biomass C/N ratio of soil was found higher under the application of organic manures. The results are in line with the findings of Kalhapure *et al.* (2013).

5.1.5 Effect of Crop Residues Management on Biological Properties of Soil

The significant improvement in the biological property of soil was observed with the application of crop residue with or without irrigation and nitrogen application. Crop residues significantly increased the microbial carbon biomass, total colony forming units, alkaline phosphatase and dehydrogenase activity of the soil at harvest of the crop. The results revealed that the maximum soil microbial carbon biomass (183.59, 188.84 and 186.40 mg kg^{-1}), soil microbial population (33.35, 34.21 and 33.78 10^8 CFUs g^{-1}), dehydrogenase activity (22.87, 23.50 and 23.19 µg TPF g^{-1} 24 hr^{-1}) and alkaline phosphatase activity (24.61, 25.64 and 25.13 µg*p*-nitrophenol g^{-1} soilh^{-1}) was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was remained at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during both the years of experimentation. The addition of organic manures and crop residues might have increased the soil organic carbon, which is most important component to determine the soil health. There was a highly positive and significant correlation between total organic carbon and microbial carbon biomass ($r = 0.96^{**}$), Total CFUs ($r = 0.97^{**}$), alkaline phosphatase activity ($r = 0.97^{**}$) and dehydrogenase activity ($r = 0.97^{**}$), which indicates that increased organic matter might have improved the microbial activity in the soil resulting increased soil microbial population and enzymatic activities. Similarly, Sharma *et al.* (2011) found a significant increase in carbon mineralization, soil microbial biomass carbon and soil dehydrogenase activity with increasing organic amendment.Similar results were also had been reported by Boggs *et al*. (2000) who found highest microbial biomass C in soils treated with organic manures followed by inorganic fertilizers. These results are closely in conformity with the findings of Verma and Goyal (2018), Goyal *et al*. (2000), Leite *et al*. (2009), Gong *et al*. (2009) and Kong *et al*. (2011) who reported that the soil microbial application of organic manures and crop residues significantly increase the soil microbial activity, soil microbial biomass and soil microbial carbon.

5.1.6 Effect of Crop Residues Management on Different Chemical Pools of Carbon

An analysis of soil samples was done and studied the effect of crop residues on carbon Chan pool revealed that supplementation of crop residue in soybean crop significantly altered the soil carbon Chan pool. Results revealed that the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} had significantly influenced the soil microbial carbon, total organic carbon, dissolved organic carbon, hot water extractable carbon, particulate organic carbon and nitrogen. The statistically higher total organic carbon (9.0, 10.12 and 9.56 g kg^{-1}), dissolved organic carbon (223.74, 234.79 and 229.26 mg kg^{-1}) and hot water extractable carbon (0.70, 0.73 and 0.72 g kg^{-1}) was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} during both the years of investigation as well as on pooled data analysis. Soil organic carbon (SOC) generally increases with carbon input before the soil become carbon saturated. Inorganic fertilizer alone or in combination with organic manures, has been widely shown to increase SOC content (Purakayastha *et al.,* 2008). The statistically higher particulate organic matter carbon (8.52, 8.74 and 8.63 g kg^{-1}) and particulate organic matter nitrogen (0.53, 0.55 and 0.54 g kg^{-1}) was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} during both the years of investigation as well as on pooled data analysis. Particulate organic matter C (POM−C) being considered as a measure of labile SOM (active C fraction) is primarily of plant−derived remains with recognizable cell structure and typically includes fungal spores, hyphae, and charcoal (Spycher *et al.,* 1983, Waters and Oades, 1991; Gregorich and Ellert, 1995) which are generally physically protected inside the macro aggregates (Camberdella and Elliot, 1992, Six *et al.,* 1998). Measures of POM have been tied to microbial growth and nutrient supply and suggest that it is closely related to biologically mediated C, N and in some soils P availability (Gregorich *et al.,* 1994, Hasssink, 1995, Barrios *et al*., 1996, Wander and Bollero, 1999). Particulate organic matter carbon fraction is affected by application of residue, aggregation and aggregate mineralization (Chan 2001). The large pool of particulate organic matter maintains soil structure and macro-aggregation (Campbell *et al*. 1999). These pools enhance labile and stabilized SOM fractions in the soil. The statistically higher Chan pool carbon very labile (3.17, 3.38 and 3.27 g kg^{-1}), labile (1.30, 1.33 and 1.31 g kg^{-1}) and less labile (2.23, 2.77 and 2.50 g kg^{-1}) was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} during both the years of experimentation and pooled data basis. However, the minimum non labile Chan pool carbon (2.30, 2.65 and 2.48 g kg^{-1}) was reported with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}. Total and labile SOC concentrations were probably enhanced by substantial build up in C inputs with organic manures, stubble, root biomass, rhizodeposition and manure (Ghosh *et al*., 2012; Das *et al*., 2013). The increasing trend of labile carbon in soils along with fertilization and manuring could be explained by the amount of C input as the rate of labile C change is directly related to C inputs from organic amendments and stubble, root biomass and rhizodeposition (Hassink 1995; Jastrow *et al*., 2007). The higher amount of organic matter input in NPK+FYM (from stubble, root biomass, rhizodeposition and manure) treatments promoted labile C concentration in the soil and higher amounts of root biomass and exudates in the soils with NPK+organic manure treatments, recorded significantly higher grain and straw yields throughout the experimental duration than the unfertilized control and NPK treatments (Gregorich *et al.,* 1995; Fan *et al.,* 2005; Prakash *et al.,* 2007).

Higher soil microbial population with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} facilitated the conversion of crop residue carbon to SOC, leading to higher SOC as evidenced by Choudhary *et al*. (2018a, b) in CA-based maize-wheat system after 3 years of continuous cultivation in NW India. Phalke *et al.* (2017) found that incorporation of crop residues along with fertilizers substantially improved labile carbon pools. The similar results are also corroborated with the finding of Manna *et al*. (2007a,b). Further an analysis of data revealed that the application of crop residues along with irrigation and urea fertilizers had significantly increased the carbon mineralization at 15, 30, 60 and 90 DAS. The significantly higher carbon was mineralized with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} at 15 DAS (0.200 mg CO_2 100 g^{-1} soil), 30 DAS (0.390 mg CO_2 100 g^{-1} soil), 60 DAS (0.608 g kg^{-1}) and 90 DAS (0.821 g kg^{-1}) on pooled basis data. The maximum water-soluble carbohydrates (4.46 g kg^{-1}) and carbon (68.56 g kg^{-1}) was also significantly higher with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}. This might be due to the increased microbial population at different stages of crop growth, which have mineralised the soil organic carbon. Debosz *et al*. (2002) also opined that the application of organic amendments had significantly increased mineralization of nutrients in the soil. The results are in line with the findings of Choudhury *et al.* (2018), Ghosh *et al.* (2018) and Naresh *et al.* (2018).

5.1.7 Effect of Crop Residues Management on Economics

Application of crop residue has significantly increased the returns and benefit cost ratio of soybean crop during both the years as well as pooled analysis. The results revealed that the maximum net return 51976 and 53379 ha^{-1} was gained with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was remained at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during both the years of experimentations. However, on pooled analysis the maximum net return 52678 ha^{-1} was with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher over rest of the treatments. Similarly higher benefit cost ratio 2.05, 2.11 and 2.08 was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was remained at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during 2019 and 2020 but significantly higher over rest of the treatments on pooled data analysis respectively. The increased net return and benefit cost ratio is due to the higher seed yield produced with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} and less cost of inputs. These results closely in corroborate with the findings of Ravi *et al.* (2019).

5.2 EFFECT OF NUTRIENT MANAGEMENT

5.2.1 Effect of Nutrient Management on Growth

Results revealed that application of recommended dose of fertilizers has significantly increased soybean growth attributes *viz*., plant height, chlorophyll content, number of total and effective root nodules, fresh and dry weight of nodules and leghaemoglobin content in the root nodules during both the years of investigation as well as pooled data basis. The maximum plant height (46.35, 46.79 and 46.57 cm), total nodules plant^{-1} (63.63, 63.43 and 63.53), effective nodules plant^{-1} (24.62, 25.16 and 24.89), nodules fresh weight (231.81, 236.88 and 234.34 mg plant^{-1}), nodules dry weight (69.36, 71.06 and 70.21 mg plant^{-1}), leghaemoglobin content (2.26, 2.31 and 2.28 mg g^{-1}) and chlorophyll content (4.03, 4.13 and 4.08 mg g^{-1}) was recorded with the application of F_4 :125% RDF, which was significantly higher over rest of the treatment means of RDFs but statistically at par with F_3:100% RDF (20:40:40 NPK kg ha^{-1})in the years 2019, 2020 and on pooled basis data analysis. Increasing the amount of RDF in soil has increased the amount of N, P and K in the soil to the point where it was sufficient. N, P, and K are the most crucial plant nutrients for maximizing a crop's genetic potential via growth and development. Pandey *et al.* (2017) reported that increased fertilizer dose wielded positive effect on plant growth characters and application of 125% RDF has supplied higher N, P and K doses, which helped in achieving reported higher values of growth characters. The newly added and equally circulated supply of N, P and K in the fenugreek plant has resulted in rapid growth of individual plants and increased growth traits. Increasing levels of RDFs lead to increased cell division, cell enlargement and increase in size of all its morphological parts (Adesoji *et al.*, 2013). Higher amount of nitrogen (Undie *et al.*, 2012), phosphorous (Chen *et al.*, 2013) and potash (Tabatabaii *et al.*, 2011) helps in increasing growth parameters of soybean. The number and weight of nodules was increased with increasing levels of RDFs, because the phosphorus plays vital role in the development of root nodules, which was in close agreement with the findings of Singh and Kumar (2012).

5.2.2 Effect of Nutrient Management on Yield Attributes and Yield

Application various recommended dose of fertilizers significantly increased the yield attributes and yield of soybean crop. It was observed that the application of F_4:125% RDF produced significantly higher pods plant^{-1}, seeds pod^{-1} and test weight during the period of investigation. It was testified that the maximum pods plant^{-1} (73.52, 73.98 and 73.75), number of seed pod^{-1} (3.73, 3.77 and 3.75) and test weight (113.44, 113.17 and 113.30 g) was recorded with the application of F_4:125% RDF, which were remained at par with the supply of F_3:100% RDF (20:40:40 NPK kg ha^{-1}) during 2019, 2020 as well as on pooled data analysis. Further, results revealed that the maximum seed yield (1771.43, 180.23 and 1789.33 kg ha^{-1}), haulm yield (3510.44, 3520.40 and 3515.42 kg ha^{-1}) and biological yield (5281.87, 5327.63 and

5304.75 kg ha^{-1}) was recorded with application of F_4:125% RDF, which was statistically at par with the application of F_3:100% RDF (20:40:40 NPK kg ha^{-1}) during both the years of investigation as well on pooled data.

Increased RDF might result in the more photosynthates being transferred to the sink, which resulted in increased yield attributes. Increased number of pods plant^{-1}, pod length, and seed yield could be attributed to an increase in the number of branches, plant height, number of pods plant^{-1}, and length of pod, as well as nutrient management practices, which have provided a basic cause for yield attributes and seed yield, which is an output of consecutive transformation from the source to sink relationship. It can also be related to the nutrient management practices, which have increased the soil physical, biological and chemical properties, and finally lead to increase the nutrient use efficiency. Increasing levels of nutrients has significantly increased the yield and yield attributes (Pandey *et al*., 2017). The results of present investigation are in corroborate with findings of Mohod *et al.* (2010), Gajbhiye *et al*. (2011) and Ghodke *et al*. (2018).

5.2.3 Effect of Nutrient Management on Nutrient Content and Uptake by Seed and Haulm of Soybean Crop

The analysis of plant samples revealed that application of F_4:125% RDF have maximum nitrogen content of haulm (2.22, 2.24 and 2.23%), phosphorus content of seed (0.0.248, 0.255 and 0.252%) and haulm (0.130, 0.131 and 0.131 %) and potassium content of seed (1.05, 1.09 and 1.07%) and haulm (2.74, 2.76 and 2.75%) which were remained at par with the application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) during both the years of experimentation as well as on pooled analysis. Further the crop supplied with aforesaid nutrient management practices accumulated significantly higher micro nutrients *viz*., Fe, Zn, S, Cu, Mn in both seed and haulm during both the years of carrying out tests as well as on pooled analysis. An investigation of data revealed that uptake of nitrogen, phosphorus, potassium and micronutrients such as zinc, iron, sulphur, copper, and manganese at harvest was significantly increased with increasing dose of RDFs. The application of F_4 :125 % RDF recorded highest uptake of nitrogen by seed (108.04, 110.67 and 109.35 kg ha^{-1}) and haulm (78.08, 78.96 and 78.52 kg ha^{-1}), phosphorus by seed (4.41, 4.62 and 4.52 kg ha^{-1}) and haulm (4.55, 4.61 and 4.58 kg ha^{-1}), potassium uptake by seed (18.69, 19.83 and 19.26 kg ha^{-1}) during both the years of research and pooled analysis, which were remained statistically at par with the application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) during both the years of experimentations but significantly higher on pooled data analysis. The higher concentration of plant nutrient in the seed and haulm of soybean might be due to increased application of recommended dose of fertilizers, which have facilitated more availability of plant nutrients in the soil with application of F_4 :125 % RDF. The higher uptake of nutrients is because of cumulative effect of higher seed and haulm yield and nutrient content in the same. The conclusions of present investigation are closely in conformity with Koushal and Singh (2011) and Pandey *et al*. (2017).

5.2.4 Effect of Nutrient Management on Physico-Chemical Properties of Soil

The application of RDFs significantly sustained the soil health. The application of F_4 :125 % RDF significantly increased the soil organic carbon (0.68 g kg^{-1}), which was statistically at par with the application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) (0.67 g kg^{-1}) on pooled basis. The increase in soil organic carbon is may be due to increase root growth and decomposition of organic matter. The suggestively higher soil organic carbon in fertilized treatments over the control can be described by the higher yield and related better expanse of root residues and stubbles of crops added in soil (Ghosh *et al*., 2003). Long-term studies have also found that full dosages of RDFs result in more soil organic carbon than unfertilized soil (Swarup and Wanjari, 2000). Soil organic carbon content improved in fertilized plots compared to unfertilized plots owing to C addition through roots and crop residues, greater humification rate constant, and lower decay rate, according to Kundu *et al*., (2002). The statistically higher CEC {25.72 mol (P^+) kg^{-1}}, pH (7.85, 7.84 and 7.84) and EC (0.350, 0.336 and 0.343 dSm^{-1}) was also recorded with F_4 :125 % RDF. The application of NPK significantly increases the CEC of soil. This may be explained by the retention of applied NPK in the soil colloid (Radulov *et al*., 2011) and the organic carbon content of the soil, which is the most significant factor controlling soil CEC (Rashidi and Seilsepour, 2008). The results of the present investigations are in line with the findings of Czarnecki and During (2015) who reported that continued long-term fertilizer use increased soil organic carbon and CEC. The bulk density porosity increased significantly with increasing dose of recommended dose of fertilizers. The water holding capacity remained unaffected with application of RDFs during both the years but differing significantly over rest of treatments on pooled data basis. The maximum water holding capacity (46.65%) was obtained with the application of F_4 :125% RDF, which remained at par with the F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) on pooled basis. Results revealed that the maximum soil available nutrients were affected significantly with the application of RDFs. The significantly maximum available nitrogen (271.70 kg ha^{-1}), phosphorus (26.77 kg ha^{-1}) and potassium (366.42 kg ha^{-1}) was obtained with application of F_4 :125 % RDF, which was remained at par with the application of F_3:100% RDF (20:40:40 NPK kg ha^{-1}) on pooled analysis but did not affected significantly during both the years of experimentation. The significantly maximum DTPA extractable zinc (0.71 mg kg^{-1}), Mn (4.0 mg kg^{-1}), Fe (4.19 mg kg^{-1}) Cu (2.44 mg kg^{-1}) was also recorded higher with F_4 :125% RDF, which was at par with the application of F_3:100% RDF (20:40:40 NPK kg ha^{-1}). Soil available plant nutrient increase with increasing dose of fertilizers. These results ore in line with the findings of Khan and Wani (2017), Choudhury *et al.* (2018) and Ghosh *et al.* (2018).

5.2.5 Effect of Nutrient Management on Biological Properties of Soil

The significant improvement in the biological properties of soil was observed with the application of recommended dose of fertilizers. Nutrient management practices had significantly increased the microbial carbon biomass, total colony forming units, alkaline phosphatase and dehydrogenase activity of the soil at harvest of the crop. The results revealed that the maximum soil microbial carbon biomass (186.47, 190.47 and 188.47 mg kg^{-1}), soil microbial population (32.98, 33.67 and 33.32 10^8CFUs g^{-1}) was recorded with the application of F_4 :125% RDF, which was remained at par with the application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) during both the years of experimentation, whereas differing significantly on pooled analysis. The increased microbial population can be ascribed due to the increased soil organic carbon with increasing fertilizer doses which have increased the plant root growth and biomass and plant cover. The population of soil microorganisms (NFBs and PSB) increased with increasing dose of inorganic fertilization compared to the control (Basak *et al*., 2017). The maximum dehydrogenase activity (22.30, 22.81 and 22.56 µg TPF g^{-1} 24 hr^{-1}) and alkaline phosphatase activity (24.57, 25.68 and 25.13 µg*p*-nitrophenol g^{-1} $soilh^{-1}$) was recorded with the application of F_4 :125 % RDF, which was remained at par with the application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) during both the years of experimentation, whereas differing significantly on pooled analysis. Fertilizer application may have a preliminary impact on soil biological activity and nutrient recycling. The increased dehydrogenase activity is due to the increased microbial population and soil organic carbon in the soil because it presents only in living cells and one of the most significant soil biological indicators. It plays a significant role in the early stages of oxidation of soil organic matter by moving electrons or hydrogen from substrate to acceptors. The results of this investigation are closely in line with findings of (Basak *et al.*, 2017), who reported that application of inorganic fertilizers cause an increase in activities of all the soil enzymes but at different rates.

5.2.6 Effect of Nutrient Management on Different Chemical Pools of Carbon

An analysis of soil samples was done and studied the effect of nutrient management practices on carbon Chan pool revealed that supplementation of RDFs in soybean crop significantly altered the soil carbon Chan pool. Results revealed that the application of F_4 :125% RDF had significantly influenced the soil microbial carbon, total organic carbon, dissolved organic carbon, hot water extractable carbon, particulate organic carbon and nitrogen. The statistically higher total organic carbon (9.14, 10.26 and 9.70 g kg^{-1}), dissolved organic carbon (226.36, 236.81 and 231.59 mg kg^{-1}), hot water extractable carbon (0.68, 0.72 and 0.70 g kg^{-1}) particulate organic matter carbon (8.18, 8.47 and 8.32 g kg^{-1}) and particulate organic matter nitrogen (0.49, 0.53 and 0.51 g kg^{-1}) was obtained with application of F_4 :125% RDF during both the years of investigation as well as on pooled data analysis. The microbial biomass is defined as the living component of the SOM (Jenkinson and Ladd, 1981) and its amount in the soil reflects the total organic matter content; this proportion comprising 1-5% (w/w) of the SOC (Sparling *et al.*, 1997). Soil microbial biomass serves as a feed tank and is a key factor in determining nutrient availability in soils. The use of inorganic fertilisers can boost plant biomass productivity, which upsurges residue return to the soil and hence improves soil organic carbon and biological activity. It has been found that crop root development and rooting density increased soil microbial biomass, which is typical of plant responses to recommended fertilizer rates. Kanchikerimath and Singh (2001) reported that inorganic fertilizers with organic manures amplified the soil organic carbon content because of advanced soil organic carbon in manure and fertilizers which can be favourable for the growth and development of roots into deeper layers due to the relatively loose soil and high soil water content. Dissolved organic carbon is believed to be derived from plant roots, litter and soil humus and is a labile substrate for microbial activity Liang *et al.* (1997) and Kalbitz *et al.* (2000). The dissolved organic carbon (DOC) is the primary energy source for soil microorganisms and is an indicator of the carbon availability to soil microorganisms (Stevenson, 1994). The concentration of DOC varied widely among all the treatments and a significant increase was observed in surface soils under different fertilizer treatments compared with CK. In the long-term, the quantity of organic residues is the main factors influencing the amount and composition of DOC. Rudrappa *et al*. (2006) conveyed that the increasing organic carbon in the soil might enhance the POC accumulation. OnTl *et al*. (2015) suggest that macro aggregate formation drives short-term responses of POM, which are influenced by both soil and root system properties. Crops that maximize root biomass and annual root productivity (BNPP) will lead to the largest increases in protected soil C stocks.

The statistically higher Chan pool carbon very labile (3.29, 3.48 and 3.39 g kg^{-1}), labile (1.14, 1.13 and 1.14 g kg^{-1}) and less labile (2.12, 2.89 and 2.50 g kg^{-1}) was recorded with the application of $F_{4:}$125% RDF during both the years of experimentation and pooled data basis. However, the minimum non labile Chan pool carbon (2.59, 2.76 and 2.67 g kg^{-1}) was reported with F_4:125% RDF. The increase in the soil organic carbon might be due to the long-term addition of crop residue in the soil and continuous addition of NPK with organic manures has sequestered more carbon. The collective movement of carbon concentrations in soils along with fertilization could be explained by the amount of carbon input. The rate of labile carbon change is directly related to carbon inputs from organic amendments and stubble, root biomass, rhizodeposition. The higher amount of organic matter input from RDFs (from crop stubble, root biomass and root deposition) treatments promoted labile carbon concentration in the soil. According to Li *et al*. (2020) additions of inorganic fertilizers significantly influenced microbial community composition and structure, by changing microbial preference and boosting the number of bacteria capable of digesting complex carbohydrate. Microbial alterations caused by the addition of inorganic fertilizers hastened the degradation of soil organic carbon, resulting in a decrease in the slow carbon pool and total SOC pool but an increase in the active carbon pool.

Further data revealed that the application of fertilizers had significantly increased the carbon mineralization at 15, 30, 60 and 90 DAS. The significantly higher carbon 0.176, 0.335, 0.542 and 0.734 mg CO_2 $100g^{-1}$ soilwas mineralized with F_4 :125 % RDF at15, 30, 60 and 90 on pooled basis data. The maximum water-soluble carbohydrates (4.41, 4.45 and 4.48 mg kg^{-1}) and carbon (67.26, 69.47 and 68.37 mg kg^{-1}) was also significantly higher with the application of $F_{4:}$125 % RDF during both the years as well as on pooled basis respectively. Carbon mineralisation is a measure of overall biological activity in the soil, which includes soil microbes, macrofauna, and plant roots. It represents the indigenous soil microbial pool's total activity and energy expenditure. Carbon mineralization is a key metric for monitoring microbial-mediated activities such as organic matter decomposition in soil. Hence, increased microbial biomass and soil organic carbon might have increased the mineralization of carbon in the soil. Basak *et al.* (2017) found that application of NPK through inorganic fertilizers had significantly increased the mineralization of carbon and nitrogen as compared to the control treatment. The results of the present investigation are in line with the findings of Naresh *et al.,* (2018), who revealed that balanced fertilization and integrated fertilization resulted in increased particulate organic carbon, carbon mineralization and microbial biomass carbon, whereas particulate organic nitrogen and microbial biomass nitrogen found more in integrated fertilization compared to control treatment.

5.2.7 Effect of Nutrient Management on Economics

Application of nutrients through RDFs has significantly increased the returns and benefit cost ratio of soybean crop during both the years as well as pooled analysis. The results revealed that the maximum net return Rs 51309, 52672 and 51991 ha^{-1} was gained with the application of F_4 :125 % RDF, which was statistically remained at par with the application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}) (Rs 50236, 51844 and 51040 ha^{-1}) during both the years of experimentations and pooled analysis. Similarly higher benefit cost ratio 1.95, 2.01 and 1.98 was obtained with application of F_3:100 % RDF (20:40:40 NPK kg ha^{-1}), which was remained at par with F_4 :125 % RDF during 2019 and 2020 and on pooled data analysis respectively. Increased net return and benefit cost ratio might be attributed due to the increased seed and haulm yield because of application of inorganic fertilizations and less cost of inputs and higher gross returns.

5.3 Combined Effect of Crop Residues and Nutrient Management

The maximum grain yield (1912.6 kg ha^{-1}), haulm yield (3695.3 kg ha^{-1}) and biological yield (5607.9 kg ha^{-1}) was produced under combined application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} + F_4 :125 % RDF. Crop residues along with RDFs returns the fertility of soil by releasing the essential plant nutrients, increasing soil organic matter, aeration and porosity, decreasing soil bulk density and keeping the soil moist, which will be favourable for bumper growth resulting in increased photosynthesis, more accumulation of photosynthates in the sink and producing a greater number of branches, pods per plants, seeds per pod, weight of seeds consequently increased seed and haulm yield. The treatment supplying more quantity of inorganic fertilizers along with crop residue has given significantly higher seed, haulm and biological yield as compare to the treatments with alone crop residue or inorganic fertilizers. This might be attributed to the improved creation and expansion of typically favoured the crop to extract and uptake soil moisture and nutrients from larger volume of the soil with collective use of crop residues and inorganic fertilizers. Hati *et al.* (2001) found similar findings in soybean in vertisols. Soil fertility and physical behaviour were maintained by a balanced application of inorganic fertilizer and organic sources, resulting in increased soybean yields. Chaturvedi and Chandel (2005) discovered that applying a 100 per cent recommended dose along with organic residues enhanced the biological condition, which helped to boost soybean production.

The combined application of crop residues and inorganic fertilizers such as RDFs of NPK has significantly increased the uptake of nutrients by seed and haulm of soybean crop. The results revealed that the maximum nitrogen uptake by grain (115.55 kg ha^{-1}) and haulm (86.44 kg ha^{-1}), P uptake by seed (4.97 kg ha^{-1}) and haulm (4.95 kg ha^{-1}), K uptake by seed (21.85 kg ha^{-1}) and haulm (105.93 kg ha^{-1}), zinc uptake by haulm (54.16 g ha^{-1}), iron uptake by seed (85.29 g ha^{-1}) and haulm (303.96 g ha^{-1}), Mn uptake by seed (126.53 g ha^{-1}) and copper uptake by seed (23.06 g ha^{-1}) was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4 :125%

RDF, which was statistically at par with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+F_3:100% RDF (20:40:40 NPK kg ha^{-1}) with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4 :125 % RDF:125 % RDF. The increasing dose of RDFs along with crop residues might have increased the soil available nutrient status and favoured the crop plant to extract more amount of nutrients from the soil, which had significantly increased the crop yield resulting more uptake of nutrients from the soil. According to Lorenz and Lal (2005) high surface covered organic matter input may enhance the synthesis of dissolved organic carbon, which may be transferred to soil layers and so contribute to subsurface carbon storage, which enhances the soil fertility status and increased the uptake of nutrients from the soil.

The addition of organic matter like crop residues along with the RDFs of NPK will increase the soil organic carbon. The continuous addition of organic matter like crop residues on the soil generates a favourable situation for the cycling of carbon and formation of macroaggregates. The results this investigation also revealed that maximum labile carbon (1.5 g kg^{-1}), less labile carbon (2.98 g kg^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_1: Control. However, the maximum non labile carbon (3.64 g kg^{-1}) was recorded with CR_1: Crop residue incorporation without irrigation + F_2:75 % RDF. The results revealed that maximum carbon mineralization at 30 DAS (0.438 mg CO_2 100 g^{-1}), 60 DAS (0.677 mg CO_2 100 g^{-1}) and 90 DAS (0.907 mg CO_2 100 g^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+ F_4 :125 % RDF. The increase in soil organic carbon was highly corelated with particulate organic carbon ($r = 0.96^{**}$). Increase in the particulate organic carbon has significant effect on carbon Chan pool and very strong and positive corelation between POC and very labile carbon (r = 0.97**), labile (r = 0.55*), less labile (r = 0.89**), dissolved organic carbon (r = 0.95**) and water-soluble carbon (r = 0.92**) was observed. However, there was a negative correlation between POC with non-labile carbon (r = -0.80**), which indicates that with increased organic carbon matter

Chan pool very labile, less labile and labile increased. According to Rudrappa *et al.* (2006), an increase in organic carbon intake might boost particulate organic matter carbon accumulation. Straw and farm yard manure can increase root biomass and microbial biomass detritus, which is the major source of POC, according to Purakayastha *et al*. (2008). It's possible that the enhanced biochemical recalcitrance of root litter raised POC levels in soil, depending on the amount of root biomass generated.The carbon source in the soil treated by crop residue treatment was more abundant, which improved the microbial activity and accelerated the carbon pool mineralization process.

6. SUMAMRY AND CONCLUSION

6.1 EFFECT OF CROP RESIDUE MANAGEMENT

6.1.1 Growth Parameters

- The maximum plant height in the year 2019, 2020 and pooled basis was 44.92, 45.07 and 45.0 cm respectively recorded with the application of treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- On pooled basis the maximum chlorophyll content of fresh leave at flowering was 4.14 mg g^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over rest of the levels of crop residue management.
- The maximum number of total nodules 62.85, 64.41 and 63.63 $plant^{-1}$ and effective nodules 25.08, 25.54 and 25.31 was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} during both the years of experimentation *viz*., 2019, 2020 and on pooled basis.
- The significantly maximum concentration of leghemoglobin 2.31, 2.37 and 2.34 mg g^{-1} during both the years of experimentation an on pooled basis was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, respectively.
- The significantly higher nodules' fresh weight (237.53, 242.73 and 240.13 mg $plant^{-1}$) and nodules' dry weight (71.07, 72.82 and 71.95mg $plant^{-1}$) during both the years 2019, 2020 and pooled basis respectively, was recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.

6.1.2 Yield Attributes and Yield

- Significantly higher pods $plant^{-1}$ 73.77, 73.92 and 73.85 during 2019, 2020 and pooled basis, was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.

- Application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} gave significantly higher number of seeds pod^{-1} during 2019, 2020 and pooled basis was 3.76, 3.80 and 3.78.
- The application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} gave highest test weight 112.31, 112.23 and 112.27 g during 2019, 2020 and pooled basis.
- On pooled basis, the significantly superior grain yield was produced with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (1774.52 kg ha^{-1}).
- On the basis of means of treatments of both the years the maximum haulm yield 3465.81 kg ha^{-1} was also recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (3330.73 kg ha^{-1}).
- On the basis of pooled data of both the years the maximum biological yield 5240.33 kg ha^{-1} was also recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically superior over remaining levels of crop residue management practices.
- The highest harvest index 33.98 per cent was obtained with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (33.65%) and CR_2: Crop residue incorporation with irrigation (32.68%)

6.1.3 Nutrient Content

- The application of various crop residue management failed to show any significant effect on nitrogen content of grain in 2019, 2020 and on pooled basis. On mean basis the maximum nitrogen content of haulm 2.19 per cent was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was not differing significantly with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (2.13%)

- On the basis of means of two-year data the maximum phosphorus content of grain 0.25 per cent and haulm 0.13 per cent was obtained with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} (0.245%).
- On the basis of pooled data, the significantly superior K content of grain 1.07 per cent and haulm 2.74 per cent was recorded with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- On pooled basis the maximum sulphur content of grain and haulm was significantly superior with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (0.43 and 0.32 %).
- The significantly highest Zn content of grain and haulm was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (23.30 and 14.11 ppm).
- On pooled analysis the highest concentration of iron in grain and haulm (44.44 and 80.49 ppm) was found in application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- On pooled basis the maximum concentration of Mn in grain and haulm of soybean was 64.43 and 50.92 ppm recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- The significantly highest copper content of grain 12.73 ppm was recorded with CR_1: Crop residue incorporation without irrigation on pooled basis. The maximum Cu content of haulm in the year 2019, 2020 and on pooled basis was maximum in CR_2: Crop residue incorporation with irrigation 8.61, 8.62 and 8.61 ppm respectively.

6.1.4 Nutrient Uptake

- The means of both the years demonstrated that the maximum nitrogen uptake by grain 108.37 kg ha^{-1} and haulm 76.0 kg $ha^{-1}$was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- On the basis of means of two-year data the maximum phosphorus uptake by grain 4.44 kg ha^{-1} and haulm 4.50 kg ha^{-1} was obtained with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}
- The significantly superior K uptake by grain 19.07 kg ha^{-1} and haulm 95.31 kg ha^{-1} was recorded with the CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- The maximum sulphur uptake by grain and haulm was significantly superior with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (7.76 and 11.16 g ha^{-1}).
- Results revealed that the significantly highest Zn uptake by grain and haulm was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} (41.52 and 48.94 g ha^{-1}), which was differing significantly with rest of the treatment.
- The highest uptake of iron by soybean grain and haulm(78.95 and 279.25 g ha^{-1}) was found with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- On pooled basis the maximum Mn uptake by grain and haulm of soybean was 114.60 and 176.93 g ha^{-1} recorded with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- The highest Cu uptake by grain and haulm of soybean 19.67 and 28.11 g ha^{-1} was attained with CR_2: Crop residue incorporation with irrigation.

6.1.5 Physio-Chemical Properties

- The soil pH was decreased in the year 2020 as compared to the 2019. The lowest soil pH 7.45, 7.43 and 7.44 was recorded with the application of CR_4, which was significantly lowest among the various treatment of crop residue management in the both years and pooled basis, respectively.
- The lowest soil electrical conductivity (0.301, 0.285 and 0.293 dSm^{-1}) was recorded with the application of CR_4, which was significantly lowest in the year 2019, 2020 and pooled basis, respectively.
- The maximum organic carbon 0.69 g kg^{-1} was recorded with treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- The significantly highest CEC of soil 25.50 C mol (P^+) kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.
- The significantly minimum bulk density (1.27, 1.24 and 1.25 Mg m^{-3}) was observed with application of CR4. However, the highest bulk density was recorded with the application of CR1 in both the years of experimentation as well as on pooled basis.
- The maximum porosity (53.15, 54.32 and 53.73%) was recorded with the application of CR4 during 2019, 2020 and pooled basis. However, the lowest porosity was recorded with CR1.
- The significantly higher water holding capacity was observed with application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of treatments of crop residues.
- The maximum soil available nitrogen 275.65 kg ha^{-1}, phosphorus 27.16 kg ha^{-1} potassium 365.79 kg ha^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher and differing with rest of levels of crop residue management.

- The maximum DTPA extractable zinc in the soil at harvest 0.72 ppm was recorded with application of CR_2: Crop residue incorporation with irrigation, which was significantly higher over rest of the levels on pooled basis. the maximum soil DTPA extractable iron 4.21 ppm, Mn 3.98 ppm was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}.

6.1.6 Soil Biological Properties

- The maximum alkaline phosphatase activity 25.13 μg*p*-nitrophenol g^{-1} soilh^{-1} AND dehydrogenase activity 23.19 μg TPF g^{-1} 24 hr^{-1} was also observed with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of crop residue management practices in the soybean crop.
- The statistically maximum soil microbial population 33.35, 34.21 and 33.78 10^8 cfu g^{-1} was observed with the treatment CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} during 2019, 2020 and on pooled basis.
- The statistically highest soil microbial biomass carbon 186.22 mg kg^{-1} was analysed with treatment application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1},

6.1.7 Different Chemical Pools of Carbon

- On pooled basis the maximum total organic carbon 9.56 g kg^{-1} was obtained in the plot supplied with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was statistically at par with the application of CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}.
- The maximum dissolved organic carbon 229.26 mg kg^{-1} was obtained in the plot supplied with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher than other levels of crop residue management.

- The maximum hot water exchangeable carbon 0.55 g kg^{-1} was recorded with CR_3: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}, which was also differing significantly with CR_2: Crop residue incorporation with irrigation (0.46 g kg^{-1}) and CR_1: Crop residue incorporation without irrigation (0.39 g kg^{-1}) on pooled basis.
- The significantly higher particulate organic matter carbon 8.52, 8.74 and 8.63 g kg^{-1} and particulate organic matter nitrogen 0.53, 0.55 and 0.54 g kg^{-1} was recorded with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly with rest of treatments of crop residue management during both the years of experimentation and pooled basis.
- The maximum very labile carbon 3.17, 3.38 and 3.27 g kg^{-1}, labile carbon 1.30, 1.33 and 1.31 g kg^{-1} and less labile carbon 2.23, 2.77 and 2.50 g kg^{-1} and minimum non labile carbon Chan pool 2.30, 2.65 and 2.48 g $kg^{-1}$was observed with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, during 2019, 2020 and on pooled basis.
- Maximum carbon mineralization 0.200mg CO_2 100 g^{-1}at 15 DAS, 0.390mg CO_2 100 g^{-1}at 30 DAS, mineralization 0.608mg CO_2 100 g^{-1}at 60 DAS and 0.816mg CO_2 100 g^{-1}at 90 DAS was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was significantly higher over rest of the levels of crop residue management treatments during both the years as well as on pooled basis data.
- The maximum water-soluble carbon 67.71, 69.41 and 68.56 mg kg^{-1} and water-soluble carbohydrates 4.40, 4.51 and 4.46 mg kg^{-1} was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was suggestively superior over rest of the levels of crop residue management treatments during both the years and pooled basis data, respectively.

6.1.8 Economics

- The significantly higher net return ` 52678 ha^{-1} was obtained with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}, which was differing significantly over rest of the treatments of crop residue management on pooled data.
- The statistically higher B-C ratio 2.05, 2.11 and 2.08 was obtained with the application of CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1} in 2019, 2020 and on pooled basis data analysis.

6.2 EFFECT OF NUTRIENT MANAGEMENT

6.2.1 Growth Parameters

- On pooled basis the tallest plant (46.57 cm) was observed with the application of F_4:125% RDF, which was significantly superior over lower levels of nutrient management.
- the maximum chlorophyll content of fresh leaves at flowering was 4.08 mg g^{-1} of fresh leave weight with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF on pooled basis.
- On pooled basis the maximum total number of nodules $plant^{-1}$ (63.53), effective nodules (24.84), fresh nodule weight (234.34 mg $plant^{-1}$) and dry nodule weight (70.21 mg $plant^{-1}$) was recorded with F_4:125% RDF which was statistically at par with the F_3:100% RDF.
- Statically highest leghemoglobin content of nodules was recorded with the application of F_4:125% RDF (2.28 mg g^{-1}), which was not differing significantly with treatment F_3:100% RDF, followed by F_2:75 % RDF (2.16 mg g^{-1}) on pooled basis.

6.2.2 Yield Attributes and Yield

- An application of F_4:125% RDF gave statistically higher number of pods $plant^{-1}$ (64.44, 64.65 and 64.54), seeds pod^{-1} (3.73, 3.77 and 3.75) and test weight (113.44, 113.17 and 113.30 g) during 2019, 2020 and pooled basis correspondingly, which was not differing significantly with F_3:100% RDF.

- The maximum grain yield (1771.43, 1807.23 and 1789.33 kg ha^{-1}), haulm yields (3510.44, 3520.40 and 3515.42 kg ha^{-1}) and biological yields (5281.87, 5327.63 and 5304.75kg ha^{-1}) was obtained with the application of F_4:125% RDF, which was statistically at par with treatment F_3:100% RDF during both the years of research as well as on pooled basis respectively.
- On pooled basis the maximum harvest index 33.80 per cent was attained with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (33.75%).

6.2.3 Nutrient Content

- Application of various fertility levels did not show any momentous outcome on nitrogen content of grain in 2019, 2020 and on pooled basis. On mean basis the maximum nitrogen content of haulm 2.23 per cent was obtained with F4: 125% RDF.
- On pooled basis the maximum P content of seed and haulm (0.252 and 0.131 %), was obtained with F_4:125% RDF which was at par with F_3:100% RDF.
- On the basis of pooled data, the maximum K content of grain and haulm (1.07 and 2.75%) was recorded with the F_4:125% RDF, which was statistically superior over rest of treatments.
- The significantly superior concentration of sulphur in grain and haulm (0.44 and 0.32) was obtained with application of F_4:125% RDF, which was differing significantly with rest of levels of RDFs on pooled basis.
- The significantly highest Zn content of grain and haulm (23.11 and 14.22 ppm), was recorded with F_4:125% RDF, which was statistically at par with F_3:100% RDF.
- On pooled analysis the highest concentration of iron in grain and haulm (43.76 and 80.54 ppm) was found with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF.
- The maximum concentration of Mn in grain and haulm of soybean was 64.53 and 51.00 ppm recorded with application of F_4:125% RDF, which was not differing statistically with F_3:100% RDF and F_2:75 % RDF.

- The maximum concentration of Cu in grain and haulm of soybean was 13.03 and 9.25 ppm recorded with application of F_4:125% RDF, which was significantly superior over rest of the treatment on pooled basis.

6.2.4 Nutrient Uptake

- The maximum nitrogen uptake by grain and haulm (109.35 and 78.52 kg ha^{-1}) was obtained with F_4:125% RDF, which was at par with F_3:100% RDF.
- The significantly higher P uptake by soybean grain and haulm (4.52 and 4.58 kg ha^{-1}) was in F_4:125% RDF, which differs significantly with rest of levels of nutrient management on the basis of pooled data.
- The significantly maximum K uptake by grain and haulm (19.26 and 96.70 kg ha^{-1}) was recorded with the F_4:125% RDF.
- On pooled basis the significantly higher uptake of sulphur by grain and haulm7.84 and 11.28 g ha^{-1} were obtained with the application of F_4:125% RDF, which was differing significantly with rest of levels of RDFs.
- The significantly highest Zn uptake by grain and haulm (41.50 and 49.98 g ha^{-1}) was recorded with F_4:125% RDF, which was statistically at par with F_3:100% RDF (39.90 and 47.40 g ha^{-1}).
- The highest uptake of iron by grain and haulm78.40 and 283.36g ha^{-1} was found with application of F_4:125% RDF, which was statistically at par with F_3:100% RDF (75.57 and 218.08 g ha^{-1}).
- The maximum uptake of Mn through grain and haulm of soybean was 115.59 and 1179.56 g ha^{-1} recorded with application of F_4:125% RDF, which was not differing significantly with F_3:100% RDF.
- The maximum uptake of Cu though grain and haulm of soybean 23.24 and 32.52 g ha^{-1} was recorded with application of F_4:125% RDF, which was significantly superior over rest of the treatment.

6.2.5 Physio-Chemical Properties

- The maximum soil pH 7.84 was recorded with the application of 125% RDF, which was statistically similar to the application of 50 and 100 per cent RDF on pooled basis. However, the lowest soil pH was recorded with the control.

- The statistically maximum EC (0.350, 0.336 and 0.343 dSm^{-1}) was recorded with 125 per cent RDF, which was at par with F3 during both the years but significantly higher on pooled basis, respectively.
- The maximum organic carbon 0.68 g kg^{-1} was recorded with treatment F_4:125% RDF, which was statistically at par with application of F_3:100% RDF (0.67 g ka^{-1}).
- Suggestively maximum CEC of soil 25.72 C mol (P^+) kg^{-1} was recorded with F_4:125% RDF, which was differing statistically with F_3:100% RDF (24.69 C mol (P^+) kg^{-1}), F_2:75 % RDF (22.76 C mol (P^+) kg^{-1}) and F_1: Control (22.37 C mol (P^+) kg^{-1}).
- The minimum bulk density (1.296, 1.261 and 1.278 mg m^{-3}) was recorded with control in 2019, 2020 and pooled basis, respectively.
- The maximum porosity (52.19, 53.48 and 52.83%) was recorded with control. Whereas, the lowest porosity was obtained in 125% RDF.
- On the basis of pooled analysis, the maximum water holding capacity 46.65 per cent was recorded with the application of F_4:125% RDF, which was at par with the F_3:100% RDF (46.11%).
- The maximum soil available nitrogen 271.70 kg ha^{-1}, phosphorus 26.77 kg ha^{-1} and 366.42 kg ha^{-1} was recorded with the application of F_4:125% RDF, which was at par with the F_3:100% RDF.
- The maximum DTPA extractable zinc 0.71 ppm, iron 4.19 ppm, Mn 3.98 ppm, and copper 2.44 ppm was recorded with the application of F_4:125% RDF, which was statistically at par with the F_3:100% RDF (0.70 ppm).

6.2.6 Biological Properties

- The maximum alkaline phosphatase activity 25.13 μg*p*-nitrophenol g^{-1} $soilh^{-1}$, dehydrogenase activity 22.56 μg TPF g^{-1} 24 hr^{-1}, populations of microbes 33.32 10^8 cfu g^{-1}, soil microbial biomass carbon 188.47 mg kg^{-1} was observed with F_4:125% RDF, which was differing significantly with rest of nutrient management practices in the soybean crop.

6.2.7 Different Chemical Pools of Carbon

- On pooled basis the maximum total organic carbon 9.70 g kg^{-1}, dissolved organic carbon 231.59 g kg^{-1}, hot water exchangeable carbon 0.70 g kg^{-1} was obtained in the plot supplied with F_4:125% RDF, which was statistically superior and differing significantly with rest of levels of nutrient management.
- The results revealed that the significantly higher particulate organic matter carbon (8.18, 8.47 and 8.32 g kg^{-1}), particulate organic matter nitrogen (0.49, 0.53 and 0.51 g kg^{-1}) was recorded with the application of F_4:125% RDF, which was differing significantly with rest of treatments of nutrient management during both the years of experimentation and pooled basis.
- The maximum very labile carbon (3.39 g kg^{-1}), labile carbon (1.14 g kg^{-1}) and less labile carbon 2.50 g kg^{-1} and minimum non labile carbon (2.48 g kg^{-1}) was observed with F_4:125% RDF, which was differing significantly with rest of treatment means on pooled basis.
- The significantly higher carbon mineralization at 15 DAS (0.176mg CO_2 100 g^{-1}), 30 DAS (0.335mg CO_2 100 g^{-1}), 60 DAS (0.542 mg CO_2 100 g^{-1}) and 90 DAS (0.734 mg CO_2 100 g^{-1}) was recorded with the application of F_4:125% RDF on pooled basis.
- The significantly higher water-soluble carbon (67.26, 69.47 and 68.37 mg kg^{-1}) and water-soluble carbohydrates (4.41, 4.56 and 4.48 mg kg^{-1}) was recorded with F_4:125% RDF during 2019, 2020 as well as on pooled basis, respectively.

6.2.8 Economics

- The statistically higher net return ` 51309, 52672 and 51991 $ha^{-1}$ was gained with the application of $F_4$:125% RDF, which was at par with the net return gained with $F_3$:100% RDF (50236, 51844 and 51040 ` ha^{-1}) during the year 2019, 2020 and pooled basis respectively.
- The statistically higher benefit cost ratio 1.95, 2.01 and 1.98 was recorded with the application of F_3:100% RDF, which was at par with the F_4:125% RDF (1.92, 1.97 and 1.95) during the year 2019, 2020 and pooled basis respectively.

6.3 COMBINED EFFECT OF CROP RESIDUES AND NUTRIENT MANAGEMENT

- The maximum grain yield (1912.6 kg ha^{-1}), haulm yield (3695.3 kg ha^{-1}) and biological yield (5607.9 kg ha^{-1}) was produced under combined application of CR_4 + F_4.
- The maximum nitrogen uptake by grain (115.55 kg ha^{-1}) and haulm (86.44 kg ha^{-1}), P uptake by seed (4.97 kg ha^{-1}) and haulm (4.95 kg ha^{-1}), K uptake by seed (21.85 kg ha^{-1}) and haulm (105.93 kg ha^{-1}), zinc uptake by haulm (54.16 g ha^{-1}), iron uptake by seed (85.29 g ha^{-1}) and haulm (303.96 g ha^{-1}), Mn uptake by seed (126.53 g ha^{-1}) and copper uptake by seed (23.06 g ha^{-1}) was recorded with application of CR_4+F_4, which was statistically at par with CR_4+F_3.
- Maximum labile carbon (1.5 g kg^{-1}), less labile carbon (2.98 g kg^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+F_1: control. However, the maximum non labile carbon (3.64 g kg^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}+F_2: 50% RDF.
- The maximum carbon mineralization at 30 DAS (0.438 mg CO_2 100 g^{-1}), 60 DAS (0.677 mg CO_2 100 g^{-1}) and 90 DAS (0.907 mg CO_2 100 g^{-1}) was recorded with CR_4: Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolyticmicrobes @ 2.0 kg ha^{-1}+F_4: 125% RDF. Based on the above findings it may be inferred that substantial improvement in plant height, chlorophyll content, Total nodules $plant^{-1}$, effective nodules $plant^{-1}$, Leghaemoglobin content (mg g-1), Fresh and Dry Weight of nodules, Pods $plant^{-1}$,Seeds pod^{-1}, Seed yield, Haulm yield, Biological yield, nutrient content and uptake by N, P, K,S, Zn, Fe, Mn and Cu in seed and Hulm, protein content seed and net returns could be obtained with the application of Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg $ha^{-1}$and 100% RDF during both the years as well as in pooled analysis.

CONCLUSION

Based on the findings it may be inferred that substantial improvement in plant height, chlorophyll content, total nodules plant^{-1}, effective nodules plant^{-1}, leghaemoglobin content, fresh and dry weight of nodules, pods plant^{-1}, seeds pod^{-1}, seed yield, haulm yield, biological yield, nutrient content and uptake by N, P, K, S, Zn, Fe, Mn and Cu in seed and haulm, protein content seed and net returns could be obtained with the application of crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}and 100% RDF during both the years as well as in pooled analysis.

The application of crop residue and fertility levels significantly increased organic carbon, cation exchange capacity, WHC, available nitrogen, phosphorus, potassium and DTPA-extractable micronutrients (Zn, Fe, Mn and Cu), alkaline phosphate activity, dehydrogenase activity, MBC and soil microbial population, TOC, DOC, Hot water extractable carbon, POM-C-N, Chan pool, C_{min}, Water soluble Carbon, Water soluble carbohydrates in soil after harvest of crop during both the years, as well as in pooled analysis.

The higher seed yield (1909.4 kg ha^{-1}), haulm yield (3617.1 kg ha^{-1}), biological yield (5526.6 kg ha^{-1})N, P , K,S, Zn, Fe, Mn uptake net returns (` 57393 ha^{-1}) and B:C ratio (2.20) was obtained under the combined applicationof Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}and 100% RDF(20:40:40). During both the years as well as in pooled analysis. The seed yield of soybean was found significant and positively correlated with stover yield, biological yield and different chemical pools of carbon in soil. The different chemical pools of carbon were also correlated positively and significant among them indicating dynamic equilibrium in the soil solution.

Therefore, in this Chambal Command area for soybean variety RKS-45, the application of Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}and 100% RDF(20:40:40) as a most profitable dose is being recommended for higher seed yield net returns per hectare and B:C.

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Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine max* (L.) Merrill] under Chambal Command Area

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Dr. S. C. Meena[**] Major Advisor

ABSTRACT

A field experiment entitled **"Effect of Crop Residue & Nutrient Management on Carbon Dynamics and Soil Health in Soybean [*Glycine -max* (L.) Merrill] under Chambal Command Area"** was conducted at Agriculture Research Station, Ummedganj- during two consecutive *Kharif* seasons of the year 2019-20 and 2020-21 to study the effect of crop residue and nutrient management on growth, yield and quality of soybean in Chambal commandarea,to work out the nutrient content and uptake bysoybean, to assess the physico-chemical and biological properties of soil and to evaluate different chemical pools of carbon and their significance in relation to soil andcrop.The experiment consisted of 16 treatment combinations in factorial randomized block design with three replications with two factors Crop residue & Nutrient management and both the factors have four levels. The levels of crop residue management are CR_1 Crop residue incorporation without irrigation, CR_2 Crop residue incorporation with irrigation, CR_3 Crop residue incorporation with irrigation and application of urea@ 25 kg ha^{-1}, CR_4 Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ cellulolytic microbes @ 2.0 kg ha^{-1} and Nutrient management are F_1 Control**,** F_2 75% RDF**,** F_3 100% RDF (20:40:40 NPK kg ha^{-1}) and F_4 125% RDF. The crop residue incorporated in plots one month before sowing. Variety "RKS-45" of soybean was sown as per recommended package of practices.

Results revealed that application of crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ cellulolytic microbes @ 2.0 kg ha^{-1}along with 100% RDF increased plant height, chlorophyll content, total nodules $plant^{-1}$, effective

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nodules plant^{-1}, leghaemoglobin content, fresh and dry weight of nodules, pods plant^{-1}, seeds pod^{-1}, seed yield, haulm yield, biological yield, nutrient content and uptake by N, P, K, S, Zn, Fe, Mn and Cu in seed and haulm, protein content seed in soybean and nutrient content along with their uptake by crop (N, P, K,S and micronutrient *viz.,* Fe, Zn, Cu and Mn). Enriched fertility of soil via application of Crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ cellulolytic microbes @ 2.0 kg ha^{-1} and 100% RDF significantly decreased the bulk density and increased the porosity and water holding capacity as compared to 100% RDF.

Further results showed that organic carbon, available N, P, K, Sand micronutrients *viz.,* Fe, Zn, Cu and Mn in soilwere found higher at harvest stage of soybean with the application ofCrop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ cellulolytic microbes @ 2.0 kg ha^{-1}with 100% RDF.Total organic carbon, cation exchange capacity, WHC, available nitrogen, phosphorus, potassium and DTPA-extractable micronutrients (Zn, Fe, Mn and Cu), alkaline phosphate activity, dehydrogenase activity, MBC and soil microbial population, TOC, DOC, Hot water extractable carbon, POM-C-N, Chan pool, C_{min}, Water soluble Carbon, Water soluble carbohydrates in soil after harvest of crop during both the years, as well as in pooled analysis significantly influenced due to crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1}+ cellulolytic microbes @ 2.0 kg ha^{-1}along with100% RDF.

The higher seed yield (1909.4 kg ha^{-1}), haulm yield (3617.1 kg ha^{-1}), biological yield (5526.6 kg ha^{-1}) N, P , K, S, Zn, Fe, Mn uptake net returns (` 57393 ha^{-1}) and B:C ratio (2.20) was obtained under the combined application of crop residue incorporation with irrigation and application of urea @ 25 kg ha^{-1} + cellulolytic microbes @ 2.0 kg ha^{-1}and 100% RDF(20:40:40). During both the years as well as in pooled analysis. The seed yield of soybean was found significant and positively correlated with stover yield, biological yield and different chemical pools of carbon in soil. The different chemical pools of carbon were also correlated positively and significant among them indicating dynamic equilibrium in the soil solution.

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nksuksa o"kksaZ ds nkSjku vkSj lkFk gh iwfyr fo'ys"k.k esa mPp cht mit ¼1909-4 fdxzk gsDVs;j$^{\&1}$½] Hkqlk mit ¼3617-1 fdxzk gsDVs;j$^{\&1}$½] tSfod mit ¼5526-6 fdxzk gsDVs;j$^{\&1}$½ ukbVªkstu] QkLQksjl] iksVsf'k;e] lYQj] tLrk] eSxuht ,oa dkWij viVsd 'kq) ykHk ¼` 57393 gsDVs;j &1½ vkSj ykHk yxr vuqikr ¼2-20½ flapkbZ vkSj ;wfj;k 25 fdyks gsDVs;j$^{\&1}$ $ lsY;qyksykbfVd jksxk.kq 2-0 fdyks gsDVs;j$^{\&1}$ vkSj 100% vkjMh,Q ds lkFk Qly vo'ks"kksa dks 'kkfey djus ds la;qä vkosnu ds rgr çkIr fd;k x;k FkkA lks;kchu dh cht mit egRoiw.kZ vkSj ldkjkRed :i ls LVksoj mit] tSfod mit vkSj feêh esa dkcZu ds fofHkUu jklk;fud iwyksa ds lkFk lglac) ikbZ xbZA dkcZu ds fofHkUu jklk;fud iwy Hkh muesa ls ldkjkRed vkSj egRoiw.kZ lglac) Fks] tks feêh ds ?kksy esa xfr'khy larqyu dk ladsr nsrs gSaA

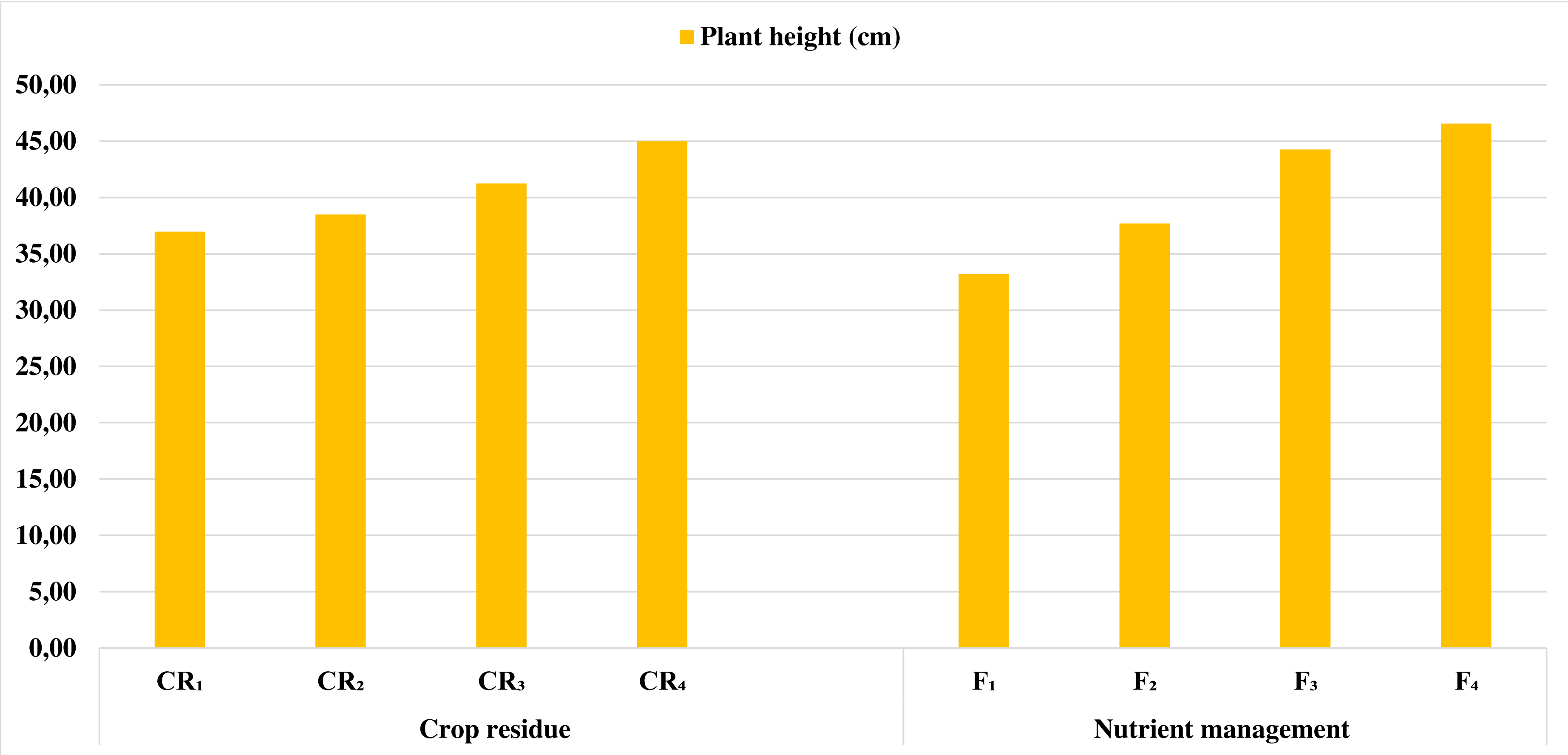

Fig. 4.1: Effect of crop residues and nutrient management on plant height of soybean during both the years and pooled analysis

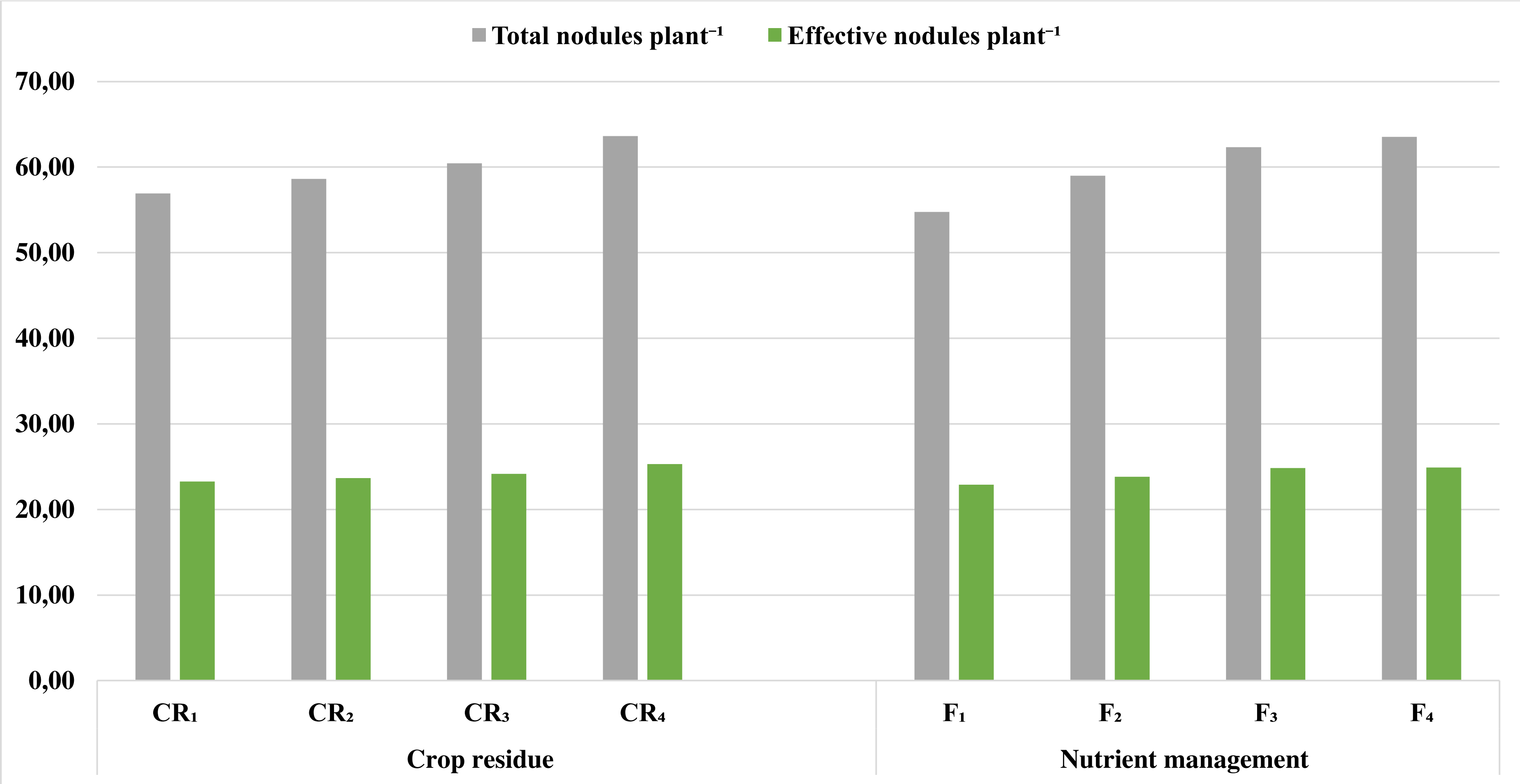

Fig. 4.2: Effect of crop residues and nutrient management on total and effective nodules of soybean during both the years and pooled analysis

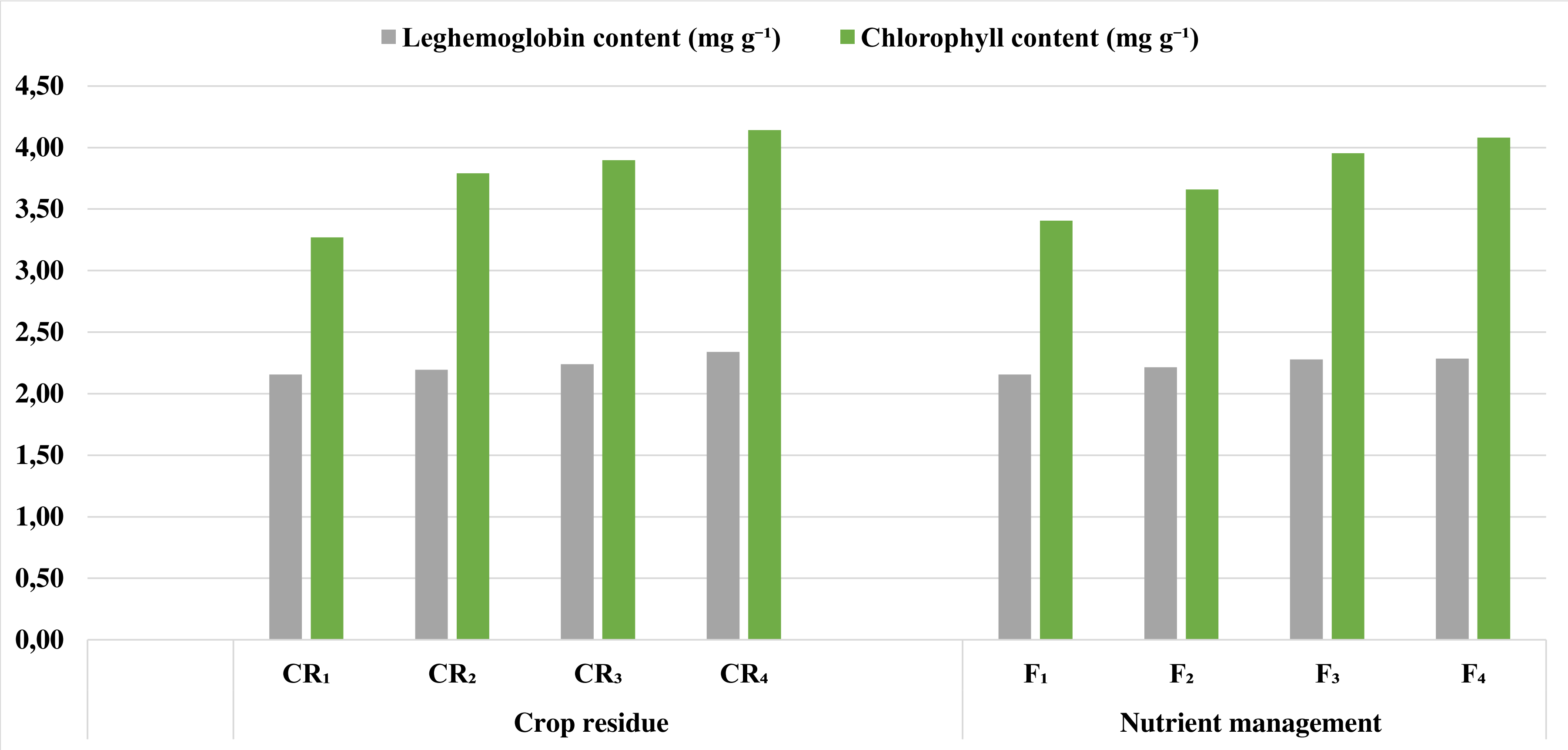

Fig. 4.3: Effect of crop residues and nutrient management on leghaemoglobin and chlorophyll content during both the years and pooled analysis

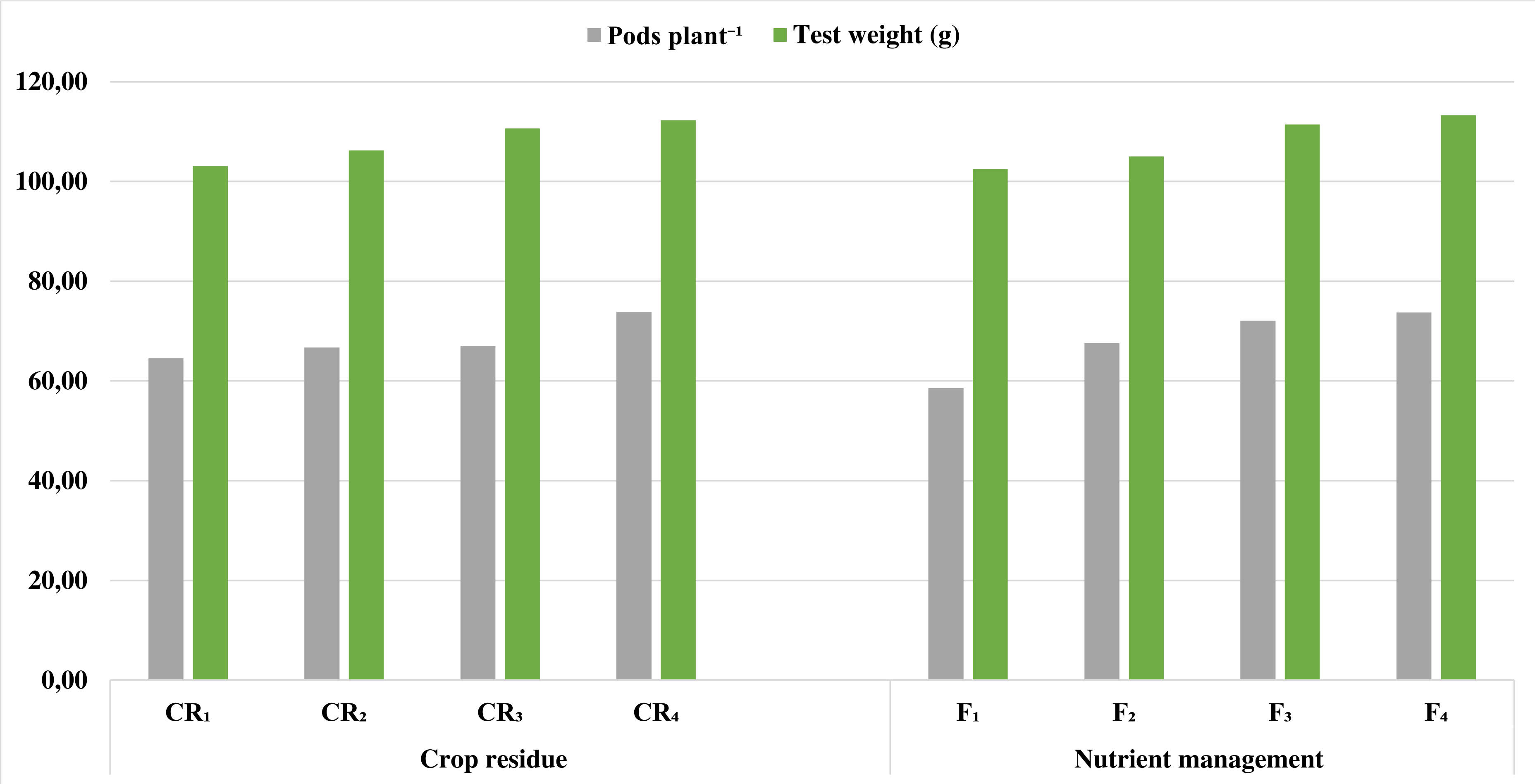

Fig. 4.4: Effect of crop residues and nutrient management on yield attributes of soybean during both the years and pooled analysis

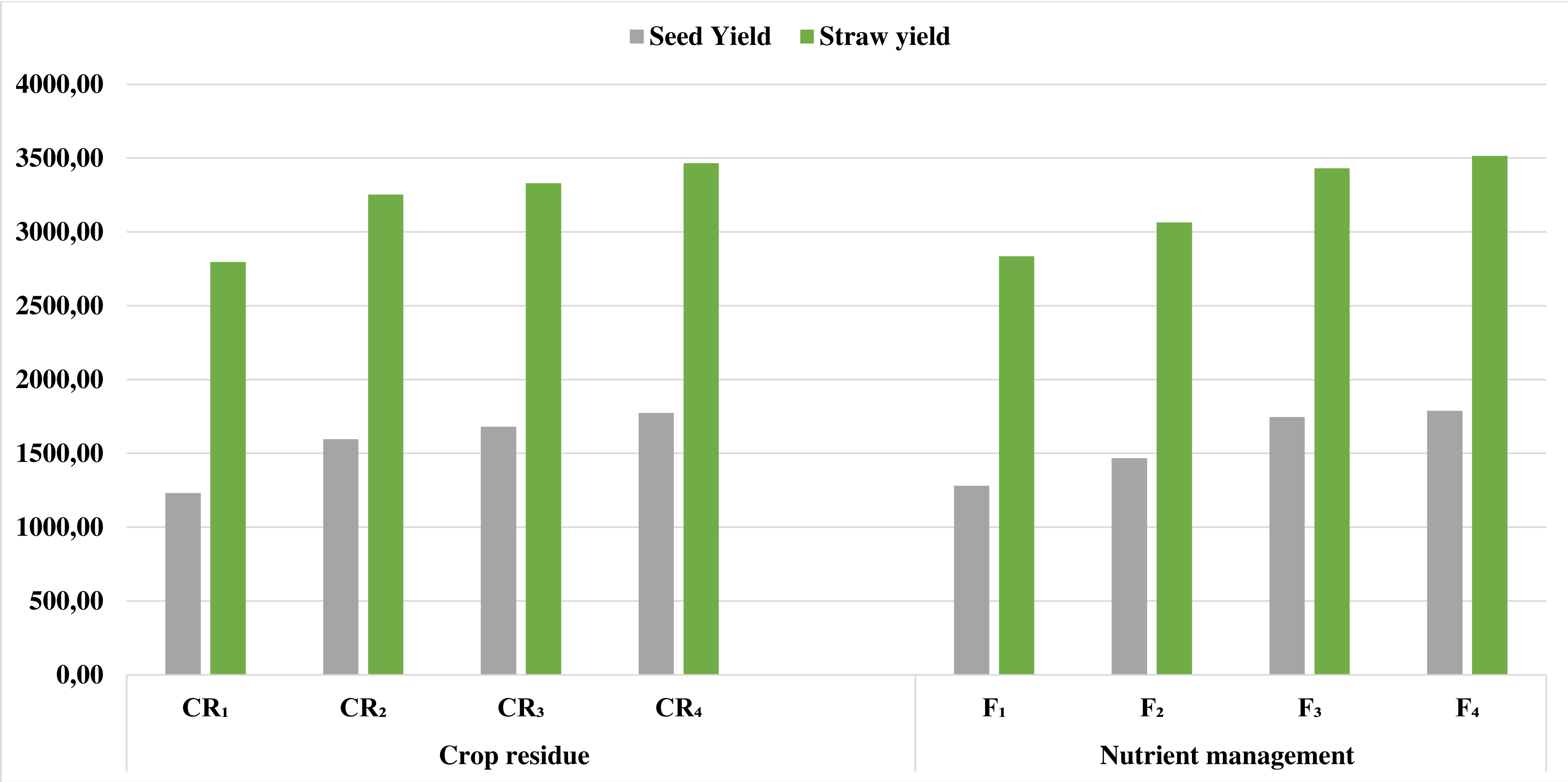

Fig. 4.5: Effect of crop residues and nutrient management on yield of soybean during both the years and pooled analysis

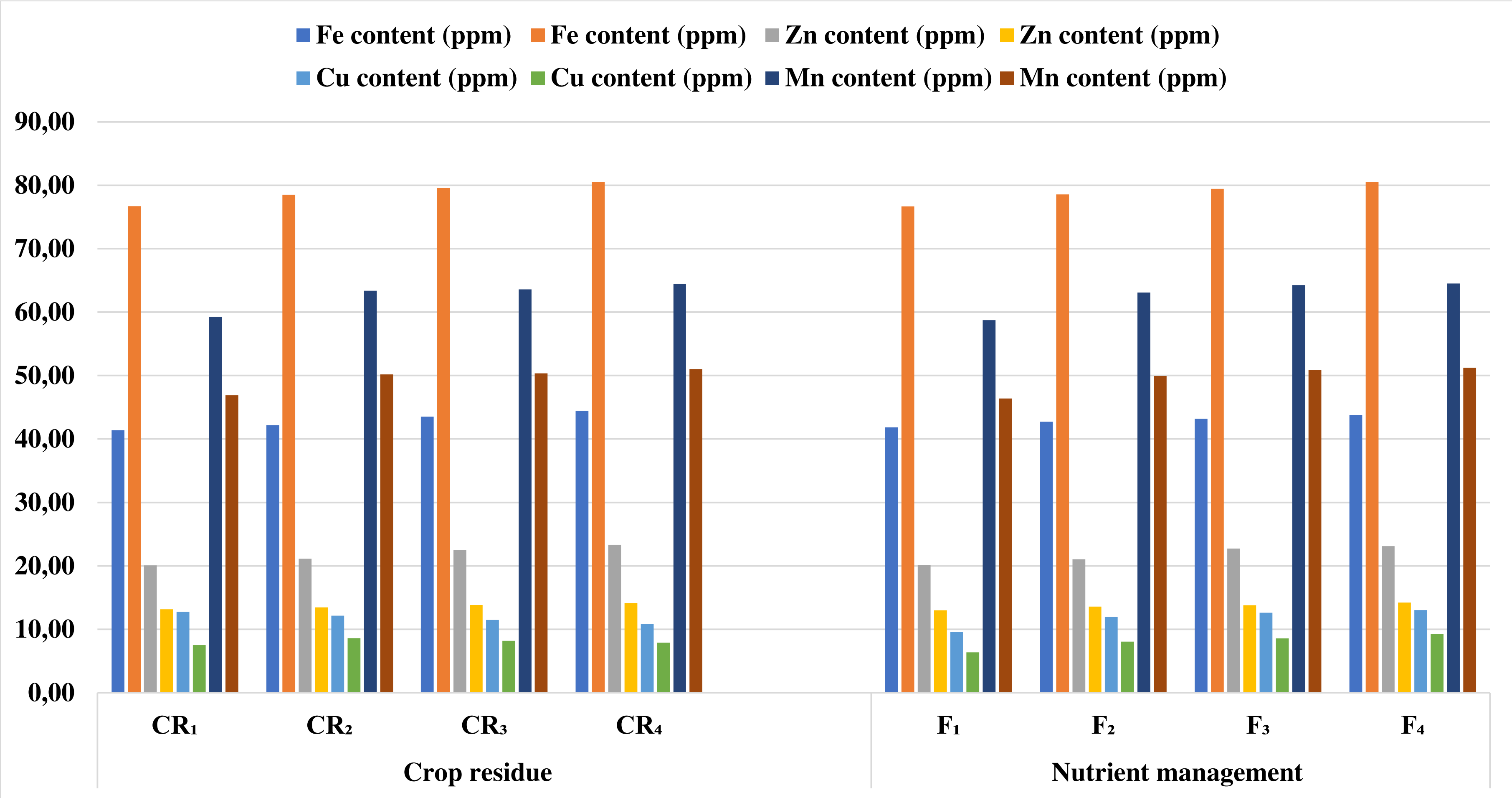

Fig. 4.6: Effect of crop residues and nutrient management on micro nutrient content in seed and haulm of soybean on pooled analysis

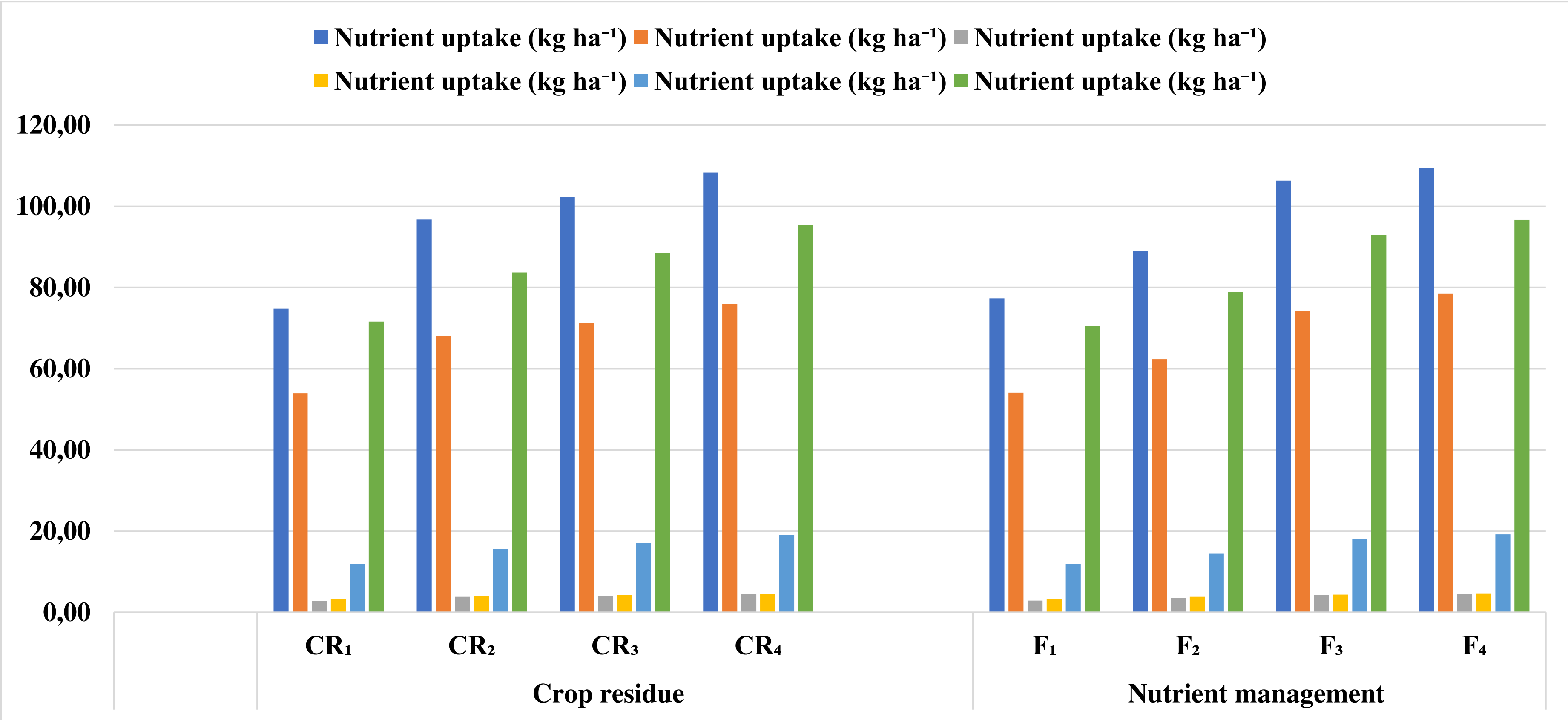

Fig. 4.7: Effect of crop residues and nutrient management on nutrient uptake by seed and haulm of soybean on pooled analysis

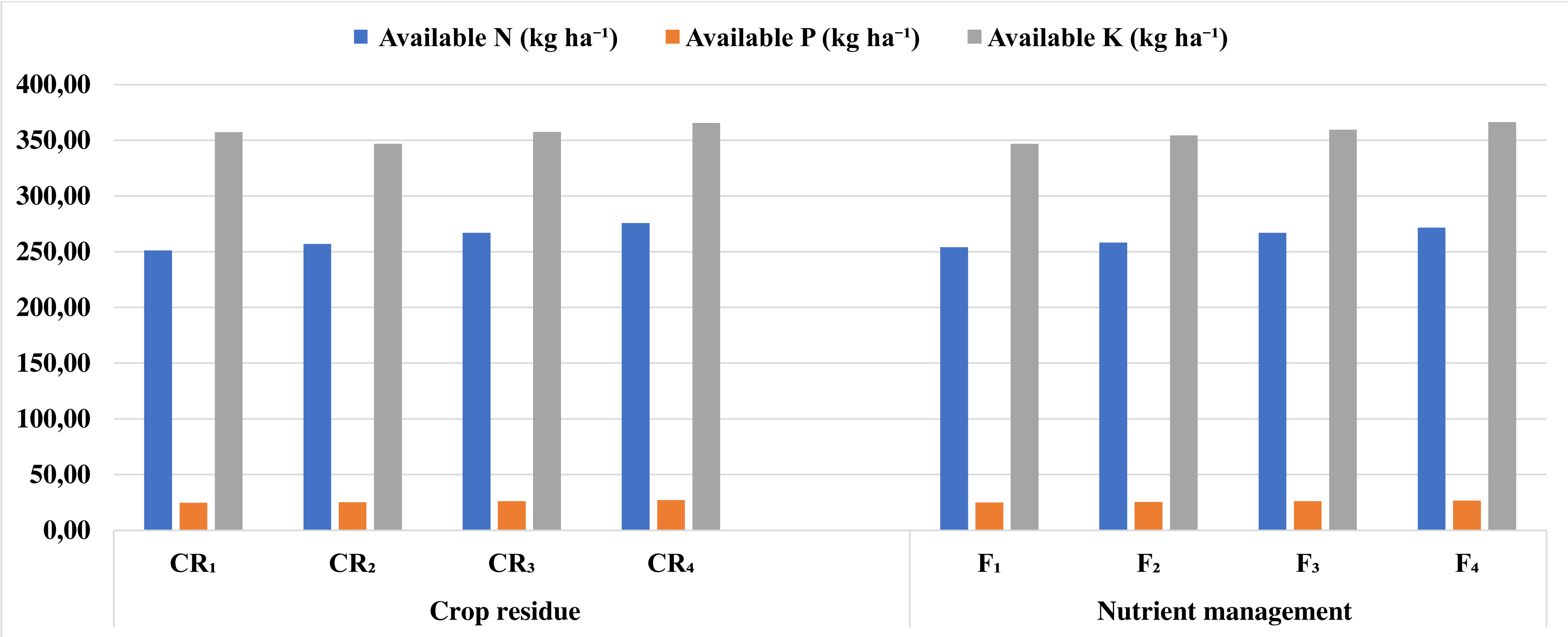

Fig. 4.8: Effect of crop residues and nutrient management on soil available nutrients after harvest on pooled analysis

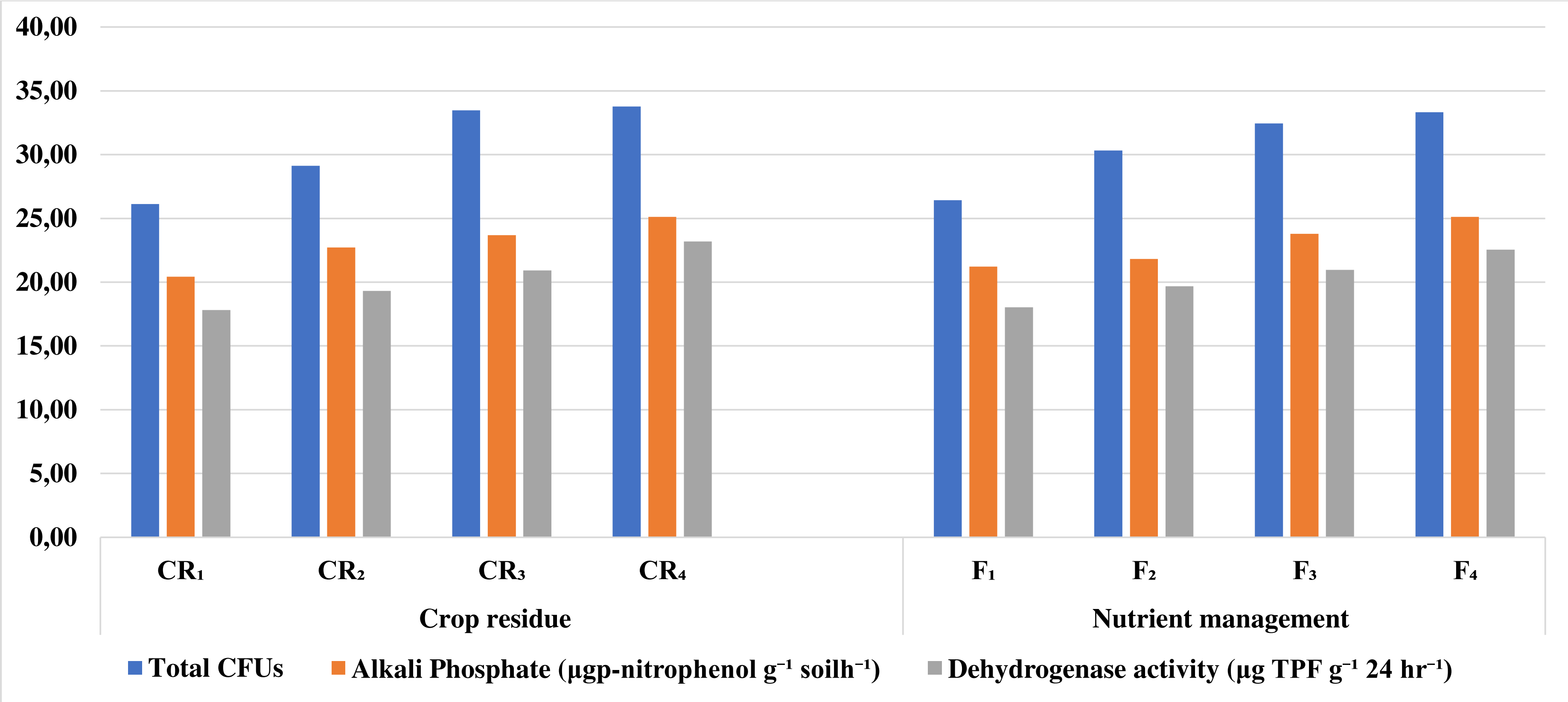

Fig. 4.9: Effect of crop residues and nutrient management on total soil biological properties after harvest on pooled analysis

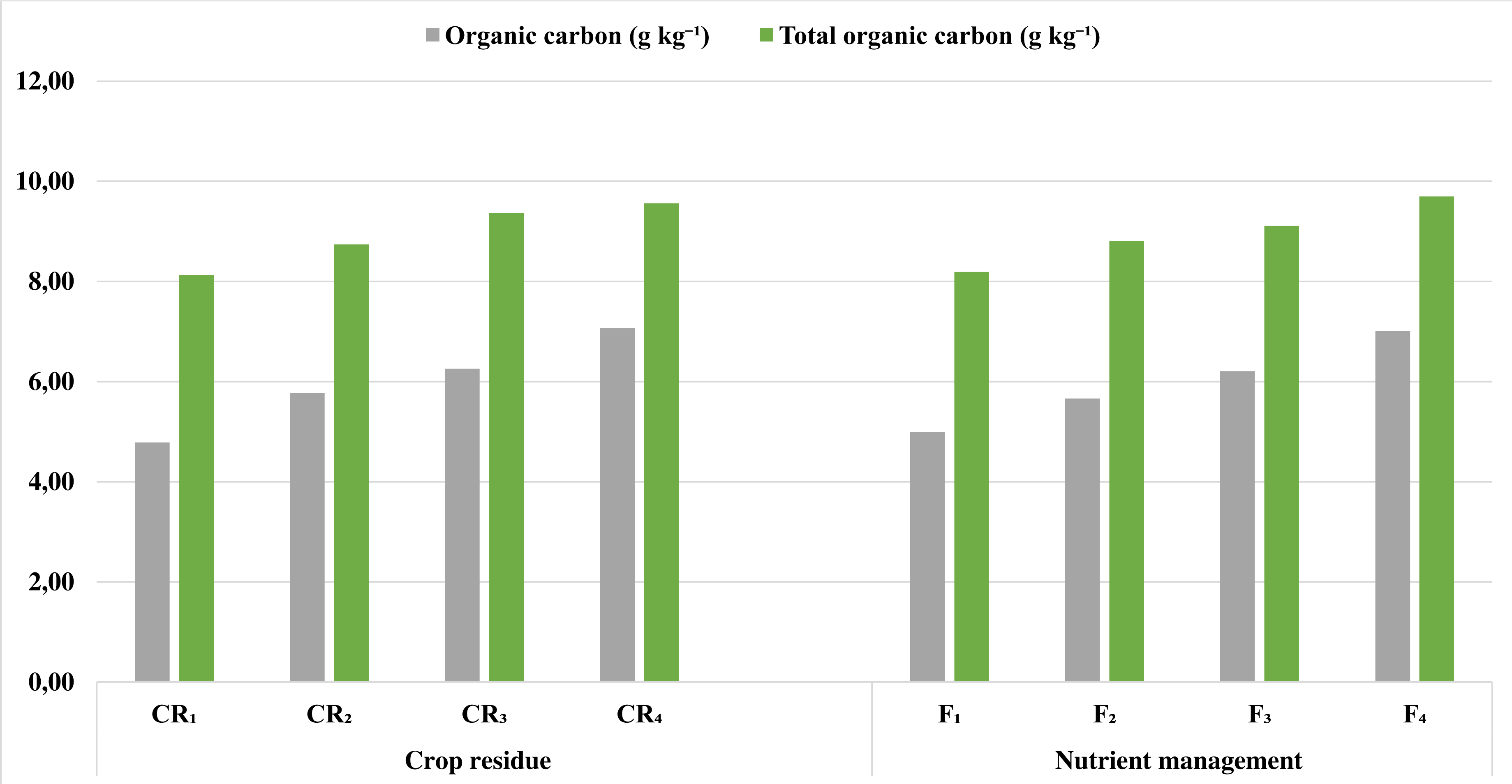

Fig. 4.10: Effect of crop residues and nutrient management on soil organic carbon after harvest during both the years and pooled analysis

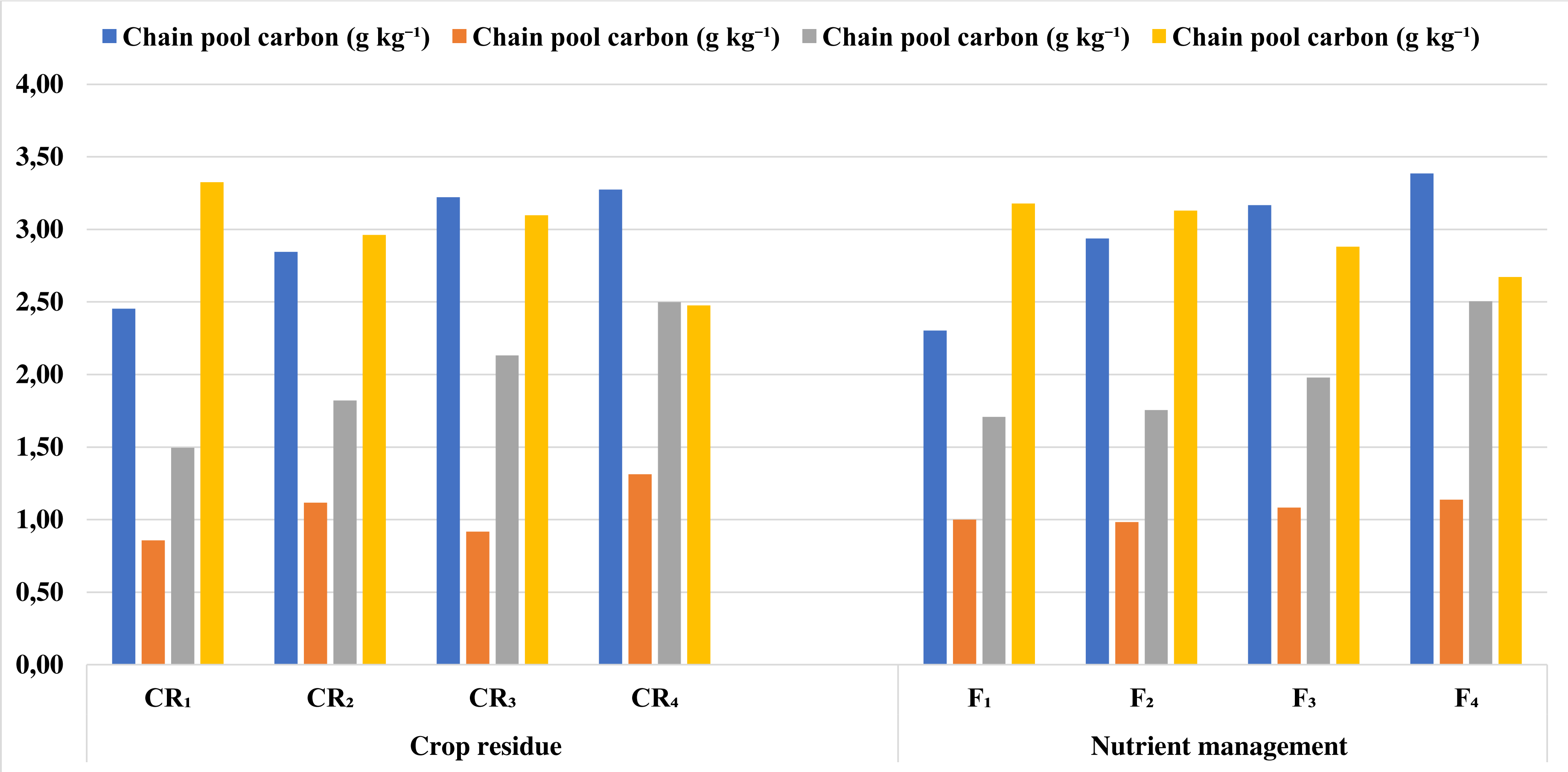

Fig. 4.11: Effect of crop residues and nutrient management on Chan pool carbon after harvest on pooled analysis

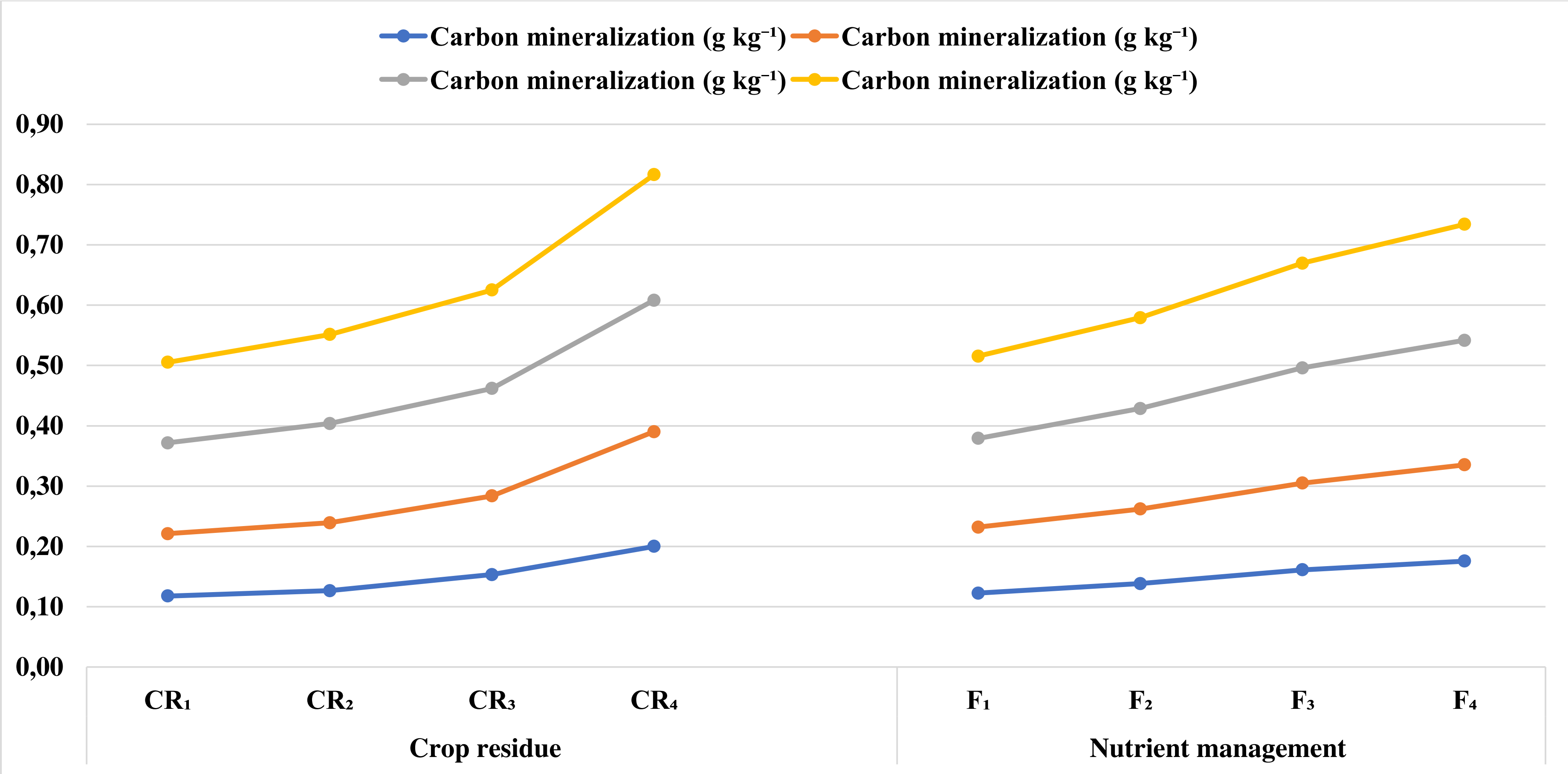

Fig. 4.12: Effect of crop residues and nutrient management on carbon mineralization after harvest on pooled data analysis basis

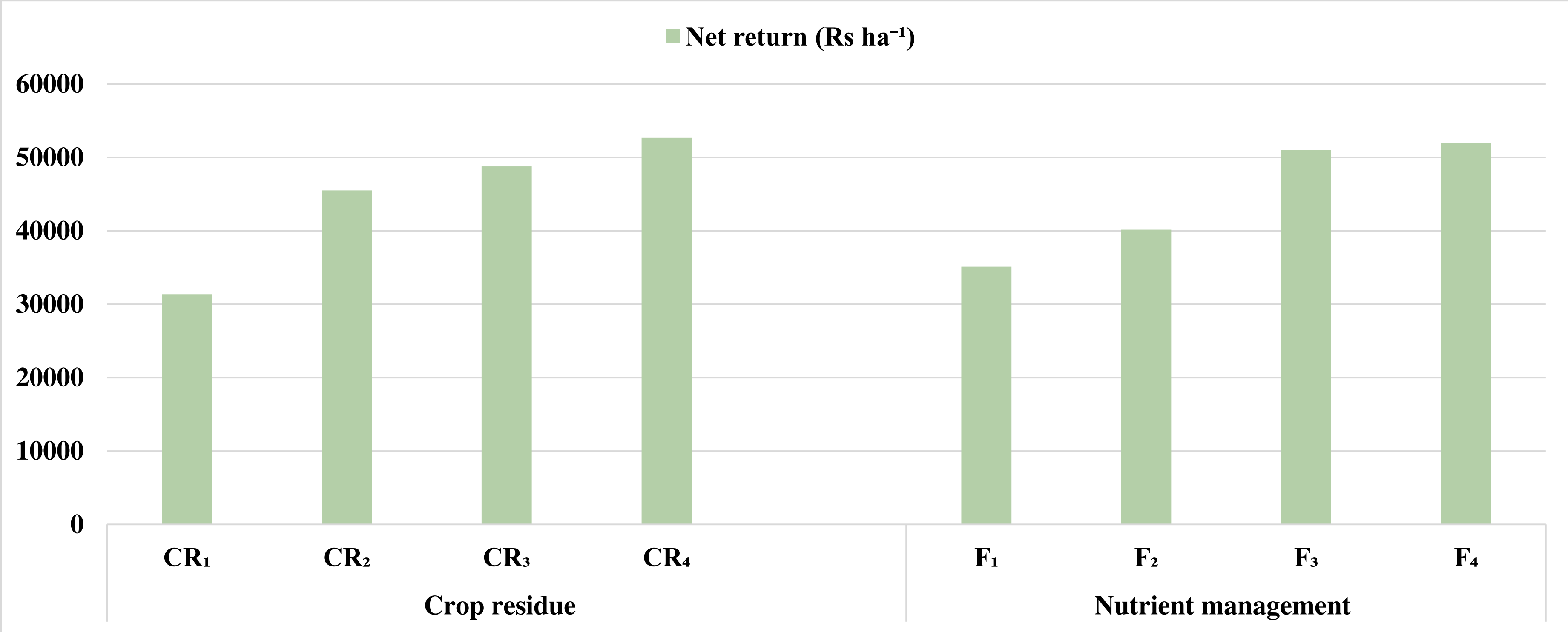

Fig. 4.13: Effect of crop residues and nutrient management on net return during both the year and on pooled analysis

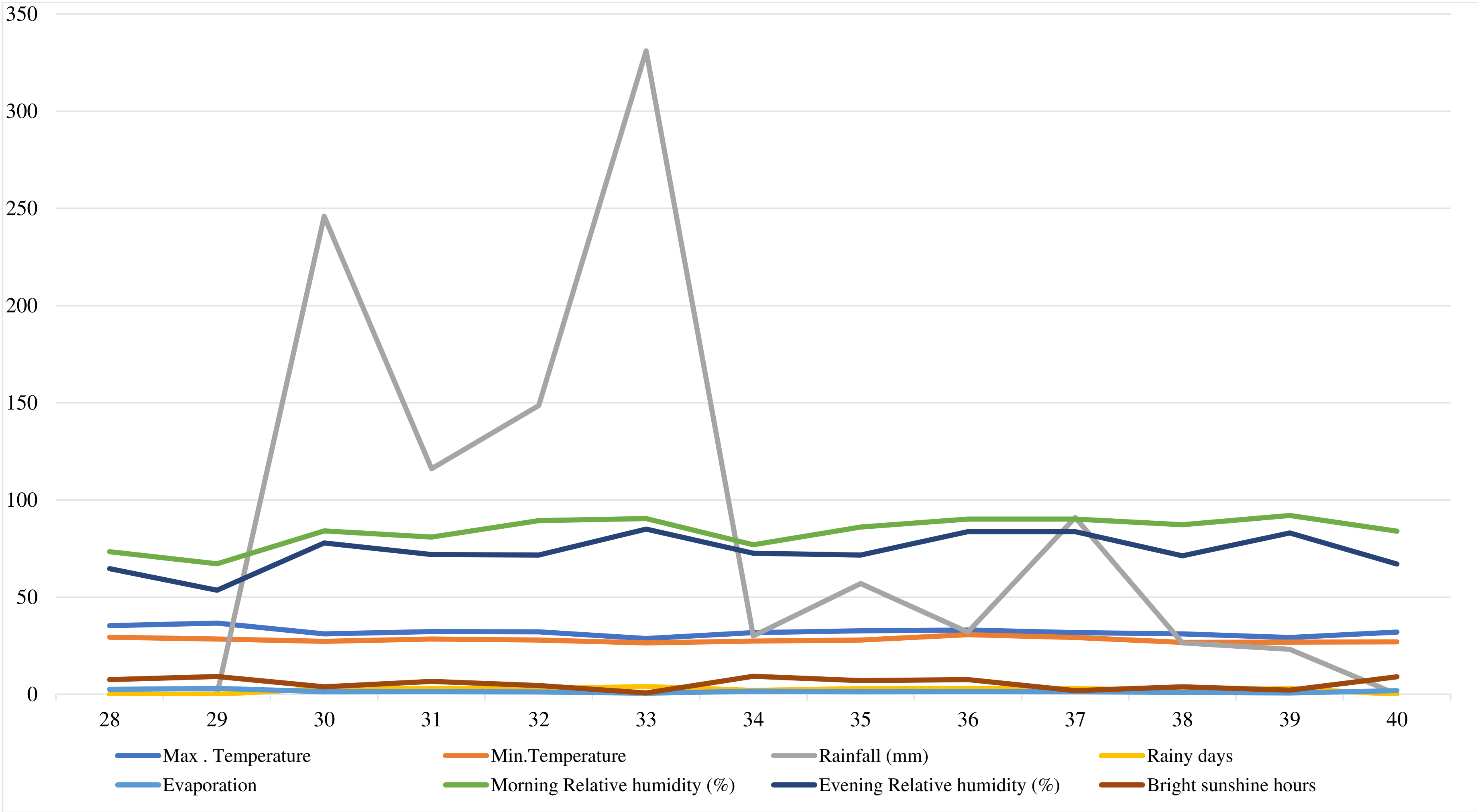

Fig. 3.1a: Mean weekly weather parameters during the crop growth period *Kharif* (2019)

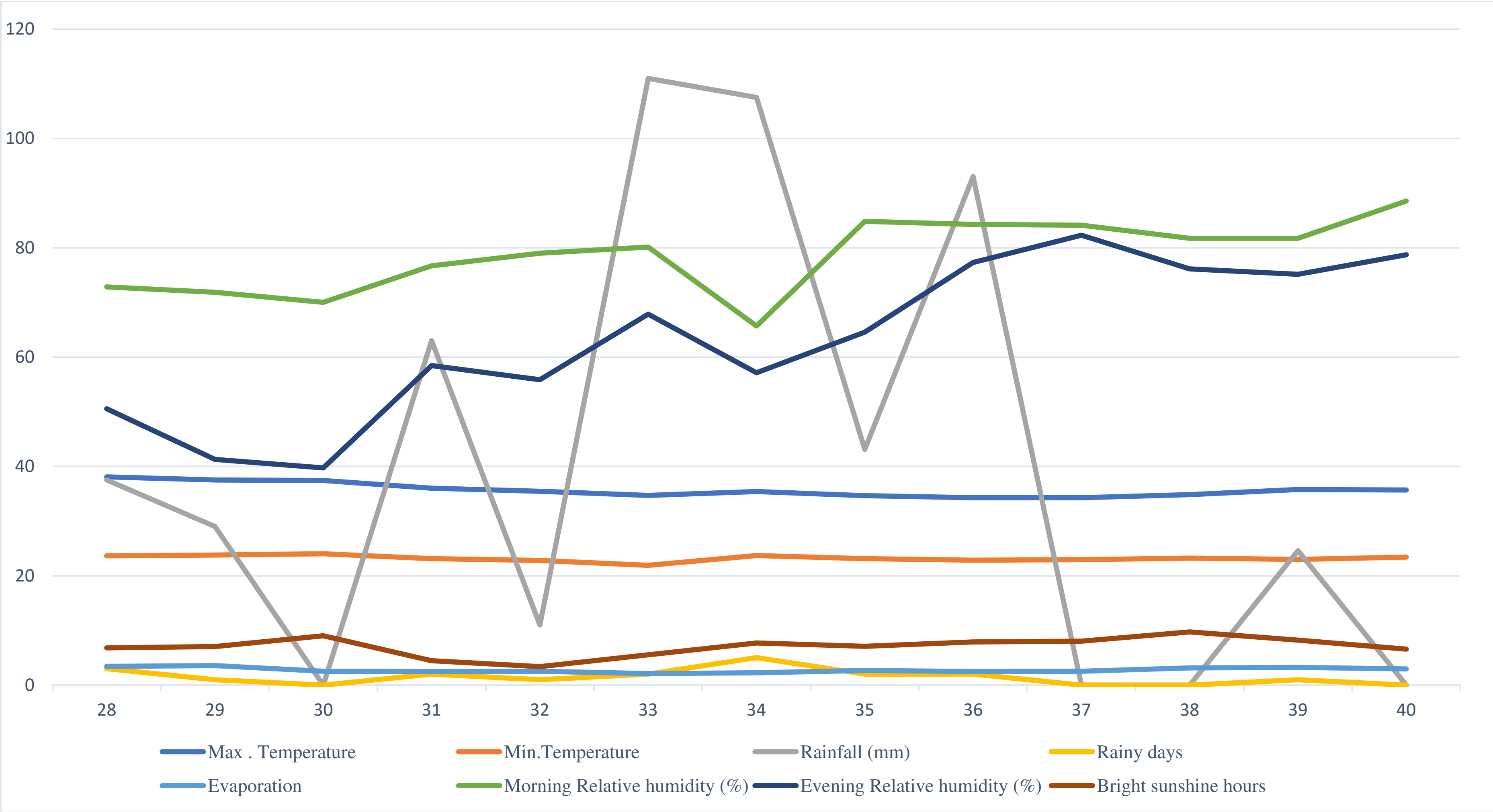

Fig. 3.1b: Mean weekly weather parameters during the crop growth period *Kharif* (2020)

Plate 1: Panoramic view of the experiment

Plate 2: Panoramic view of the experiment

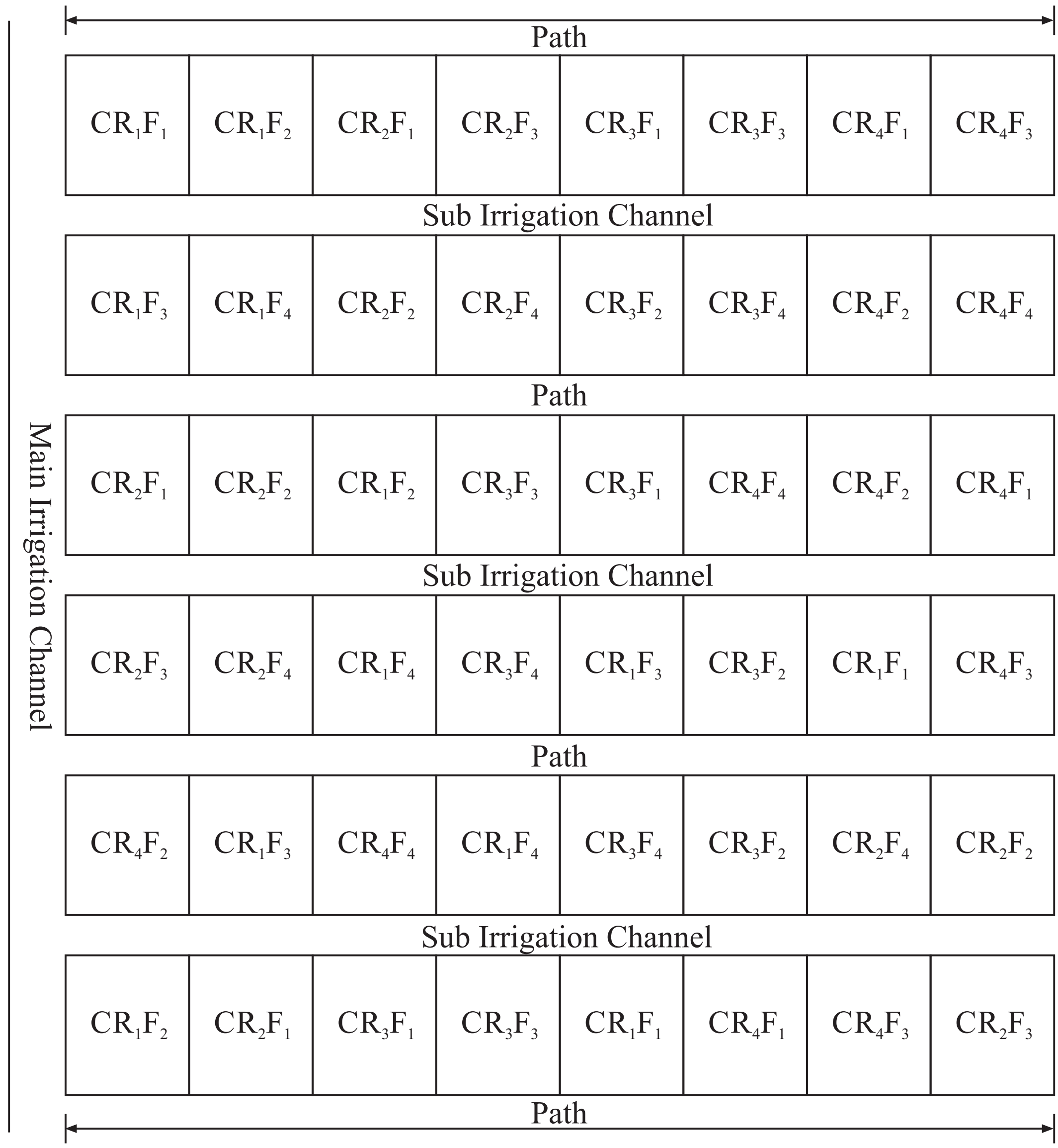

Fig. 3.2 : Layout of Experiment

APPENDIX-I

Analysis of variance for plant height, chlorophyll content, total and effective nodules

Source of variation	*df*	MSS							
		Plant height (cm)		Chlorophyll content (mg g^{-1})		Total nodules		Effective nodules	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	2.06	1.33	0.12	0.17	204.96	197.37	35.35	35.46
Treatment	15	115.39	125.80	0.52	0.68	84.81	44.12	4.49	4.28
CR	3	149.43*	148.18*	1.60	1.65*	99.51*	98.49*	9.65*	9.03*
F	3	422.81*	476.33*	0.90*	1.36*	299.20*	99.13*	11.12*	10.42*
CR x F	9	1.581	1.497	0.034	0.131	8.448	7.664	0.561	0.653
Error	30	15.52	13.64	0.09	0.05	33.96	33.61	2.43	2.79

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-II

Analysis of variance for leghaemoglobin content, fresh and dry weight of nodules, pods plant^{-1}and seed pod^{-1}

Source of variation	*df*	MSS									
		Leghaemoglobin content (mg g^{-1})		Weight of nodules plant^{-1} (mg)				Pods plant^{-1}		Seed pod^{-1}	
				Fresh		Dry					
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.01	0.01	0.86	0.90	1.01	1.06	6.86	10.65	0.21	0.26
Treatment	15	0.03	0.03	279.58	291.95	25.03	26.28	149.86	161.75	0.21	0.22
CR	3	0.07*	0.08*	780.48*	815.01*	69.87*	73.35*	196.35*	194.18*	0.54*	0.56*
F	3	0.04*	0.04*	448.02*	467.84*	40.11*	42.11*	520.59*	583.36*	0.42*	0.41*
CR x F	9	0.01	0.01	56.47	58.96	5.06	5.31	10.78	10.41	0.04	0.04
Error	30	0.01	0.01	109.30	114.14	6.99	7.34	39.99	37.62	0.10	0.11

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-III

Analysis of variance for yield

Source of variation	*df*	MSS									
		Test weight (g)		Yield (kg ha^{-1})						Harvest index (%)	
				Seed		Haulm		Biological			
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	162.41	162.41	11927	74461	198319	68020	113946	279627	25.72	4.62
Treatment	15	113.23	113.23	320874	290435	590368	613212	1654806	1688667	27.44	13.10
CR	3	228.40*	228.40*	724481*	632447*	815484*	1244720*	3070581*	3646389*	47.85*	18.42
F	3	330.01*	330.01*	725727*	664827*	1376146*	1064932*	4098684*	3410124*	21.69	20.89
CR x F	9	2.59	2.59	51387*	51633*	253403*	252136*	368255*	462274*	22.54	8.73
Error	30	50.50	50.50	19286	22628	104868	91203	129667	99023	8.75	9.84

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-IV

Analysis of variance for nitrogen and phosphorus content in seed and haulm

Source of variation	*df*	MSS							
		Nitrogen content (%)				Phosphorus content (%)			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.005	0.252	0.013	0.033	0.0001	0.0002	0.000004	0.0000182
Treatment	15	0.003	0.006	0.085	0.100	0.0003	0.0006	0.000068	0.0000976
CR	3	0.006	0.008	0.189*	0.170*	0.0007	0.0009	0.000128	0.0001600
F	3	0.006	0.022	0.236*	0.329*	0.0010	0.0020*	0.000207	0.0003272
CR x F	9	0.000	0.000	0.000	0.000	0.0000	0.0000	0.000001	0.0000002
Error	30	0.073	0.061	0.009	0.011	0.0001	0.0001	0.000035	0.0000285

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-V

Analysis of variance for potassium and iron content in seed and haulm

Source of variation	*df*	MSS							
		Potassium content (%)				Iron content (ppm)			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.000697	0.000230	0.02509	0.002370	1.67	1.28	14.76	1.352
Treatment	15	0.013952	0.020873	0.04856	0.068008	5.65	6.58	11.15	14.804
CR	3	0.031089*	0.035834*	0.08680	0.114063	22.03	22.86	26.17	38.748
F	3	0.038664*	0.068528*	0.15601	0.225970*	5.96	9.96	29.58	35.261
CR x F	9	0.000002	0.000002	0.00001	0.000002	0.08	0.03	0.01	0.003
Error	30	0.001609	0.001817	0.01123	0.013023	3.00	3.22	10.56	8.931

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-VI

Analysis of variance for zinc and copper content in seed and haulm

Source of variation	*df*	MSS							
		Zn content (ppm)				Cu content (ppm)			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.02	0.01	0.02	0.02	0.01	0.01	0.06	0.02
Treatment	15	9.38	10.21	0.89	1.29	6.82	7.61	3.86	4.43
CR	3	24.54*	25.67*	1.87	2.48	7.32*	9.22*	2.61*	2.60*
F	3	22.38*	25.38*	2.57	3.99	26.75*	28.85*	16.71*	19.53*
CR x F	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Error	30	0.97	0.86	0.31	0.31	0.22	0.24	0.10	0.11

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-VII

Analysis of variance for manganese and sulphur content in seed and haulm

Source of variation	df	MSS							
		Mn content (ppm)				S content (ppm)			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	1.80	2.78	0.15	0.15	0.001	0.0001	0.0003	0.0003
Treatment	15	28.47	32.18	20.08	20.08	0.006	0.0061	0.0023	0.0024
CR	3	62.03	66.56	41.54	41.54	0.011*	0.0119*	0.0066*	0.0070*
F	3	80.30	94.33	58.87	58.87	0.017*	0.0184*	0.0048*	0.0051*
CR x F	9	0.00	0.00	0.00	0.00	0.000	0.0000	0.0000	0.0000
Error	30	6.60	6.81	4.41	4.41	0.001	0.0005	0.0004	0.0004

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-VIII

Analysis of variance for nitrogen and phosphorus uptake by seed and haulm

Source of variation	df	MSS							
		Nitrogen uptake (kg ha^{-1})				Phosphorus uptake (kg ha^{-1})			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	48.3	617.9	41.0	88.7	0.10	0.53	0.29	0.05
Treatment	15	1215.5	1126.4	531.3	585.0	2.52	2.61	1.34	1.48
CR	3	2757.7*	2394.5*	964.6*	1203.8*	5.73*	5.56*	2.24*	3.05*
F	3	2777.2*	2659.5*	1484.0*	1500.3*	6.21*	6.78*	3.57*	3.35*
CR x F	9	180.9*	192.6	69.3	73.6	0.21	0.23	0.30	0.33
Error	30	76.5	92.3	65.7	33.9	0.10	0.11	0.15	0.13

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-IX

Analysis of variance for potassium and iron uptake by seed and haulm

Source of variation	*df*	MSS							
		Potassium uptake (kg ha^{-1})				Iron uptake (g ha^{-1})			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	1.07	8.81	57.88	25.14	13.80	141.25	1795.69	325.24
Treatment	15	49.03	53.87	656.30	713.00	718.90	683.22	4626.14	4977.25
CR	3	109.86	108.46*	1017.09*	1401.47*	1790.82*	1627.27*	7393.15	10989.35*
F	3	124.95*	149.18*	1836.84*	1755.18*	1574.15*	1544.53*	11562.96*	9824.02
CR x F	9	3.45	3.91	142.52	136.11	76.52	81.43	1391.53	1357.62
Error	30	1.94	3.55	83.62	92.37	39.05	47.29	680.30	717.69

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-X

Analysis of variance for zinc and copper uptake by seed and haulm

Source of variation	*df*	MSS							
		Zn uptake (g ha^{-1})				Cu uptake (g ha^{-1})			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	4.93	39.52	34.21	7.58	1.69	11.28	10.04	3.37
Treatment	15	257.33	255.72	158.51	177.94	73.30	72.18	114.67	124.59
CR	3	613.63*	585.25*	254.34*	376.60*	43.06	30.09	91.63*	130.22
F	3	628.34*	645.73*	424.56*	397.27*	302.34*	306.21*	459.37*	467.48*
CR x F	9	14.89	15.87	37.88	38.60	7.04	8.19	7.45	8.41
Error	30	10.13	18.80	22.52	18.11	4.17	5.02	7.77	7.80

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XI

Analysis of variance for manganese and sulphur uptake by seed and haulm

Source of variation	*df*	MSS							
		Mn uptake (g ha^{-1})				S uptake (g ha^{-1})			
		Seed		Haulm		Seed		Haulm	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	74.36	236.06	621.33	132.31	0.79	1.56	2.00	1.05
Treatment	15	1732.80	1660.54	2306.95	2401.34	9.90	10.19	11.87	12.78
CR	3	4026.48*	3702.17*	3865.08	5389.75*	22.13*	22.52*	25.43*	32.52*
F	3	4163.03*	4131.92*	6318.58*	5195.85*	25.96*	26.74*	30.12*	26.97*
CR x F	9	158.17	156.21	450.36	473.71	0.46	0.57	1.26	1.468
Error	30	62.03	115.23	286.49	250.33	0.47	0.58	1.54	1.07

* and ** Significant at 5 and 1 per cent level of significance.

APPENDIX-XII

Analysis of variance for soil physico-chemical properties pH, EC, organic carbon and CEC

Source of variation	*df*	MSS							
		pH		EC (dSm^{-1})		Organic carbon (g kg^{-1})		CEC(C mol (P^{+}) kg^{-1})	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.13	0.09	0.00204	0.00172	0.0001	0.00003	0.10	0.18
Treatment	15	0.16	0.16	0.00347	0.00354	0.0027	0.00320	8.91	12.04
CR	3	0.71*	0.70*	0.01582*	0.01624*	0.0068	0.01010	18.34*	24.85*
F	3	0.05*	0.07*	0.00121*	0.00134*	0.0066	0.00424	26.20*	35.32*
CR x F	9	0.02	0.01	0.00010	0.00004	0.0000	0.00055	0.00	0.00
Error	30	0.01	0.01	0.00003	0.00003	0.0008	0.00087	1.10	1.05

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XIII

Analysis of variance for soil physico-chemical properties BD, PD, porosity and water holding capacity

Source of variation	*df*	MSS							
		BD		PD		Porosity		WHC	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.0001	0.0022	0.000002	0.000002	0.04	2.87	0.42	2.03
Treatment	15	0.0047	0.0037	0.000002	0.000002	6.36	5.06	12.86	14.59
CR	3	0.0194*	0.0158*	0.000002	0.000002	26.27*	21.31*	52.28	59.43*
F	3	0.0026*	0.0020*	0.000002	0.000002	3.64*	2.74*	11.58	13.03
CR x F	9	0.0005	0.0003	0.000002	0.000002	0.63	0.42	0.15	0.17
Error	30	0.0001	0.0002	0.000002	0.000002	0.12	0.23	3.95	3.97

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XIV

Analysis of variance for soil available NPK

Source of variation	*df*	MSS					
		Available nutrients (kg ha^{-1})					
		N		P		K	
		2019	2020	2019	2020	2019	2020
Replication	2	16.8	6.2	0.15	0.02	229.36	45.59
Treatment	15	419.9	459.3	4.08	4.46	319.95	308.89
CR	3	1467.1	1338.5	14.24	12.99	775.50	670.61
F	3	632.4	958.1	6.14	9.30	775.50	873.19
CR x F	9	0.0	0.0	0.00	0.00	16.25	0.22
Error	30	144.1	163.1	1.26	1.52	264.67	228.88

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XV

Analysis of variance for DTPA extractable Zn, Fe, Cu & Mn

Source of variation	*df*	MSS							
		DTPA extractable (kg ha^{-1})							
		Zn		Fe		Cu		Mn	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.001	0.0003	0.003	0.0001	0.00001	0.0066	0.0004	0.0043
Treatment	15	0.002	0.0078	0.166	0.2125	0.01190	0.0165	0.1794	0.2173
CR	3	0.006	0.0309*	0.402*	0.4521*	0.00200	0.0034	0.3713*	0.4302*
F	3	0.006	0.0083	0.431	0.6102*	0.05748	0.0792	0.5255*	0.6565*
CR x F	9	0.000	0.0000	0.000	0.0000	0.00000	0.0000	0.0000	0.0000
Error	30	0.001	0.0008	0.028	0.0292	0.00986	0.0106	0.0260	0.0258

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XVI

Analysis of variance for soil biological properties

Source of variation	*df*	MSS							
		Alkaline phosphatese (µg*p*-nitrophenol g^{-1}soilh^{-1})		Dehydrogenase activity (µg TPF g^{-1}24 hr^{-1})		Soil microbial population (cfu g^{-1})		Soil microbial C biomass (mg kg^{-1})	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.05	0.04	0.12	0.01	0.04	0.03	0.16	5.09
Treatment	15	18.54	15.97	21.22	21.77	54.66	55.60	198.47	199.01
CR	3	52.94*	41.89*	61.91*	64.52*	156.89*	167.57*	354.70	354.70
F	3	39.74*	37.94*	44.17*	44.32*	116.42*	110.41*	637.64	640.33
CR x F	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Error	30	0.99	1.08	0.84	0.85	1.78	1.57	51.19	70.14

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XVII

Analysis of variance for soil microbial carbon, total organic carbon, dissolved organic hot water extractable carbon

Source of variation	*df*	MSS							
		Soil microbial C (g kg^{-1})		Total organic C (g kg^{-1})		Dissolved organic C (g kg^{-1})		Hot water extractable carbon (g kg^{-1})	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.02	0.00	0.06	0.03	28.55	3.17	0.0000	0.0001
Treatment	15	3.36	4.59	1.71	2.25	335.39	307.52	0.0843	0.0960
CR	3	9.61*	12.38*	4.46*	5.65*	568.47*	548.12*	0.2321*	0.2510*
F	3	7.18*	10.39*	4.02*	5.54*	1094.11*	989.49*	0.1896*	0.2291*
CR x F	9	0.01	0.06	0.01	0.02	4.78	0.00	0.0000	0.0000
Error	30	0.06	0.08	0.14	0.19	36.74	27.81	0.0001	0.0002

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XVIII

Analysis of variance for plant height POMC, POMN, water soluble carbon and carbohydrates

Source of variation	*df*	MSS							
		POMC (g kg^{-1})		POMN (g kg^{-1})		Water soluble C (g kg^{-1})		Water soluble Carbohydrates(g kg^{-1})	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.01	0.01	0.0001	0.0001	291.64	1.60	0.036	0.009
Treatment	15	9.60	9.89	0.0195	0.0226	739.04	327.75	1.166	1.282
CR	3	27.69*	27.23*	0.0601*	0.0625*	719.16*	813.64*	3.285*	3.404*
F	3	20.32*	22.23*	0.0374*	0.0505*	0.00*	825.09*	2.544*	3.007*
CR x F	9	0.00	0.00	0.0000	0.0000	1.61	0.00	0.000	0.000
Error	30	0.05	0.02	0.0001	0.0001	291.64	0.95	0.008	0.010

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XIX

Analysis of variance for chain pool carbon

Source of variation	*df*	MSS							
		Chain pool carbon (g kg^{-1})							
		Very labile		Labile		Less labile		Non-labile	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.001	0.001	0.005	0.004	0.03	0.05	0.07	0.07
Treatment	15	0.810	0.960	0.147	0.153	0.63	1.02	0.42	0.54
CR	3	1.631*	1.860*	0.513*	0.527*	2.00*	2.50*	1.54*	1.62*
F	3	2.377*	2.876*	0.072*	0.073*	1.02*	2.32*	0.47*	0.92*
CR x F	9	0.013	0.021	0.050*	0.055*	0.05*	0.09*	0.03*	0.06*
Error	30	0.013	0.015	0.002	0.003	0.01	0.01	0.02	0.03

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XX

Analysis of variance for carbon mineralization

Source of variation	*df*	MSS							
		Carbon mineralization (g kg^{-1})							
		15 DAS		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	2	0.00002	0.00005	0.00002	0.000001	0.0001	0.0003	0.001	0.000
Treatment	15	0.00466	0.00472	0.01891	0.019106	0.0388	0.0399	0.068	0.069
CR	3	0.01635*	0.01652*	0.06859*	0.069260*	0.1304*	0.1335*	0.220*	0.231*
F	3	0.00663*	0.00677*	0.02486*	0.025189*	0.0608*	0.0630*	0.115*	0.109*
CR x F	9	0.00010	0.00010	0.00037	0.000360	0.0010	0.0010	0.002	0.002
Error	30	0.00004	0.00006	0.00017	0.000162	0.0004	0.0005	0.001	0.001

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXI

Analysis of variance for economics

Source of variation	*df*	MSS			
		Net return (Rs ha^{-1})		BC ratio	
		2019	2020	2019	2020
Replication	2	6341178	121129975	0.01	0.19
Treatment	15	440200383	410376579	0.55	0.50
CR	3	1081168005*	994617202*	1.57*	1.41*
F	3	873608830*	773049492*	0.65*	0.53*
CR x F	9	82075027*	94738733*	0.18*	0.19*
Error	30	28545736	30339748	0.05	0.05

APPENDIX-XXII

Pooled analysis of variance for growth characters

Source of variation	*df*	MSS						
		Plant height (cm)	Chlorophyll content (mg g^{-1})	Nodules plant^{-1}		Leghaemoglobin content (mg g^{-1})	Weight of nodules plant^{-1} (mg)	
				Total	Effective		Fresh	Dry
Year	1	0.681	0.23	52.64	6.37	0.05677	590.14	66.71
Rep (Y)	4	1.699	0.14	201.16	35.40	0.00936	0.88	1.04
CR	3	297.601*	3.25*	197.81*	18.68*	0.15153*	1595.30*	143.20*
F	3	898.114*	2.19*	371.02*	21.52*	0.08698*	915.75*	82.20*
CR x Y	3	0.002	0.00	0.19	0.01	0.00002	0.19	0.02
F x Y	3	1.019	0.07	27.32	0.02	0.00001	0.11	0.01
CR x F	9	3.076	0.11	15.96	1.20	0.01096	115.41	10.36
CR x F x Y	9	0.002	0.05	0.15	0.02	0.00000	0.01	0.00
Error	60	14.582	0.07	33.79	2.61	0.01295	111.72	7.17

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXIII

Pooled analysis of variance for yield attributes, yield and harvest index

Source of variation	*df*	MSS						
		Pods plant^{-1}	Seed pod^{-1}	Test weight (g)	Yield (kg ha^{-1})			Harvest index (%)
					Seed	Haulm	Biological	
Year	1	0.70	0.03420	0.04	47471	60573	215290	2.35
Rep (Y)	4	8.75	0.23715	162.48	43194	133170	196786	15.17
CR	3	390.53*	1.09384*	417.74*	1353088*	2016911*	6671457*	62.74*
F	3	1103.04*	0.82814*	629.16*	1389579*	2427959*	7487643*	42.53*
CR x Y	3	0.01	0.00012	1.21	3840	43292	45514	3.53
F x Y	3	0.92	0.00002	0.50	975	13118	21165	0.06
CR x F	9	21.18	0.08017	1.27	97542*	444989*	742270*	28.98
CR x F x Y	9	0.01	0.00005	1.33	5478	60550	88259	2.30
Error	60	38.80	0.03420	53.37	20957	98035	114345	9.30

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXIII

Pooled analysis of variance for nutrient content of seed and haulm

Source of variation	*df*	MSS					
		Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
		Seed	Haulm	Seed	Haulm	Seed	Haulm
Year	1	0.0008	0.0198	0.00044	0.00001	0.0215	0.014245
Rep (Y)	4	0.1285	0.0230	0.00016	0.00001	0.0005	0.013728
CR	3	0.0144	0.3585*	0.00160*	0.00029*	0.0658*	0.199362*
F	3	0.0253	0.5570*	0.00279*	0.00053*	0.1039*	0.374134*
CR x Y	3	0.0001	0.0004	0.00001	0.00000	0.0011	0.001498
F x Y	3	0.0034	0.0081	0.00019	0.00001	0.0033	0.007847
CR x F	9	0.0000	0.0000	0.00000	0.00000	0.0000	0.000004
CR x F x Y	9	0.0000	0.0000	0.00000	0.00000	0.0000	0.000004
Error	60	0.0666	0.0101	0.00011	0.00003	0.0017	0.012128

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXIV

Pooled analysis of variance for nutrient content of seed and haulm

Source of variation	*df*	**MSS**					
		Iron content (ppm)		**Zn content (ppm)**		**Cu content (ppm)**	
		Seed	**Haulm**	**Seed**	**Haulm**	**Seed**	**Haulm**
Year	1	0.70	8.621	3.063	1.284	0.183	0.013
Rep (Y)	4	1.48	8.058	0.011	0.023	0.009	0.043
CR	3	44.85*	63.967*	50.089*	4.325*	16.217*	5.175*
F	3	15.56*	64.649*	47.662*	6.455*	55.571*	36.121*
CR x Y	3	0.05	0.949	0.125	0.022	0.323	0.033
F x Y	3	0.36	0.187	0.096	0.115	0.036	0.124
CR x F	9	0.05	0.005	0.000	0.000	0.000	0.000
CR x F x Y	9	0.06	0.007	0.000	0.000	0.000	0.000
Error	60	3.11	9.747	0.914	0.310	0.228	0.106

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXV

Pooled analysis of variance forMn & S content and NPK uptake

Source of variation	*df*	MSS									
		Mn content (ppm)		S content (ppm)		Uptake (kg ha^{-1})					
						Nitrogen		Phosphorus		Potassium	
		Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
Year	1	2.00	0.00	0.0038	0.0021	198.33	88.72	0.76	0.18	22.17	120.06
Rep (Y)	4	2.29	0.15	0.0006	0.0003	333.10	64.85	0.32	0.17	4.94	41.51
CR	3	128.55*	83.09*	0.0230*	0.0136*	5137.70*	2155.96*	11.28*	5.22*	218.26*	2393.36*
F	3	174.19*	117.75*	0.0357*	0.0099*	5435.74*	2978.15*	12.96*	6.93*	273.49*	3589.62*
CR x Y	3	0.05	0.00	0.0000	0.0000	14.43	12.49	0.02	0.06	0.05	25.20
F x Y	3	0.44	0.00	0.0000	0.0000	0.95	6.14	0.02	0.00	0.65	2.39
CR x F	9	0.00	0.00	0.0000	0.0000	351.78*	116.40*	0.42*	0.53*	6.88*	238.76*
CR x F x Y	9	0.00	0.00	0.0000	0.0000	21.80	26.54	0.03	0.10	0.48	39.87
Error	60	6.71	4.41	0.0006	0.0004	84.43	49.82	0.10	0.14	2.74	87.99

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXVI

Pooled analysis of variance for nutrient uptake by seed and haulm

Source of variation	*df*	MSS									
		Nutrient uptake (g ha^{-1})									
		Fe		Zn		Cu		Mn		S	
		Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
Year	1	115.89	892	58.96	49.59	10.00	5.67	267.21	147	3.29	4.69
Rep (Y)	4	77.52	1060	22.23	20.89	6.48	6.70	155.21	377	1.17	1.53
CR	3	3411.40*	18078*	1197.41*	621.31*	70.96*	219.42*	7717.73*	9140*	44.63*	57.51*
F	3	3118.48*	21348*	1274.01*	821.56*	608.53*	926.03*	8294.60*	11484*	52.69*	57.05*
CR x Y	3	6.69	305	1.47	9.63	2.20	2.43	10.92	114	0.03	0.44
F x Y	3	0.20	39	0.06	0.27	0.02	0.83	0.35	30	0.00	0.05
CR x F	9	147.34*	2399*	28.44	65.51*	14.61*	12.51	294.89*	784	0.95	2.25
CR x F x Y	9	10.60	350	2.32	10.98	0.62	3.35	19.48	140	0.08	0.48
Error	60	43.17	699	14.47	20.32	4.59	7.78	88.63	268	0.53	1.31

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXVII

Pooled analysis of variance for physic-chemical property of soil

Source of variation	*df*	MSS							
		pH	EC (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	CEC (C mol (P^{+}) kg^{-1})	BD	PD	Porosity	WHC
Year	1	0.0133	0.00490	0.0408	12.70	0.03411	0.0000000	46.45	201.60
Rep (Y)	4	0.1140	0.00188	0.0001	0.14	0.00110	0.0000021	1.46	1.23
CR	3	1.4059*	0.03205*	0.0167*	42.94*	0.03507*	0.0000042	47.39*	111.60*
F	3	0.1228*	0.00254*	0.0106*	60.59*	0.00456*	0.0000042	6.34*	24.58*
CR x Y	3	0.0001	0.00002	0.0002	0.26	0.00014	0.0000000	0.19	0.11
F x Y	3	0.0007	0.00001	0.0002	0.93	0.00003	0.0000000	0.04	0.02
CR x F	9	0.0290	0.00013	0.0003	0.00	0.00063	0.0000042	0.86	0.32
CR x F x Y	9	0.0007	0.00001	0.0003	0.00	0.00014	0.0000000	0.19	0.00
Error	60	0.0075	0.00003	0.0008	1.08	0.00013	0.0000021	0.18	3.96

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXVIII

Pooled analysis of variance for soil available nutrients

Source of variation	*df*	MSS						
		Available nutrients (kg ha^{-1})			DTPA extractable nutrients (ppm)			
		N	P	K	Zn	Cu	Mn	Fe
Year	1	36.79	0.36	258.77	0.0193	0.0064	0.049	0.054
Rep (Y)	4	11.49	0.09	137.47	0.0004	0.0033	0.002	0.001
CR	3	2804.01*	27.22*	1428.82*	0.0224*	0.0053	0.800*	0.853*
F	3	1567.11*	15.21*	1630.30*	0.0145*	0.1357*	1.177*	1.031*
CR x Y	3	1.52	0.01	17.28	0.0140	0.0001	0.001	0.001
F x Y	3	23.47	0.23	18.39	0.0001	0.0009	0.005	0.010
CR x F	9	0.00	0.00	7.50	0.0000	0.0000	0.000	0.000
CR x F x Y	9	0.00	0.00	8.97	0.0000	0.0000	0.000	0.000
Error	60	153.63	1.39	246.78	0.0008	0.0102	0.026	0.029

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXIX

Pooled analysis of variance for soil biological properties

Source of variation	*df*	MMS							
		Alkaline phosphate	Dehydrogenage activity	Soil microbial population	Soil microbial C biomass	Soil microbial C	Total organic C	Dissolved organic C	Hot water extractable carbon (g kg^{-1})
Year	1	37.96	6.76	15.79	660.58	11.96	24.721	3354.3	0.010
Rep (Y)	4	0.05	0.06	0.04	2.62	0.01	0.026	15.9	0.000
CR	3	93.83*	126.37*	324.36*	709.41*	21.83*	10.234*	1114.3*	0.483*
F	3	77.60*	88.46*	226.57*	1236.47*	17.42*	10.374*	2022.3*	0.418*
CR x Y	3	1.00	0.06	0.10	0.00	0.16	0.033	2.3	0.000
F x Y	3	0.08	0.04	0.26	41.50	0.15	0.033	61.3	0.001
CR x F	9	0.00	0.00	0.00	0.00	0.04	0.000	2.4	0.000
CR x F x Y	9	0.00	0.00	0.00	0.00	0.03	0.000	2.4	0.000
Error	60	1.03	0.85	1.68	60.67	0.07	0.046	32.3	0.000

* and ** Significant at 5 and per cent level of significance

APPENDIX-XXX

Pooled analysis of variance for POMC & N, water soluble carbon & carbohydrates and chain pool carbon

Source of variation	*df*	MSS							
		POMC	POMN	Water soluble C	Water soluble Carbohydrates	Chain pool carbon			
						Very labile	Labile	Less labile	Non-labile
Year	1	1.70	0.020	81.48	0.33	0.750	0.001	7.290	2.198
Rep (Y)	4	0.01	0.000	2.74	0.02	0.001	0.004	0.039	0.072
CR	3	54.91*	0.122*	1545.91*	6.68*	3.486*	1.025*	4.417*	3.097*
F	3	42.52*	0.087*	1539.83*	5.54*	5.237*	0.126*	3.190*	1.322*
CR x Y	3	0.01	0.000	6.76	0.01	0.004	0.015	0.083	0.064
F x Y	3	0.03	0.001	4.42	0.01	0.016	0.019	0.148	0.064
CR x F	9	0.00	0.000	0.00	0.00	0.028	0.099*	0.096*	0.050*
CR x F x Y	9	0.00	0.000	0.00	0.00	0.006	0.006	0.047	0.036
Error	60	0.03	0.000	1.28	0.01	0.014	0.003	0.006	0.021

* and ** Significant at 5 and per cent level of significance

APPENDIX-XXXI

Pooled analysis of variance for carbon mineralization

Source of variation	***df***	**MSS**			
		Carbon mineralization (g kg^{-1})			
		15 DAS	**30 DAS**	**60 DAS**	**90 DAS**
Year	1	0.00017	0.00064	0.0006	0.0057
Rep (Y)	4	0.00003	0.00001	0.0002	0.0004
CR	3	0.03287*	0.13785*	0.2636*	0.4513*
F	3	0.01339*	0.05004*	0.1237*	0.2239*
CR x Y	3	0.00000	0.00001	0.0002	0.0003
F x Y	3	0.00001	0.00001	0.0001	0.0001
CR x F	9	0.00020	0.00072*	0.0019*	0.0033*
CR x F x Y	9	0.00001	0.00001	0.0001	0.0002
Error	60	0.00005	0.00016	0.0005	0.0008

* and ** Significant at 5 and 1 per cent level of significance

APPENDIX-XXXII

Pooled analysis of variance for economics

Source of variation	*df*	MSS	
		Net return	BC ratio
Year	1	80007866	0.14
Rep (Y)	4	63735576	0.10
CR	3	2070179417*	2.96*
F	3	1644237704*	1.17*
CR x Y	3	5605790	0.01
F x Y	3	2420618	0.01
CR x F	9	165645399*	0.35*
CR x F x Y	9	11168361	0.02
Error	60	29442742	0.05

* and ** Significant at 5 and 1 per cent level of significance

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