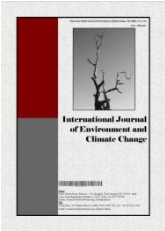

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Conservation Tillage and Nutrient Strategies Enhances Crop-Water Productivity and Economic Profitability of Wheat (*Triticum Aestivum* L)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Decline in soil fertility is one of the major constraints to sustainable crop production and profitability. To meet the increasing demand for the growing population the issue of low soil fertility needs to be addressed moreover, excessive pumping of groundwater over the years to meet the high irrigation water requirement of rice-wheat system has resulted in over exploitation of groundwater in the Indo-Gangetic plains (IGP) of India. Replacement of traditional wheat cultivation practices under conservation agriculture (CA) based management (tillage, and crop establishment management) practices are required to promote sustainable agriculture. Furthermore, inefficient nutrient management practices are responsible for low crop yields and nutrient use efficiencies in wheat under rice-wheat cropping system (RWCS). A field experiment was conducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture &

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Technology, Meerut (U.P.), India to evaluate the effects of tillage and crop establishment (TCE) methods, and nutrient management practices on crop yields, water productivity and profitability of wheat under RWCS. The main plot treatments included four combinations of TCE [Furrow irrigated raised beds (FIRB), Roto tillage (RT), Reduced tillage (RTW) and conventional tillage (CT), with six nutrient management practices [N_1 Control, N_2 100% Recommend Dose of Fertilizer, N_3 100% RDF + NPK consortia + Bio-stimulant, N_4 75% RDF + NPK consortia + Bio-stimulant, N_5 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation, and N_6 and 75% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation]. Crop water productivity and net returns under FIRB were significantly increased by 11.7% and 13.8% compared to CT respectively, during year of experimentation. Study showed that conservation agriculture based sustainable practices (FIRB) and nutrient strategies 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation approach provided opportunities for enhancing crop and water productivity, and profitability of wheat crop in North-West IGP of India. Treatments with N and conservation agriculture were the most profitable. A combined use of conservation agriculture and organic and chemical fertilizers is the best bet for increasing, wheat crop yield and associated return on investment.

Keywords: Conservation tillage; productivity; profitability; fertility levels; crop establishment.

1. INTRODUCTION

Globally, the *per capita* arable land area will continue to decrease (it decreased from 0.415 ha in 1961 to 0.214 ha in 2007) while average cereal yield will need to be increased by about 25% from 3.23 t ha^{-1} in 2005/07 to 4.34 t ha^{-1} by 2030 [1] . India contributes approximately 12% (77.63 mt) of the global wheat (*Triticum aestivum L*.) production. It is an input intensive crop, grown on 13% of the cropped area in the Indo-Gangetic plains (IGP). Wheat is cultivated as a component of rice-wheat cropping system (RWCS) in IGP. The majority of Indian soils are low in N and therefore loading of urea (46% N) is practiced. Integrated nutrient management practices and resource conservation technologies are used to enhance crop productivity in sustainable agriculture [2]. This has become more important in the wake of global climate change which demands more judicious use of available resources. Thus, the major target in the regime of global climate change is water and energy conservation.

Intensive cultivation degrades the soil structure and causes excessive break down of soil aggregates [3] resulting in soil compaction, soil erosion, increased salinization and loss of soil organic matter. Consequently, the resulting loss of soil nutrients and degraded plant rooting environment results in low productivity, low crop yields and high food insecurity [4]. To alleviate object poverty and foster achievement of food security, sustainable farming systems aimed at improving soil health, conserving soil water, and increasing crop production while protecting the environment are pivotal. Stakeholders have advocated for conservation agriculture as one of the panaceas to problems caused by conventional agriculture in that it has the potential to redress declining soil fertility, improve crop productivity and increase profits as well as household food security [5].

Tillage affects the physical, chemical, and biological properties of the soil [6]. A proper tillage can alleviate soil-related constraints whereas an improper tillage leads to deterioration in soil structure. The latter further accelerate erosion, depletion of soil organic matter (SOM) and soil fertility as well as the disruption of the nutrient cycle [7-8]. The conservation and addition of SOM are crucial for biological, chemical and physical soil functionality and nutrient cycling particularly of N. The N-cycling largely depends on the microbial activities in the soil [9]. The conservation tillage improves soil organic carbon (SOC) concentration, water storage and reduces soil erosion, and subsequently enhances soil quality and resilience [10].

Many factors affect the sustainability of wheat production under the RWCS. Some important factors are SOM content, indigenous nutrient supply of micronutrient, ground water, percolation [11] etc. In order to overcome these limitations and to sustain crop productivity and soil fertility, a system (multi-component) approach involving INM practices, i.e., water conservation strategies, conservation tillage and application of organic nutrients may yield good substitute of conventional green revolution practices for wheat cropping. [12] Have reported higher or almost equal yield for rice-wheat cropping system under conservation tillage as compared to conventional tillage. Though, an integrated approach for tillage, water and nutrient management for wheat crop has not been reported. In order to increase wheat yields and ensure sustainable productivity, the potential effect of crop management practices like balanced nutrient application and conservation tillage on wheat crop yield and financial returns, needs to be understood. Against this background, research station study was set up with an aim of determining the effect of interaction between organic and chemical fertilizers and tillage on crop- water productivity and profitability.

2. MATERIALS AND METHODS

The experiment was conducted at Crop Research Centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut situated in Indo-Genetic plains of western Uttar Pradesh in Western Plains Zone. It is geographically located at 29° 05' 19''N latitude, 77° 41' 50'' E longitudes and an elevation of 237 meters above the sea level during Rabi 2020-21. The climate of this region is semi-arid and sub-tropical with extreme hot weather in summer and cold weather in winter season. There is gradual decrease in mean daily temperature in January reaching as low as 5.6^{0}C and further a gradual increase is registered reaching as high as 36.6^{0}C in months of April. Occasionally, frost does occur during the months of December and January. The maximum temperature was highest in fourth week of April during the year of study. Rainfall was occurred 177.0 mm rainfall was received during crop period in 2020-21. The soil was sandy loam with pH 8.7 (1:2.5 soils to water). The topsoil of the experimental site was sandy loam overlying silty clay, with an abrupt change to sandy loam at about 90 cm. Bulk density was 1.52 g/cm in the topsoil. Organic carbon 0.44%, available N 222.8 kg ha^{-1} , P 16.7 kg ha^{-1} and available K 241.5 kg ha^{-1} at the start of the experiment in 0 to 15 cm soil layer during 2020-21.The treatments consist of four tillage practices T_1 Furrow irrigated raised beds, T_2, Roto tillage T_3 Reduced tillage, T_4 Conventional tillage) and six nutrient management [N_1 Control, N_2 100% RDF, N_3 100% RDF + NPK consortia + Bio-stimulant, N_4 75% RDF + NPK consortia + Bio-stimulant, N_5 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation, and N_6 and 75% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation].The study was made in split plot design with three replications. In FIRBS, 12 cm high and 90 cm broad bed with a furrow width of 30 cm between the beds was prepared with planting six rows of wheat in rows 15 cm apart [13]. Half dose of N and full dose of P and K through urea, single super phosphate and muriate of potash, respectively, were applied at sowing and remaining N was applied as per treatments. Wheat WB-02 was sown on 06 November in 2020 harvested on 27 April in 2021. Other management practices were adopted as per recommendations of the crop under irrigated conditions. Data on yield attributes, grain and biological yield of wheat were calculated as per the standard procedures.

Soil water content was measured gravimetrically at 0-15, 15-30, 30-60 and 60-90 cm depths before sowing and at harvest of wheat crop. Depth-wise bulk density values were determined using soil core sampler at sowing and at harvest for each treatment. Water content at each depth was averaged and converted to a volume basis using a pre determined value of bulk density for respective treatment, time and depth.

2.1 Statistical Analysis

All the data recorded were analyzed by using the standard procedure of statistical analysis for split-plot design [14]. Analysis of variance (ANOVA) was used to determine the effect of each treatment when the F-ratio was significant; a multiple mean comparisons was performed using C.D. (Critical Difference) (0.05 probability level) values. The data has been analyzed by statistical package MSTAT.

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Attributes

3.1.1 Spike length

Treatment N_5 (100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation) considerably enhanced spike length over the N_2 (100% RDF) and N_4 (75% RDF + NPK consortia + Bio-stimulant) treatments, as seen in Fig. 1. Treatments N_3 (100% RDF + NPK consortia + Bio-stimulant) and N_6 (75% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation) were statistically equivalent in terms of spike length during the year of research. When comparing several nutrient management regimens, all of them produced considerably longer spike lengths than control plots. These findings are similar to those of [3,15].

3.1.2 Productive tillers m^{-2}

The data on productive tillers m^{-2} depicted in Fig. 1 showed that productive tillers m^{-2} varied with different tillage practices, with significantly higher productive tillers m^{-2} recorded with FIRB (T_4) treatment, which was on par with conventional tillage (T_4) during the study year and gave 3.2, and 4.2 percent more productive tillers m^{-2} as compared to reduced tillage. Moreover, an increasing trend of number of productive tillers m^{-2} was recorded in N_5 treatment of 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation nutrient management strategy and number of productive tillers m^{-2} declined with N_3 treatment of 100% RDF + NPK consortia + Bio-stimulant nutrient management strategy but was statistically at par. However, treatments N_6 were statistically superior to N_2 and both were recorded a higher number of productive tillers m^{-2} to N_1 treatment during the year of experimentation, respectively.

3.1.3 Grains spike^{-1}

During the research year, the T_1 treatment with FIRB tillage techniques generated considerably more grains spike^{-1} than the other treatments. When comparing the number of grains spike^{-1} among wheat plants grown under different nutrient management approaches to control plots, the data in Fig. 1 demonstrated a considerable increase. Among various treatments, highest number of grains spike^{-1} was recorded with the application of 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (N_5) which was at par with treatments including 100% RDF + NPK consortia + Bio-stimulant (T_3), and 75% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (T_6) during the year of study. The minimum number of grains per spike was recorded in control plots during experimentation.

3.1.4 Test weight

The weight of each individual grain, computed from 1000 grain weight (test weight), is an essential yield parameter that indicates how efficient the grain filling process was. The 1000 grain weight data shown in Fig. 1 demonstrated that the T_1 sowing technique considerably enhanced 1000 grain weight above all other treatments year but was statistically at par with the T_4 treatment. T_4 treatment, on the other hand, resulted in significantly higher grain weight than T_2 and T_3 treatments. Wheat grains differed slightly in test weight among different nutrient management practices. The 1000-grain weight ranged from 30.1 to 41.5 g, the lowest being in control plots and the highest achieved with application of 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (N_5). Also, application of 100% RDF + NPK consortia + Bio-stimulant recorded higher test weight over 100% RDF during experimentation.

3.1.5 Grain yield

The most significant criterion for evaluating the effectiveness of applied treatments is grain yield. Crop productivity is the rate at which a crop acquires biomass, which is primarily determined by photosynthesis and the conversion of light energy into chemical energy in green plants. Fig. 2 shows the grain yield information. The differences in grain yield owing to the primary effects of various treatments were statistically significant. Tillage crop establishment had a substantial impact on grain yield. T_1 (furrow irrigated raised beds) yielded the most grain (44.28 q ha^{-1}), while T_4 (conventional tillage) yielded a statistically equal yield (42.40 q ha^{-1}). When T_3 (roto tillage) and T_2 (non-tillage) establishment techniques were utilized instead of T_3 (roto tillage) and T_2 (non-tillage), grain yield was lowered by 6.6 percent and 7.3 percent, respectively (reduced tillage). FIRB, on the other hand, saw a 19.3 percent increase in yield when compared to the conventional method. There was yield improvement due to proper nutrient and moisture utilization in FIRB, respectively over conventional practices.

Different levels of nutrient management strategies had a substantial impact on grain yield. In the N_5 treatment, a significantly higher grain yield of (47.10 q ha^{-1}) was produced, which was statistically comparable to the N_3 treatment. N_6 (75 percent RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation) nitrogen level and nitrogen application at N_2 “100 percent RDF” treatments produced significantly higher grain yield than N_4 (75 percent RDF + NPK consortia + Bio-stimulant) nitrogen level and nitrogen application. Treatment N_1, on the other hand, had the lowest grain production (25.65 q ha^{-1}) during the experiment. Similar findings have been observed by other researchers [16, 17]. Bio-fertilizers are low-cost nutrient sources that could be utilized to increase crop yields in low-input agriculture instead of chemical fertilizers. Several authors have reported more than double the yields with application of NPK over the control [7,18].

3.1.6 Straw yield

Straw production is a function of crop biomass created throughout the crop growth phase, and it contributes significantly to overall crop leftovers due to its use as cow feed. The straw yields shown in Fig. 2 clearly revealed that during the testing, all of the nutrient management treatments were significantly greater than the control plot (no nutrient management). Treatment T_1 was shown to be considerably superior to all other treatments, with the exception of T_4, which also reported statistically significant straw yield (68.18 q ha^{-1}) when compared to T_2 and T_3. Tillage practices with nitrogen application management of varied degrees of nitrogen treatments resulted in substantial differences in straw yield. Treatment N_5 was comparable to treatments N_3 and N_6, but N_1 had the lowest straw yield (42.25 q ha^{-1}).

The pronounced effect of nutrient management application based on nitrogen and bio-stimulant levels was observed on the straw yield of wheat during experimentation. There was significant increase in straw yield due to application of different levels of nitrogen (100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation N_5; 100% RDF + NPK consortia + Bio-stimulant N_3), over 100% RDF, respectively [19-23] found similar findings.

3.1.7 Biological yield

Total dry matter accumulation (grain + straw) by crop is a key indicator of the crop's photosynthetic efficiency and photosynthetic left over after respiration, both of which have an impact on crop output. The data in Fig. 2 showed that the highest biological yield was obtained with the T_4 treatment of sowing techniques, which was statistically equal to the T_1 treatment. However, when compared to the other treatments, the T_2 therapy yielded a much larger biological yield. During the experiment, treatment T_3 was comparable to treatment T_5. The biomass yield of wheat (grain + straw yield) was considerably influenced by different nutrient management strategies, ranging from 67.90 to 119.76 q ha^{-1} according to data represented in Fig. 2. The maximum biological yield of 119.76 q ha^{-1} was produced in (T_5) treatment with application of 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation which was found statistically at par with

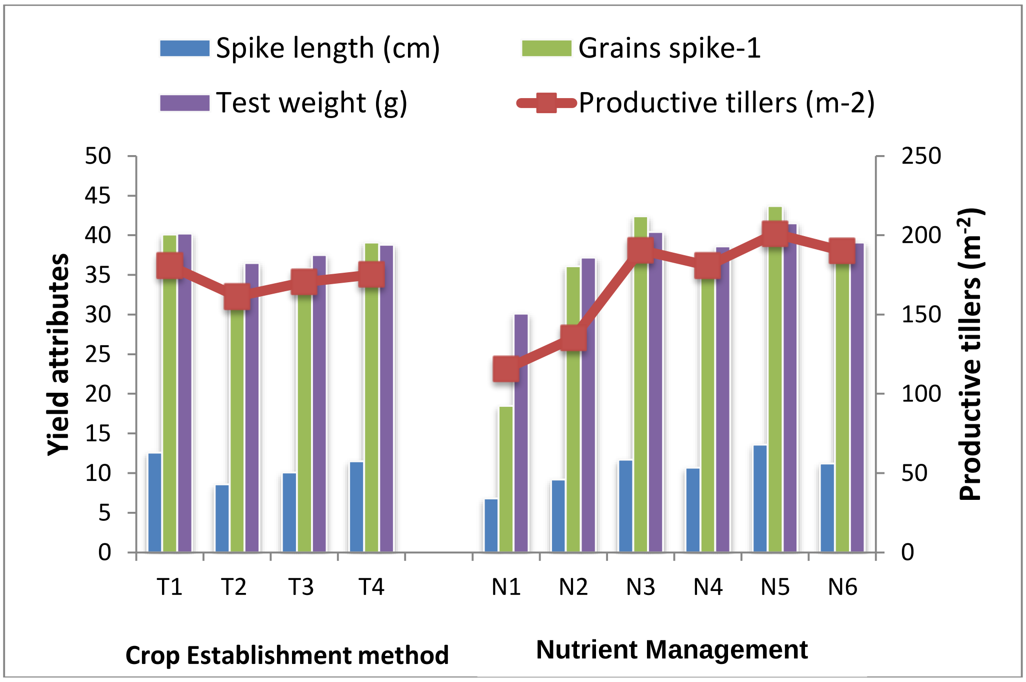

Fig. 1. Performance of Wheat under Crop Establishment Methods and Organic Fertilizer Complemented with Chemical N Fertilizer on yield attributing characters of wheat

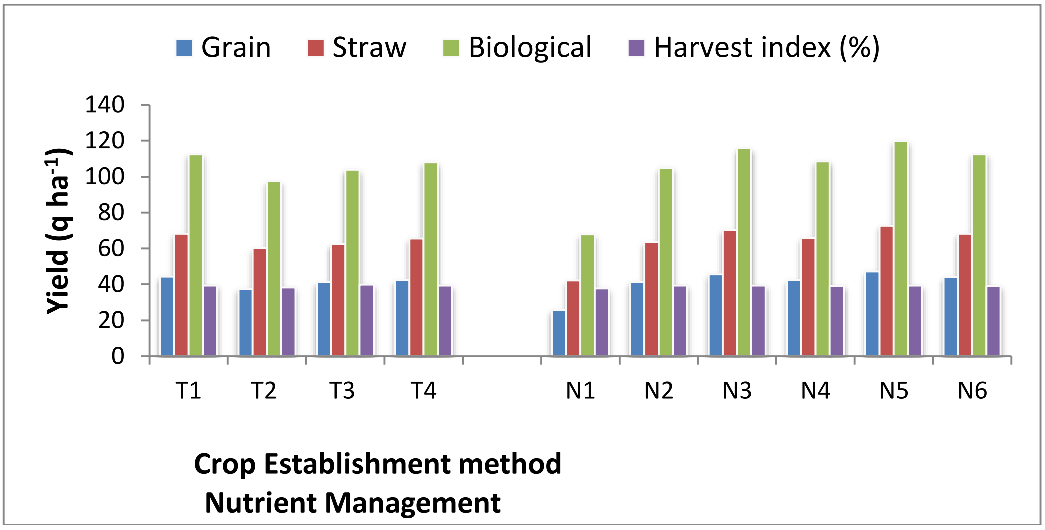

Fig. 2. Performance of Wheat under Crop Establishment Methods and Organic Fertilizer Complemented with Chemical N Fertilizer on yield (q ha^{-1}) and harvest index (%) of wheat

the biomass yield recorded in (T_3) treatment 100% RDF + NPK consortia + Bio-stimulant and during the trial year, it was much better than the other treatments. Minimum and significantly lower biomasses of 67.90 q ha-1 were produced in control plots (T_1).

3.1.8 Harvest index

The harvest index is an important indicator for measuring how well dry matter is partitioned to the economic component of the crop. The maximum value of harvest index (39.40) in wheat was obtained with the application of 100 percent RDF, followed by a treatment containing 75 percent RDF + NPK consortia + Bio-stimulant, as shown in Fig. 2. Control plots had the lowest harvest index value (37.77).

3.1.9 Soil moisture studies

In general, the profile moisture content was highest at sowing (21%) and lowest at crop maturity in all treatments during the research year. The differences were attributed to moisture preserved due to tillage establishment procedures and nutrient application treatments, as seen by the increases in profile moisture content under tillage operations. With the exception of the peaks, where the moisture content in the profile was always the same due to irrigation recharge, the moisture content of traditional tilled plots (T_4) was always lower than reduced tillage plots (T_3) over the research year. In the conventional tillage crop and roto till plots, the lowest soil moisture content was 51 DAS (15.0 and 14.8 percent), 73 DAS (13.8 and 14.2 percent), and 102 DAS (13.5 and 13.3 percent), respectively [Fig. 3]. Throughout the crop season, the traditional till crop kept the average profile soil moisture content 1.5 percent lower than the reduced tillage plots, with the exception of when the soil profile was recharged by irrigation or rainfall. [20,7] observed similar findings.

However, moisture uptake from the surface layer (0-15 cm) was somewhat increased with land layout under furrow irrigated raised beds techniques. Similarly, moisture extraction dropped marginally as profile depth increased, with the greatest reduction occurring at the 61-90 cm soil layer under roto tollage methods (1.8 and 1.9) due to excessive tillage [Fig. 3]. FIRB and reduced tillage plots utilized more moisture from the deeper profile layer than conventional and roto tillage plots throughout the research year, and vice versa. However, [24] reported that the crop establishment method had an impact on the moisture depletion pattern, with the conventional method of sowing recording the highest overall moisture depletion in wheat crop from each layer as compared to the other methods, such as reduced tillage, Rota till drill, and bed planting method of crop establishment. The amount of moisture lost reduced with soil depth due to the lower density of roots in the deeper layer compared to the upper layer. Due to increased surface evaporation, the percentage contribution of the upper 30 cm layer was higher. The highest moisture loss in the conventional approach can be attributed to lower moisture availability at the

Table 1. The impact of crop establishment methods and nutrient management on wheat consumption use (cm), water usage efficiency (kg m^{-3}) and water productivity (kg m^{-3})

Treatments	Grain yield (q ha^{-1})	Total water applied (cm)	Consumptive use (cm)	Water use efficiency (q ha^{-1} cm)	Water productivity (kg m^{-3})
Crop Establishment Methods					
T_1 Furrow Irrigated Raised Beds	41.7	25.2	19.3	2.16	1.88
T_2 Roto tillage	38.2	40.1	22.2	1.72	1.13
T_3 Reduced tillage	40.1	37.9	19.2	2.09	1.36
T_4 Conventional tillage	37.8	42.0	23.0	1.64	0.96
Mean	**41.35**	**36.3**	**20.9**	**1.90**	**1.33**
Nutrient Management					
N_1 Control	31.8	58.7	22.9	1.58	0.96
N_2 100% RDF	35.2	47.2	21.6	1.91	1.12
N_3 100% RDF + NPK consortia + Bio-stimulant	42.6	29.2	18.6	2.28	2.60
N_4 75% RDF + NPK consortia + Bio-stimulant	39.6	36.2	20.8	2.05	1.64
N_5 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation	52.0	26.8	18.1	2.33	3.20
N_6 75% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation	41.2	35.4	19.36	2.09	1.18
Mean	**41.03**	38.9	20.22	2.04	1.78

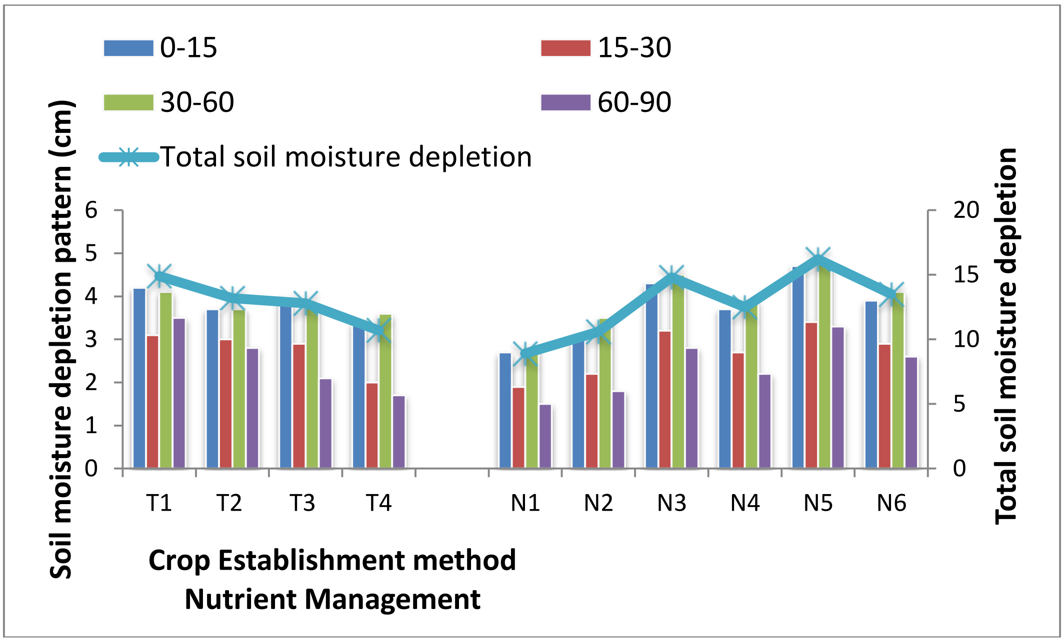

Fig. 3. Soil moisture depletion pattern at different crop stages as influenced by tillage techniques and nitrogen levels under wheat cultivation

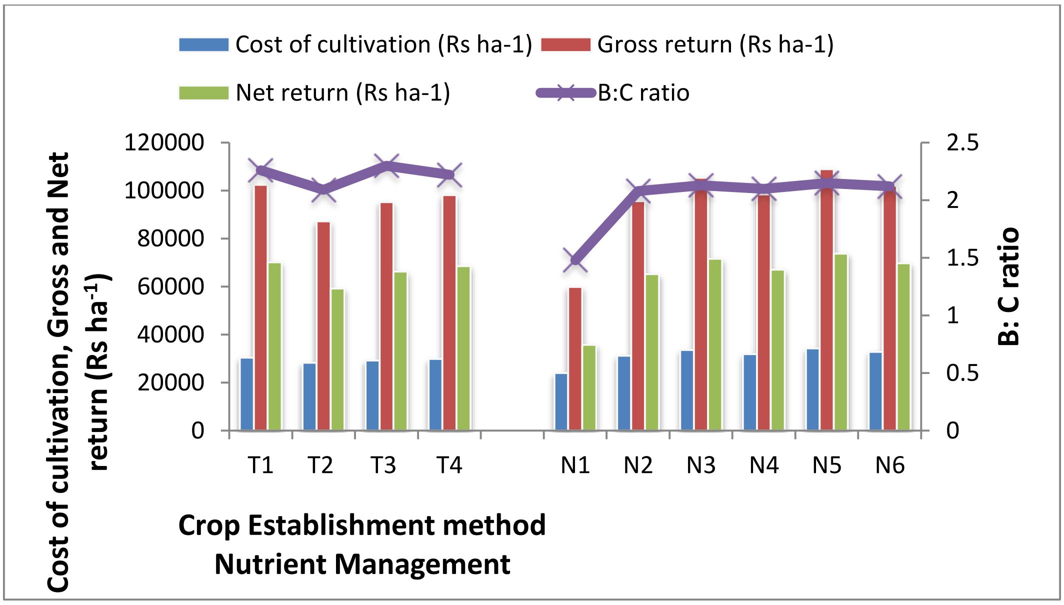

Fig. 4. Performance of crop establishment methods and organic fertilizer complemented with chemical n fertilizer on profitability of wheat

upper layer and increased evaporation from the upper surface. [25,4] found similar findings.

3.2 Water Productivity

Crop water use increased significantly in conventional till plots (T_4) compared to FIRB (T_1) and decreased in till plots (T_3) (Table 1). The highest Water Use Efficiency was reported under FIRB, followed by RT, and ROT. During the experiment, the water productivity improved as the yield grew. The Water Productivity was significantly lower in traditional till crop plots in conventional till than FIRB, reduced, and roto till crop plots. Water productivity was measured in the followed the order: FIRB>RT>ROT>CT. Similarly, to this experiment under conventional till, Aggarwal and Goswami [26] found that wheat crop water use was lower, whereas grain yield and water use efficiency were higher under treatment where furrow irrigated raised beds of 6 rows of wheat were sown on 70 cm wide beds separated by 30 cm furrow as compared to conventional flat sowing in alluvial sandy-loam soils resulted in better sown grain yield and water use efficiency. [27-28] found comparable findings.

3.3 Profitability

Maximum cost of cultivation (Rs.34240) was calculated using 100 percent RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (T_5), 100 percent RDF + NPK consortia + Bio-stimulant (N3), and 75 percent RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (N_6). During the experiment year, the lowest cost of cultivation was computed in the control plot (Rs. 24030). Tillage costs were highest in T_1 (Rs. 30500) as furrow irrigated raised bed tillage, followed by conventional tillage (T_4) (Rs. 29950), and lowest in roto tillage methods in T_2 and T_3 (Rs. 28265) respectively [Fig. 4]. Moreover, the highest gross return (Rs.108933) was found with the application of 100% RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (T_5), followed by 100% RDF + NPK consortia + Bio-stimulant (N_3), and 75 percent RDF + NPK consortia + Bio-stimulant + NPK(18:18:18) spray after II irrigation (N_6). Among the various tillage techniques, the FIRB tillage technique produced the highest gross income. This could be due to higher water use efficiency than other tillage strategies, as well as a higher grain yield gain than the other treatments. Nutrient management strategies had a considerable impact on wheat crop net returns (Fig. 4). The highest net returns and Benefits: Cost ratios were found in furrow irrigated raised beds seeded wheat among the various tillage techniques (T_1). However, maximum net returns (Rs. 73798) were estimated with higher fertilizer doses, such as 100 percent RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (T_5), followed by 100 percent RDF + NPK consortia + Bio-stimulant (N_3), and 75 percent RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation (N_6). During the investigation period, the control plot (Rs. 35797) produced the lowest net returns. Crops fertilized with 100 percent RDF + NPK consortia + Bio-stimulant + NPK (18:18:18) spray after II irrigation had the highest B: C ratio (2.15), whereas control plots had the lowest B: C ratio (1.48). Reduced tillage seeded wheat had the highest B: C ratios among the various tillage techniques (T_3). During the study year, however, the roto tillage treatment (T_2) had the lowest B: C ratio. [19,30,20] found similar results. Higher net benefits were recorded under conservation agriculture than conventional agriculture during study season. This could be associated to the lower production costs under conservation agriculture than conventional agriculture. Similarly, [31] reported higher wheat net returns under conservation agriculture (FIRB) compared to conventional agriculture. Higher net benefits as a result of fertilizer application could be attributed to higher yields recorded in crop season over the control.

4. CONCLUSIONS

Thus, it can be concluded that conventional-tilled wheat recorded yield attributes, grain and biological yield statistically similar to reduced-tilled wheat during the research year. FIRB plots showed gradual improvement in conservation of resources viz., soil moisture content and water productivity. Increasing fertility levels organic complemented chemical fertilizers from 75 to 100% + NPK consortia + Bio stimulants increased yield attributes, grain and biological yield of wheat up to 100% of the recommended fertilizer dose under conventional tillage. Increasing fertility level from 75 to 100% increased could not bring a significant impact on the soil moisture content. Treatments with N offered the most profitable options while conservation agriculture was more economical compared to conventional agriculture. There is therefore, need to continue promoting the use of organic complemented with chemical fertilizers and conservation agriculture among the farmers for enhanced crop productivity and profitability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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