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# Effect of tillage and nutrient management practices on soil properties and productivity in wheat preceded by rice under subtropical climatic conditions

**Darvin Pal, NS Rana, RK Naresh, Ashok Kumar, HL Singh, Vivek, Saurabh Tyagi and Sandeep Chaudhary**

**Abstract**
Exploitive agriculture involving nutrient input far below the quantities removed by the crops coupled with excessive tillage and indiscriminate use of irrigation water led to serious soil health problems over the years. Widespread multi-nutrient deficiencies and increased soil compaction have emerged as major constraints affecting crop productivity and farm profits. As significant increase in fertiliser consumption seems unlikely in foreseeable future due to economic and ecological reasons, the need for enhancement of nutrient use efficiency through tillage and nutrient management practices were felt more intensely than ever before. The study undertaken in in wheat preceded by rice environments has established the benefits of tillage and nutrient management. Present article overviews the significance of different tillage practices with nutrient management in improving soil properties, nutrient use efficiency and crop productivity. Therefore, we conclude that FIRB 75 cm RSR + EFR under tillage and nutrient management system were influence significantly the growth, yield attributes and yields of wheat as compared to FIRB 37 RSR+RFR alone practices under subtropical climatic conditions.

**Keywords:** conservation tillage; soil quality, nutrient management, productivity

## Introduction
Holistic management of arable soil is the key to dealing with the most complex, dynamic, and interrelated soil properties, thereby maintaining sustainable agricultural production systems, the lone foundation of human civilization. Any management practice imposed on soil for altering the heterogeneous body may result in generous or harmful outcomes Derpsch *et al.* (2010) [5]. Unsuitable management practices cause degradation in soil health as well as decline in crop productivity Ramos, *et al.* (2011) [25]. Reducing disturbance of soil by reduced tillage influences several physically López-Garrido *et al.* (2012) [18], chemically and biologically Munoz *et al.* (2007) interconnected properties of the natural body.
Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% and affects the sustainable use of soil resources through its influence on soil properties Lal and Stewart, (2013) [17]. The judicious use of tillage practices overcomes edaphic constraints, whereas inopportune tillage may cause a variety of undesirable outcomes, for example, soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient Lal, (1993) [16]. Conservation tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods for the purpose of controlling erosion process Iqbal *et al.* (2005) [10]. Conventional tillage practices cause change in soil structure by modifying soil bulk density and soil moisture content. In addition, repeated disturbance by conventional tillage gives birth to a finer and loose-setting soil structure while conservation and no-tillage methods leave the soil intact Rashidi, and Keshavarzpour, (2007) [26]. This difference results in a change of characteristics of the pores network. The number, size, and distribution of pores again control the ability of soil to store and diffuse air, water, and agricultural chemicals and, thus, in turn crop performance Khan *et al.* (2001). Losses of soil organic C (SOC) and deterioration in other properties exaggerated where conventional tillage was employed Powlson *et al.* (2012) [24]. With time, conservation tillage, on the other hand, improves soil quality indicators Plaza *et al.* (2013) [23].

Raised bed planting systems has been used since time immemorial by farmers in many parts of the world (Govaerts *et al.*, 2007) [7]. Their application has traditionally been associated with water management issues, to reduce the adverse impact of excess water on crop production or to irrigate crops in semiarid and arid regions (Sayre, 2004) [27] where water productivity is comparatively low. A widely used application of raised beds in many semi-arid and arid areas is to plant crops on the edges of beds or ridges that are formed between furrows that carry irrigation water. Monsefia *et al.*, (2016) [19] found that furrow-irrigated raised-bed planting system (FIRBS) is a form of tillage wherein sowing is done on raised-beds. This optimizes tillage operation, saves water, reduces lodging, and ensures better fertilizer use. Ladha *et al.*, (2009) [15] found no-tillage and reduced tillage systems were most profitable due to saving of labour, time, water and energy costs. There are several reports showing savings in irrigation water, labour and production costs, and higher net economic returns in no tillage and reduced tillage compared with conventional tillage systems. Thus, proper nutrient strategies are essential for wheat to optimize nutrient use without sacrificing the yield. This study investigated the effects of amount and time of nutrient application on growth and yield attributes, yield, and nutrient productivity of four tillage crop establishment methods compared with conventional method with an objective of defining an appropriate nutrient management practices matching with particular planting technique.

## Materials and Methods

### Experimental site

The field experiment was established in 2014 at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P., India research farm ($29^0$ 04', N latitude and$77^0$ 42' ‘E longitude a height of 237m above mean sea level). The region has a semiarid sub-tropical climate with an average annual temperature of $16.8^0$C. The hottest months are May and June, when the maximum temperature reaches 45 to 46°C, whereas, during December and January, the coldest months of the year, the temperature often drops below 5°C.The average annual rainfall is 765 mm, 75 to 80% of which is received through the Northwest monsoon during July to September. The predominant soil at the experimental site is classified as Typic Ustochrept. Soil samples for 0–20 cm depth at the site were collected and tested prior to applying treatments and the basic properties were non-saline (EC 0.19 dS $m^{-1}$) but mild alkaline in reaction (pH 7.9). The soil initially had 4.1 g $kg^{-1}$ of SOC and 1.29 g $kg^{-1}$ of total N (TN), 1.23 g $kg^{-1}$ of total phosphorus, 17.63 g $kg^{-1}$ of total potassium, 223 mg $kg^{-1}$ of available N, 167 mg $kg^{-1}$ of available phosphorus, and 251 mg $kg^{-1}$ of available potassium.

### Treatment details

A detailed description of crop establishment methods are necessary to compare the influence of land configuration practices on environmental performance. The experiment was laid down in Randomized Block Design with three replications the treatments comprised of twelve plots; viz. zero tillage ($T_1$), reduced tillage ($T_2$), conventional tillage ($T_3$), FIRB (37 cm)- ESR + EFR ($T_4$), FIRB (37 cm)- RSR + EFR ($T_5$), FIRB (37 cm)- RSR + EFR ($T_6$), FIRB (60 cm)- ESR + EFR ($T_7$), FIRB (60 cm)- RSR + EFR ($T_8$), FIRB (60 cm)- RSR + EFR ($T_9$), FIRB (75 cm)- ESR + EFR ($T_{10}$), FIRB (75 cm)- RSR + EFR ($T_{11}$), and FIRB (75 cm)- RSR + EFR ($T_{12}$). However, FIRB – Furrow irrigated raised bed (37, 60 and 75 cm top width), ESR- Equal seed rate (recommended dose for wheat 100 kg $ha^{-1}$ as apply), RSR-Reduced seed rate (reduced seed rate 80 kg $ha^{-1}$ as compare to recommended), EFR-Equal fertilizer rate (recommended dose for wheat $N_{100}$+ $P_{60}$ + $K_{40}$ as applied) and RFR-Reduced fertilizer rate (reduced rate of fertilizer as applied $N_{80}$ + P50 + $K_{30}$).

## Cultural Practices

### Conventional tillage

After the rice harvest, the conventional practice of two harrowing, two ploughing (using a cultivator) and one planking (using a wooden plank) followed pre-sowing irrigation and wheat was seeded in rows 20 cm apart using a seed drill with a dry-fertilizer attachment.

### Furrow Irrigated Raised Beds (FIRB)

At first primary tillage practices will be done by mouldboard plough to a depth of 15 cm and followed by two passes of disk harrow after that these beds will be made by raised bed planter with the help of tractor. The height of bed 15-20 cm from the surface and the crop will be sown on the bed 2-4 line on the bed depend on size. The width of bed will be 37.5 (2 lines), 60 (3 lines) and 75 cm (4 lines). The gap between two beds is 30 cm.

### Reduced tillage

In the minimum tillage the residues of the previous crop will be left on the soil surface. In this system tillage perse still exists, but numbers of preparatory tillage operations are reduced significantly. The soil is disturbed prior to planting by rotavator to prepare the seedbed and wheat will be sown in rows 20 cm apart.

### Zero tillage

In zero-till system, crop will be sown with minimum of soil disturbance. Seeds will be placed directly into narrow slits (2-4 cm wide and 4-7 cm deep) made with a drill fitted with chisel, inverted “T” without any land preparation.

### Fertilizer (Recommended and reduced dose of fertilizer) application crop management

Plant nutrients will be applied as different dose for wheat recommended according to state recommendation called equal fertilizer rate as treatment applied ($N_{100}$+ $P_{60}$ + $K_{40}$) and reduced fertilizer rate as treatment ($N_{80}$ + $P_{50}$ + $K_{30}$) through Urea, Di-ammonium phosphate and Muriate of potash respectively, will be placed different methods such as using zero till cum raised beds planter with inclined plate metering device and using broadcast method in other treatments. For equal fertilizer rate, the remaining half dose of N will be broadcast with dry urea in two equal splits of 25 kg N $ha^{-1}$, (N25) at crown root initiation (CRI) and the flag leaf initiation (FLI) of wheat growth stages. For reduced fertilizer rate, the remaining half dose of N will be broadcast with dry urea in two equal splits of 20 kg N $ha^{-1}$ N20 at crown root initiation (CRI) and the flag leaf initiation (FLI). For both the nutrient (phosphorous and potassium) entire dose will be apply at the time of sowing for all the treatment.

Wheat PBW-550 was sown as recommended timely sown variety for North-West-Plain Zone @ 100 kg $ha^{-1}$ for ESR treatments and 80kg seed $ha^{-1}$ for RSR treatments. For controlling weeds, pre-sowing spray was done manually by knap sack sprayer. Glyphosate a non-selective pre-sowing herbicide was applied @ 1.0 kg a.i. $ha^{-1}$ and post emergence selective herbicide Sulfosulfuron 75 % was applied @ 25a.i. $gha^{-1}$+Metasulfuron 10 % @ 4a.i. $gha^{-1}$ used after 25 DAS with 420 l of water during both years of investigation. Harvesting was done manually by improved sickle. The border of individual plot was harvested and separated as a general crop. Thereafter the total biomass production of individual net plot was harvested and left in the field for 3 days under sun drying so as to keep the grain moisture level at optimum i.e. 12 %.

**Soil Sampling and analysis**

Bulk density of soil was calculated and expressed in mega gram per cubic meter ($Mg/m^3$) (Piper, 1966) [22]. The infiltration rate of water through soil was measured using a double-ring infiltrometer from two spots within each plot. Core index was measured to obtain soil penetration resistance (SPR) in the 0-0.05; 0.05-0.15 and 0.15-0.30 m soil depths. After recording the SPR value, soil samples from the same layer was collected with the help of a tube auger for determining gravimetric moisture content.

**Yield and yield attributes determination**

Yield attributes from shoots bearing spike at the time of harvesting was recorded by using a quadrate of one square meter in each plot. However, in case of FIRB one meter row length was chosen for recording yield attributes. After harvesting, the wheat crop was sun dried and then weight of net plot area harvested was recorded in kg and expressed as q $ha^{-1}$. The produce from net plot was threshed separately by plot thresher and grain yield was recorded. Straw yield was computed from net area by subtracting the grain yield from the biological yield and later converted into q ha-1.

**Statistical analysis**

All the data recorded during the course of investigation were analyzed by analysis of variance technique (ANOVA) using the Statistical Analysis System (SAS Institute, 2001). The comparison of treatment means were made by the least significant difference (LSD) at 5% probability (p=0.05).

**Results and Discussion**

**3.1 Yield attributes and yield performance**

Data on various yields attributing characters viz. productive tiller's $m^{-2}$, number of grains $spike^{-1}$, and test weight, as influenced by tillage-cum-crop establishment methods and different nutrient management practices are presented in Figure 1 and Figure 2 revealed that the number of effective tillers $m^{-2}$ significantly highest with the FIRB 75 cm RSR + EFR followed by FIRB 60 cm RSR + EFR as compared to all the treatments. The number of grains $spike^{-1}$ was found significantly maximum in FIRB 75 cm RSR + EFR which were on par with FIRB 60 cm RSR + EFR. The minimum number of grains $spike^{-1}$ was obtained from FIRB 37 cm RSR + RFR practices, respectively. The 1000-grain weight (g) was noticed significantly highest in FIRB 75 cm RSR + EFR as compared to FIRB 37 cm RSR + RFR practices which was 23.9and 23.7 per cent higher over this treatment. The FIRB 60 cm RSR + EFR and FIRB 37 cm RSR + EFR was exhibited next higher values received in respect of 1000-grain weight and grasped 2nd and 3rd place within the treatments. However, FIRB 37 cm RSR + RFR, FIRB 60 cm RSR + RFR and FIRB 75 cm RSR + RFR was also received least 1000-grain weight. Stimulated vegetative growth of wheat on account of adequate and prolonged supply of moisture and better soil environment in FIBR tillage with nutrient management system that manifested itself in increased productive tiller's, number of grains $spike^{-1}$, and test weight (Ahmad *et al.*, 2010; Yadav *et al.*, 2011; Naresh *et al.*, 2013 and Kumawat, 2013) [1, 30].

Yield components i.e. grain, straw and biological yield of wheat were also influenced by sowing techniques and nutrient management Figure 3. Crop yield under FIRB 75 cm RSR + EFR performed significantly maximum as compared to all the treatments. Moreover, minimum grain yield was recorded under FIRB 37cm RSR + RFR during experimentation. The data further revealed that the FIRB 60 cm RSR + EFR (46.6 and 47.3 q/ha) and FIRB 37 cm RSR + EFR (44.2 and 45.0 q/ha) was also significantly higher over rest of the treatments. However, the next least value of grain yield was exhibited in FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR and Conventional flat, respectively.

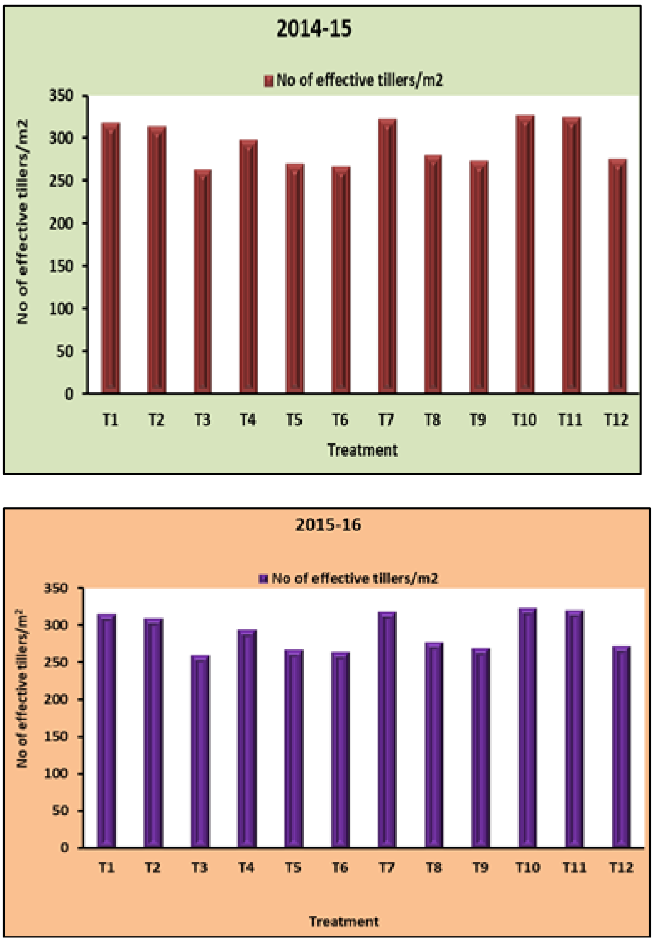
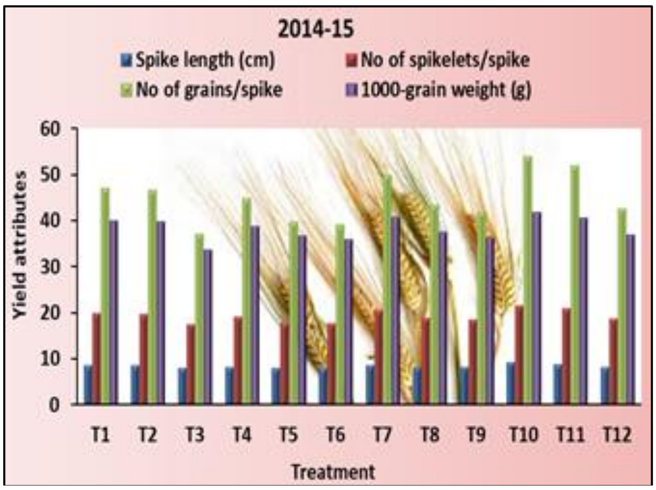



**Fig 1:** Number of effective tillers $m^{-2}$ during 2014-15 and 2015-16



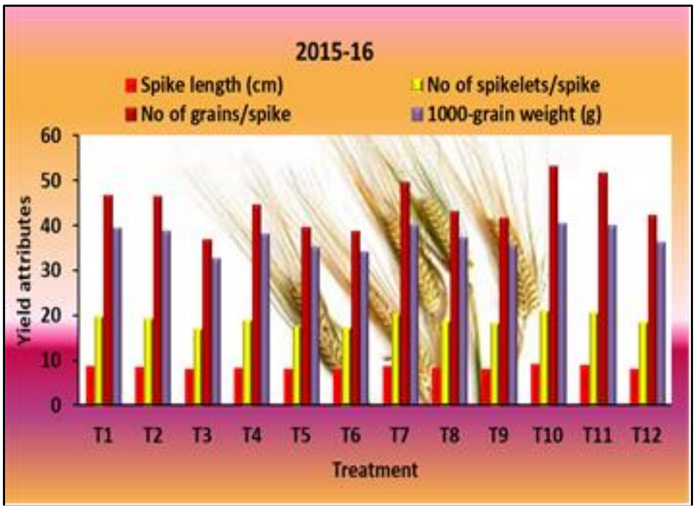



**Fig 2:** Yield attributes during 2014-15 and 2015-16

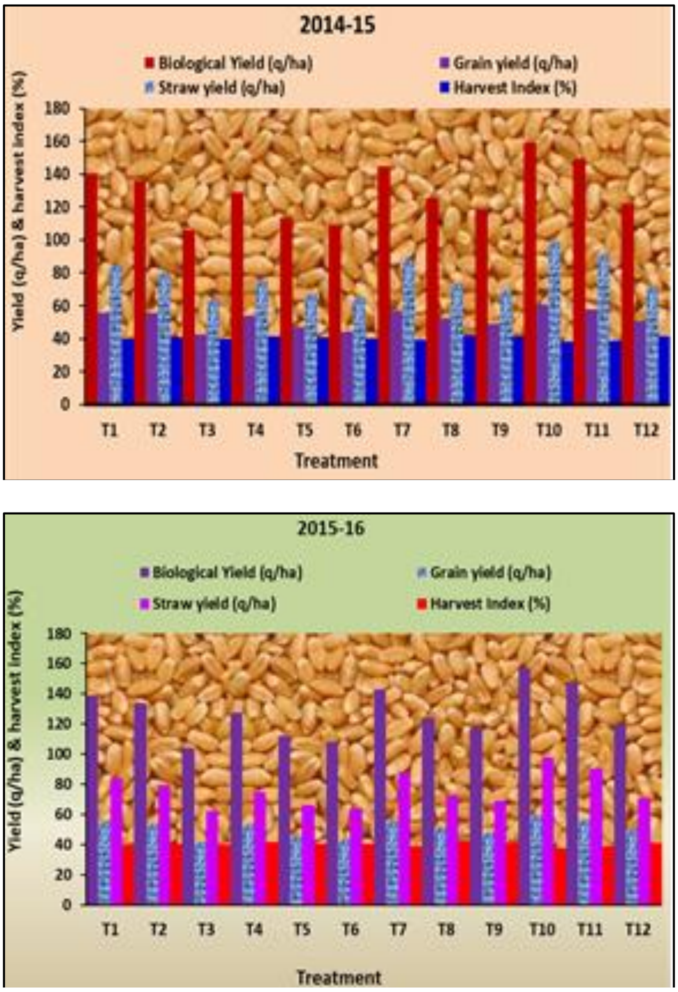



**Fig 3:** Grain, Straw and Biological Yield and Harvest Index (%) during 2014-15 and 2015-16

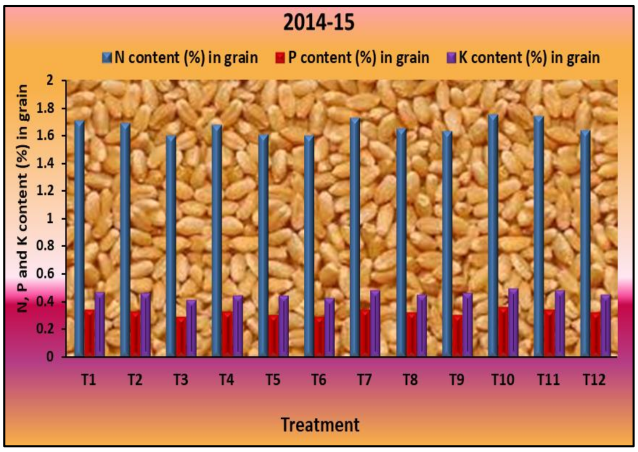
The straw yield was observed significantly highest in FIRB 75 cm RSR + EFR (69.7 and 70.5 q/ha) followed by FIRB 60 cm RSR + EFR as compared to all the treatments during experimentation. Critical examined that the data regarding straw yield, which was given in Figure 3 indicate that the straw yield was also significantly higher with FIRB 37 cm RSR + EFR, zero-till wheat, FIRB 75 cm ESR + EFR, FIRB 37 cm ESR + EFR and FIRB 60 cm ESR + EFR, respectively over rest of the treatments. The lower values of straw yield was noted with FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR, Conventional flat and reduced till flat sown, respectively during the observation period.

The biological yield was obtained significantly highest in FIRB 75 cm RSR + EFR followed by FIRB 60 cm RSR + EFR as compared to all the treatments. These treatments was also exhibited significantly at par with each other. However the least biological yield was observed from FIRB 37 cm RSR + RFR during the years of experimentation. The data further revealed that the biological yield was also higher in FIRB 37 cm RSR + EFR, zero-till wheat, FIRB 75 cm ESR + EFR, FIRB 37 cm ESR + EFR and FIRB 37 cm ESR + EFR, respectively over rest of the treatments. FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR, Conventional flat and reduced till flat sown, respectively were also produced minimum biological yield during the years of experimentation (Figure 3).

The maximum harvest index was recorded in FIRB 75 cm RSR + EFR followed by FIRB 60 cm RSR + EFR and FIRB 37 cm RSR + EFR, respectively over all treatments. The minimum harvest index was recorded with FIRB 37cm RSR + RFR followed by FIRB 60 cm RSR + RFR, and FIRB 7 cm RSR + RFR during the investigation period (Figure 3). Land configuration methods showed better improvement in roots and optimum moisture-air equilibrium throughout the crops growth besides supply of available nutrients to the crops resulting better growth and development of number of effective tillers, spike length, number of spikelet spike$^{-1}$, number of grains spike$^{-1}$ and 1000-grain weight ultimately reflected towards better yield. This was due to proportionate improvement in biological, grain and straw yield of wheat crops (Kumar and Ladha, 2011; Hakoomat *et al.*, 2013; and Kumar *et al.*, 2013) [13, 8, 14].

**Nutrient content and uptake**

The nitrogen, phosphorus and potassium content in grain was significantly highest in FIRB 75 cm ESR + EFR (1.73 and 1.75% N, 0.34 and 0.36 P and 0.47 and 0.49% in K, respectively) which was significantly at par with FIRB 75 cm RSR + EFR (1.72 and 1.74% in N, 0.33 and 0.34% in P and 0.46 and 0.48% in K, respectively) higher over all the treatments (Figure 4).The data further revealed that the nitrogen, phosphorus and potassium content in grain was also received higher from FIRB 60 cm ESR + EFR, zero-till wheat, reduced till flat sown, FIRB 37 cm ESR + EFR and FIRB 60 cm RSR + EFR plots while least content in grain was recorded with FIRB 37 cm RSR + RFR, FIRB 37 cm RSR + EFR and FIRB 60 cm RSR + RFR, respectively during both the years of investigation.



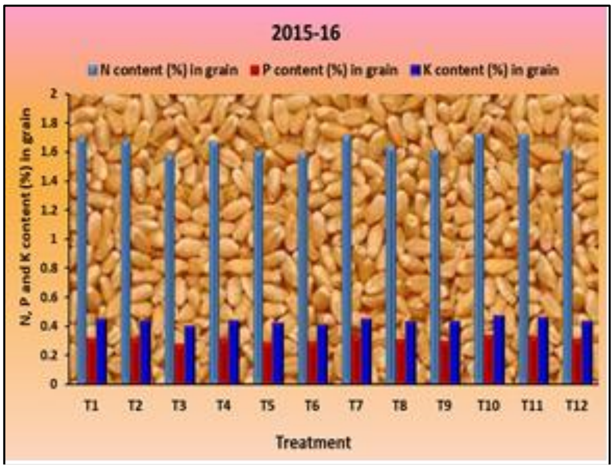



**Fig 4:** Nitrogen, Phosphorus and Potassium content in Grain during 2014-15 and 2015-16

Scanning the data revealed that the application of FIRB 75 cm RSR + EFR (0.54 and 0.57% N, 0.16 and 0.18% P and 1.66 and 1.69% K, respectively and FIRB 60 cm ESR + EFR (0.55 and 0.56% N, 0.16 and 0.18% P and 1.66 and 1.68% K, respectively was grasped 2nd and 3rd position within the treatments and achieve significant higher N, P and K content per cent in straw over rest of the treatments. Further data revealed that the N, P and K content was also higher in Zero-Till wheat, Reduced Till flat sown, FIRB 37 cm ESR + EFR and FIRB 60 cm RSR + EFR but least values of N, P and K content per cent was noted with FIRB 37 cm RSR + RFR, FIRB 37 cm RSR + EFR, FIRB 75 cm RSR + RFR and FIRB 60 cm RSR + EFR, respectively during experimentation (Figure 5).

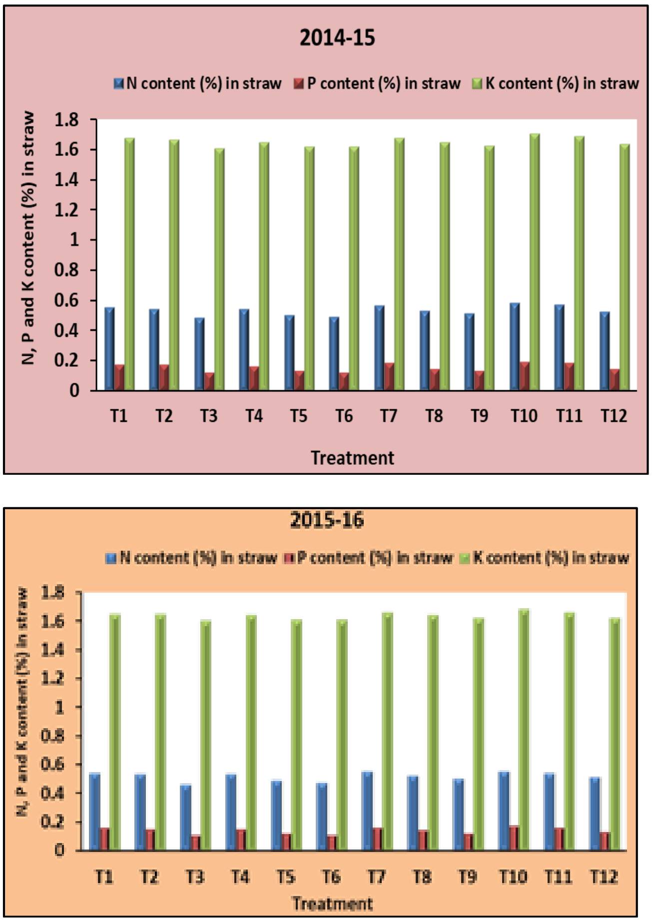



**Fig 5:** Nitrogen, Phosphorus and Potassium content in Straw during 2014-15 and 2015-16

The results indicated that nitrogen, phosphorus and potassium uptake in grain was found highest in FIRB 75 cm RSR + EFR (83.0 and 84.0 kg $ha^{-1}$ N, 16.0 and 16.2 kg $ha^{-1}$ P and 22.0 and 22.4 kg $ha^{-1}$ K, respectively) followed by FIRB 60 cm RSR + EFR (76.7 and 77.5 kg $ha^{-1}$ N, 14.5 and 15.1 kg $ha^{-1}$ P and 20.3 and 21.0 kg $ha^{-1}$ K, respectively) as compared to all the treatments. These treatments were also exhibited significant on par with each other during the years of experimentation. The minimum (47.3 and 48.0 kg $ha^{-1}$ N, 8.7 and 8.5 kg $ha^{-1}$ P and 12.4 and 12.4 kg $ha^{-1}$ K, respectively. N, P and K uptake in grain was noted with FIRB 37 cm RSR + RFR practices alone during the years of investigation. Critically examined the data revealed that the nitrogen, phosphorus and potassium uptake in grain was higher in zero-till wheat, FIRB 75 cm ESR + EFR, FIRB 37 cm RSR + EFR and FIRB 60 cm ESR + EFR while next least values was recorded in FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR, conventional flat and reduced till flat sown, respectively during 2014-15 and 2015-16 (Figure 6).

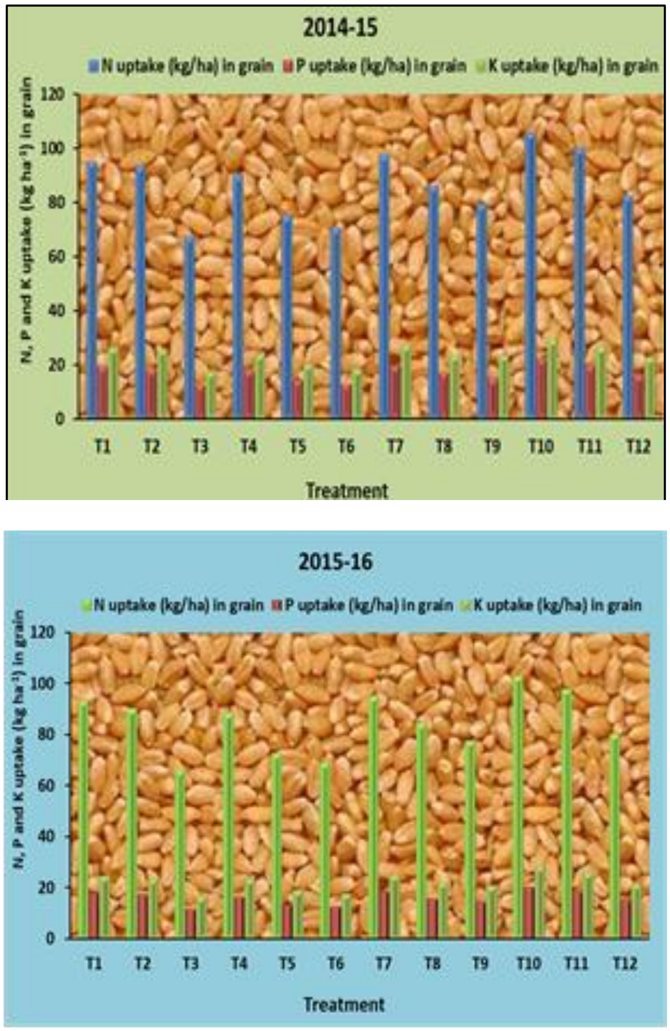



**Fig 6:** Nitrogen, Phosphorus and Potassium Uptake in Grain during 2014-15 and 2015-16

The nitrogen, phosphorus and potassium uptake in straw was found significantly highest in FIRB 75 cm RSR + EFR (38.3 and 39.5 kg $ha^{-1}$ N, 11.5 and 12.8 kg $ha^{-1}$ P and 117.3 and 117.6 kg $ha^{-1}$ K, as compared to FIRB 37 cm RSR + RFR (23.8 and 24.3 kg $ha^{-1}$ N, 5.8 and 6.0 kg $ha^{-1}$ P and 81.6 and 80.9 kg $ha^{-1}$ K, respectively. The treatment FIRB 60 cm RSR + EFR was achieved 2nd place within the treatment which was higher over rest of the treatments during the investigation periods of the crop.The data further revealed that the N, P and K uptake (kg ha$^{-1}$) in straw was recorded significantly higher FIRB 37 cm RSR + EFR, zero-till wheat, FIRB 75 cm ESR + EFR and FIRB 60 cm ESR + EFR, respectively while lowest N, P and K uptake in grain were recorded FIRB 60 cm RSR + RFR, conventional flat and FIRB 75 cm RSR + RFR, respectively during the years of investigation (Figure 7).

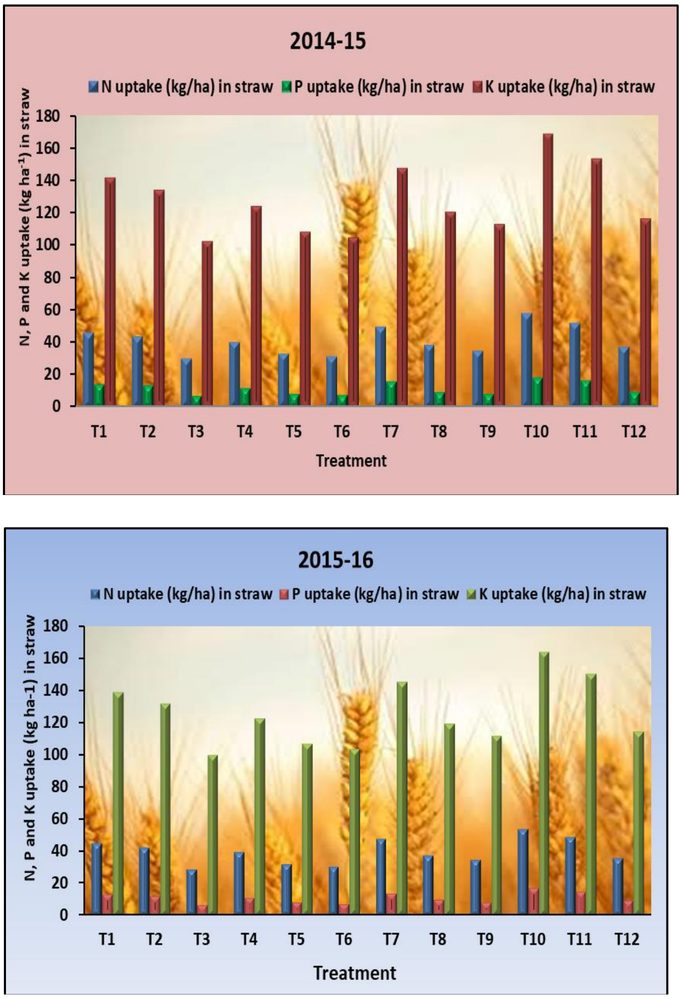



**Fig 7:** Nitrogen, Phosphorus and Potassium Uptake in Straw during 2014-15 and 2015-16

The total uptake of nitrogen, phosphorus and potassium was recorded significantly highest in FIRB 75 cm RSR + EFR (122.4 and 122.4 kg ha$^{-1}$ N, 27.5 and 29.0 kg ha$^{-1}$ P and 139.8 and 139.5 kg ha$^{-1}$ K, respectively followed by FIRB 60 cm RSR + EFR (112.7 and 113.2 kg ha$^{-1}$ N, 36.39 and 33.30 kg ha$^{-1}$ P and 180.33 and 176.59 kg ha$^{-1}$ K, as compared to all the treatments during both the year. The least values (98.30 and 94.88 kg ha$^{-1}$ N, 24.1 and 24.4 kg ha$^{-1}$ P and 133.7 and 133.9 kg ha$^{-1}$ K, of total uptake of N, P and K was obtained in conventional flat tillage alone practices during 2014-15 and 2015-16. The data further revealed that the total uptake of N, P and K was observed significantly higher in FIRB 75 cm ESR + EFR, zero-till wheat, FIRB 60 cm ESR + EFR and FIRB 37 cm RSR + EFR, respectively while lowest value was recorded in FIRB 37 cm RSR + RFR, FIRB 37 cm RSR + EFR, FIRB 60 cm RSR + RFR and FIRB 75 cm RSR + RFR, respectively during experimentation (Figure 8). The significant variation in NPK content, their uptake by grain and straw of wheat among the planting techniques might be due to better root growth, aeration, microbial activity and good drainage which might have received optimum moisture and nutrients for its growth. These findings are in accordance with Khan and Parvej (2010), Tolessa *et al.* (2014) [29] and Alalm *et al.* (2014).

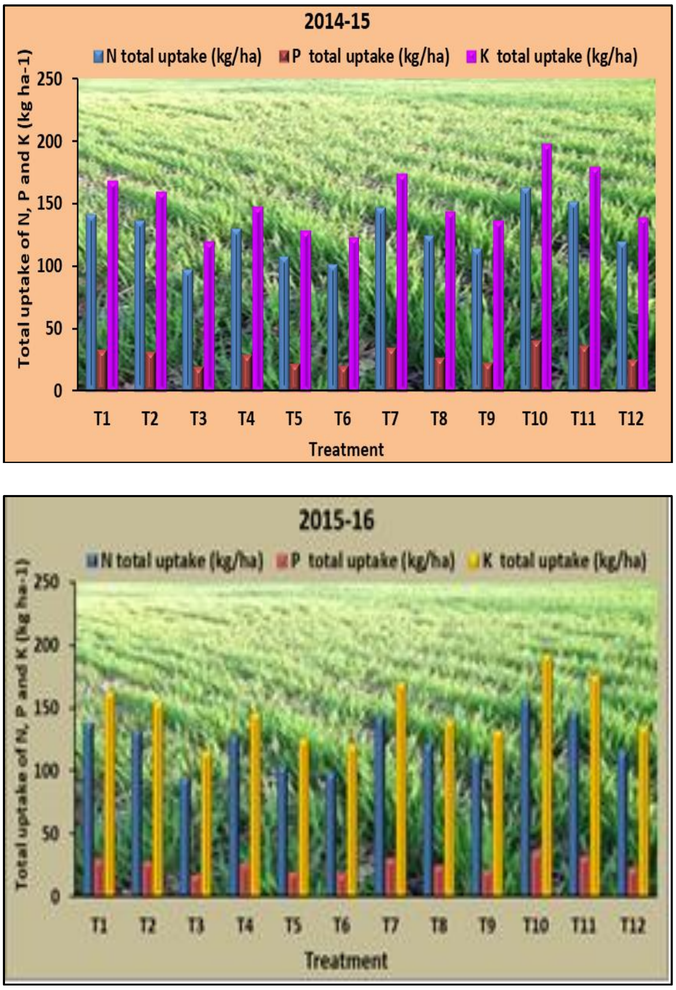
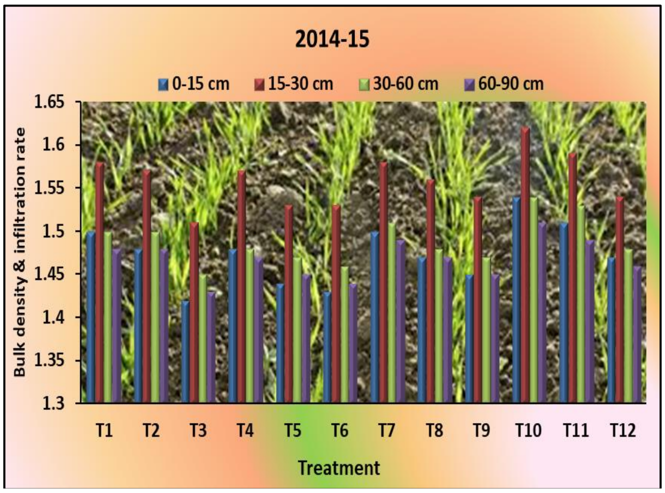



**Fig 8:** Total Nitrogen, Phosphorus and Potassium Uptake in plants during 2014-15 and 2015-16

**Physical and chemical properties of soil**

The lowest bulk density and highest infiltration rate were recorded significantly in FIRB 75 cm ESR + EFR followed by FIRB 75 cm RSR + EFR at different levels of soil as compared to all the treatment. The highest value of bulk density and lowest value of infiltration rate were received from conventional flat tillage practices during the year of study. The data was further synthesized that the bulk density was also significantly lower and infiltration rate was also significantly higher with FIRB 60 cm ESR + EFR, and FIRB 37 cm ESR + EFR, respectively while least value of bulk density and high value of infiltration rate were observed in FIRB 37 cm RSR + RFR, FIRB 37 cm RSR + EFR, FIRB 60 cm RSR + RFR, FIRB 60 cm RSR + EFR and FIRB 75 cm RSR + RFR, respectively during 2014-15 and 2015-16 (Figure 9). Organic manure treated plots exhibited higher electrical conductivities. This was probably because decomposing organic materials release acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility. However, the quantum of increase depended on the quantity of acid or acid forming substances produced which in turn depended upon the amount of the organic materials applied. Similar results have also been reported by Sharma *et al.* (2011) [28]; Choudhury and Singh, (2013) [3]; Das *et al.* (2014) [4].



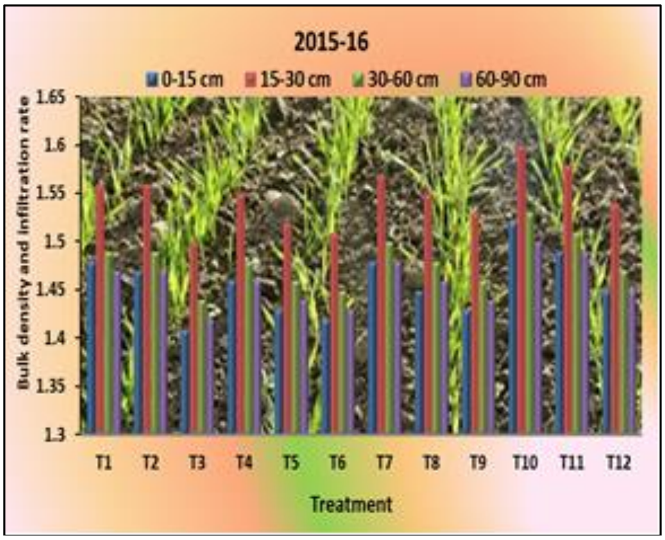
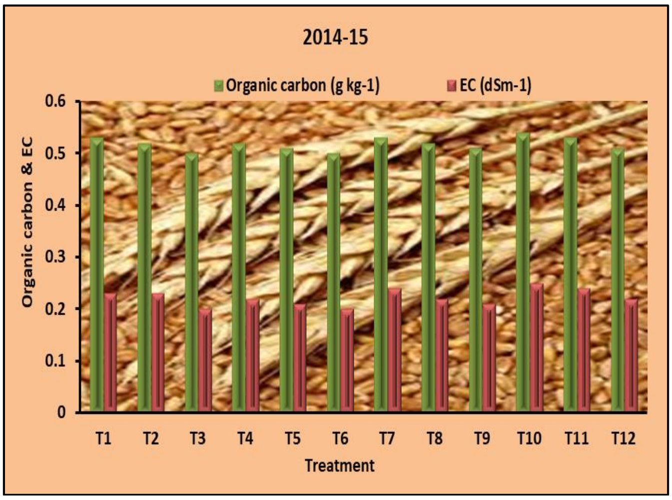




**Fig 9:** Bulk density and Infiltration rate during 2014-15 and 2015-16

The organic carbon was recorded significantly highest with FIRB 75 cm ESR + EFR followed by FIRB 75 cm RSR + EFR as compared to all the treatments during both the year of study. The lowest organic carbon was recorded in conventional flat tillage during the years of investigation. The data further revealed that the organic carbon was also significantly higher noted with FIRB 60 cm ESR + EFR, zero-till wheat, reduced till flat sown, FIRB 37 cm ESR + EFR and FIRB 60 cm RSR + EFR while least value of organic carbon was noticed with FIRB 37 cm RSR + RFR, FIRB 37 cm RSR + EFR, FIRB 60 cm RSR + RFR and FIRB 75 cm RSR + RFR, respectively during the experimental period (Figure 10). Several authors have reported that conjunctive use of tillage and chemical fertilizer enhanced the number of microorganisms and their activity. The soil microorganisms are believed to play a major regulatory role for organic carbon dynamics. Soil microbial biomass constitutes a transformation matrix for organic matter in soil and acts as an active reservoir for plant available nutrients. The results of similar nature were reported by Ji *et al.* (2013) [11] and Naresh *et al.* (2015) [21].

The electrical conductivity (dSm$^{-1}$) was recorded significantly highest with the application of FIRB 75 cm ESR + EFR which was significantly superior over all the treatments during the years of experimentation. The application of FIRB 75 cm RSR + EFR and FIRB 60 cm ESR + EFR was also recorded significantly higher electrical conductivity (dSm$^{-1}$) over rest of the treatment and marked with 2$^{nd}$ and 3$^{rd}$ position within the treatments. The least value of electrical conductivity (dSm$^{-1}$) was found in conventional flat tillage alone practices during the years of experimentation (Figure 10).



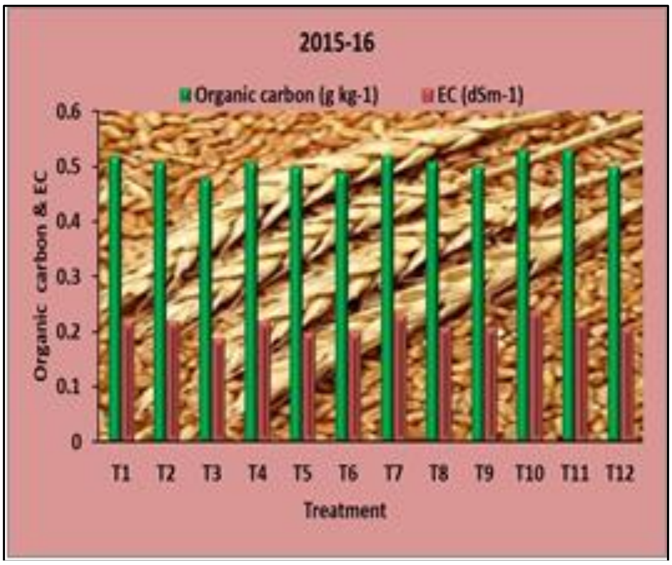
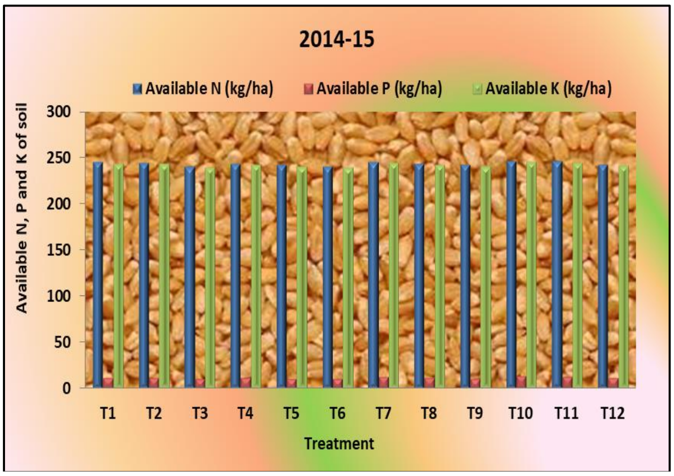




**Fig 10:** Organic carbon and electrical conductivity during 2014-15 and 2015-16

The available soil N, P and K was noticed significantly highest with the application of FIRB 75 cm ESR + EFR followed by FIRB 75 cm RSR + EFR which was significantly superior over all the treatments. The minimum available N, P and K was found in conventional flat tillage practices during the years of experimentation. It is clear from the data revealed that the available N, P and K of soil were also found higher with FIRB 60 cm ESR + EFR, zero-till wheat, reduced till flat sown, FIRB 37 cm ESR + EFR and FIRB 60 cm RSR + EFR while least value of available N, P and K of soil was noticed with FIRB 37 cm RSR + RFR, FIRB 37 cm RSR + EFR, FIRB 60 cm RSR + RFR and FIRB 75 cm RSR + RFR, respectively during the experimental period (Figure 11). These results are in agreement with the findings of El-Gizawy (2009) [6] and Hussain *et al.*, (2002) [9].



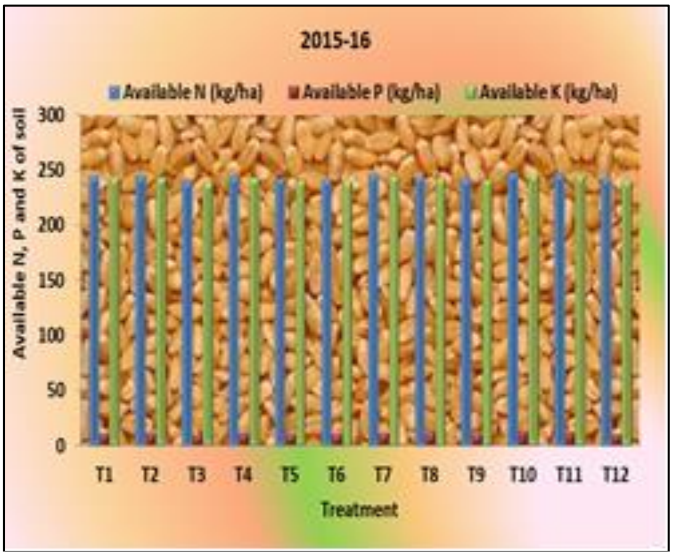
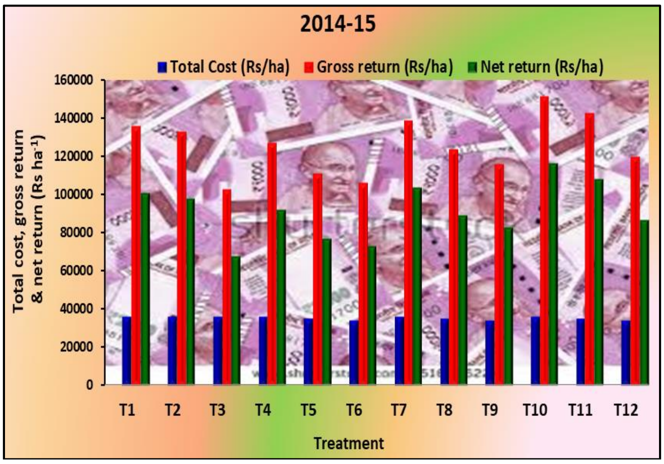




**Fig 11:** Available Nitrogen, Phosphorus and Potassium of soil during 2014-15 and 2015-16



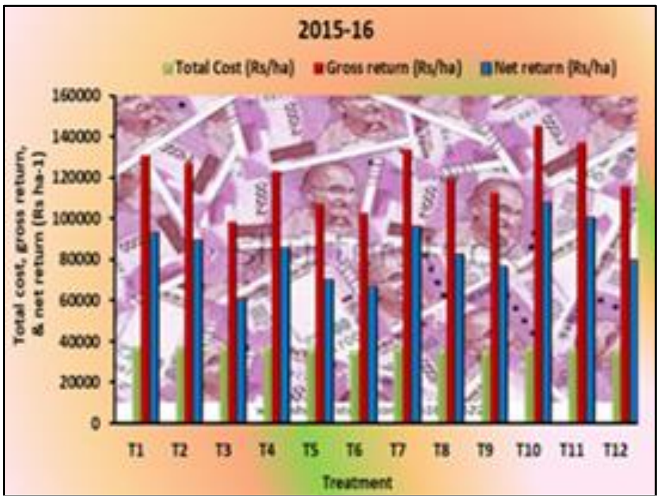




**Fig 12:** Total cost of cultivation, gross return and net return during 2014-15 and 2015-16

## Profitability

Total cost of cultivation was noticed highest in FIRB 75 cm ESR + EFR (Rs 35245 and 37692 ha-$^{1}$) and remained same in FIRB 60 cm ESR + EFR, zero-till wheat, reduced till flat sown, Conventional flat and FIRB 37 cm ESR + EFR as compared to all the treatments, while the lowest total cost was involved for the cultivation of wheat in FIRB 37 cm RSR + RFR, FIRB 60 cm RSR + RFR and FIRB 75 cm RSR + RFR viz., Rs 33527 and 35894 ha$^{-1}$ during the experimental period. The gross return was observed highest in FIRB 75 cm RSR + EFR (Rs 89977 and 104940 ha$^{-1}$) followed by FIRB 60 cm RSR + EFR (Rs 87940 and 102010 ha$^{-1}$) as compared to all the treatments during both the year. The lowest gross return was noticed in FIRB 37 cm RSR + RFR practices (Rs 58467 and 68105 ha-1) during the year of study. The data further revealed that the gross return was also obtained higher with the application of FIRB 37 cm RSR + EFR, Zero-Till wheat, FIRB 75 cm ESR + EFR, FIRB 60 cm ESR + EFR and FIRB 37 cm ESR + EFR while least value of gross return of wheat crop was recorded with FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR, conventional flat and reduced till flat sown, respectively during the experimental period (Figure 12).

The net return was observed highest in FIRB 75 cm RSR + EFR (Rs 55372 and 68048 ha$^{-1}$) while lowest net return was produced with FIRB 37 cm RSR + RFR (Rs 24940 and 32311 ha$^{-1}$) during both the year of study. The next higher net return was found in FIRB 60 cm RSR + EFR (Rs 53319 and 65118 ha$^{-1}$) and FIRB 37 cm RSR + EFR (Rs 49522 and 61047 ha$^{-1}$) over rest of the treatments and marked with 2$^{nd}$ and 3$^{rd}$ place within the treatments during the year of study. The data further revealed that the net return was found also higher in FIRB 37 cm RSR + EFR, Zero-Till wheat, FIRB 75 cm ESR + EFR, FIRB 60 cm ESR + EFR and FIRB 37 cm ESR + EFR while least value of net return of wheat crop was recorded with FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR, conventional flat and reduced till flat sown, respectively during the experimental period (Figure 12).

The benefit: cost ratio was obtained higher with the application of FIRB 75 cm RSR + EFR (2.60 and 2.84) followed by FIRB 60 cm RSR + EFR (2.54 and 2.77) as compared to all the treatments during the years of investigation. The treatments FIRB 37 cm RSR + EFR achieved also higher benefit: cost ratio (2.43 and 2.65) and marked with 3$^{rd}$ place within the treatments while the minimum benefit: cost ratio was recorded in FIRB 37 cm

RSR + RFR (1.74 and 1.90) during the study period. Scanning the data revealed that the benefit: cost ratio was also obtained higher with the application of FIRB 37 cm RSR + EFR, Zero-Till wheat, FIRB 75 cm ESR + EFR, FIRB 60 cm ESR + EFR and FIRB 37 cm ESR + EFR while lowest value of benefit: cost ratio of wheat crop was produced with FIRB 60 cm RSR + RFR, FIRB 75 cm RSR + RFR, conventional flat and Reduced Till flat sown,, respectively during the experimental period (Figure 12).

## Conclusion

From the foregoing discussion it is amply clear that conservation agriculture practices with chemical fertilizers play a key role to improving soil quality in the sub -tropical climatic conditions of India, and for minimizing the depletion of OC under continuous cropping, particularly in energy intensive double cropping regions. Conservation agriculture techniques with nutrient management practices help maintaining production sustainability without any detriment to the environment. Agro-eco-region specific practical technologies need to be developed in the light of availability of various resources for making the best use of valuable data generated under tillage and nutrient management practices. Successful conservation agriculture mechanism integrated and soil fertility management would depend on a concerted effort by a multitude of actors (public and private). Working in a participatory mode is the need so as to enhance the production and economic viability of millions of smallholder farms currently struggling with declining soil fertility and poor management of plant nutrients.

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