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# Effect of Conservation Agricultural and Nitrogen Management Practices on Productivity, Profitability, Nutrient-uptake and Response Functions of N-fertilization in Wheat

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**A B S T R A C T**

A field experiment was carried out at ICAR-Indian Agricultural Research Institute, New Delhi for two consecutive years to evaluate the effect of conservation agricultural and nitrogen management practices on productivity, profitability, nutrient-uptake and response functions of N-fertilization in wheat in maize-wheat cropping system. There were six main-plot treatments of tillage and crop establishment techniques, *i.e.* conventional tillage-flat-bed (CT-F), CT-raised-bed (CT-B), zero tillage-flat-bed with crop-residue (ZT-F+R) and without crop-residue (ZT-F), ZT-raised-bed with crop residue (ZT-B+R) and without crop-residue (ZT-B), and four sub-plot treatments of nitrogen (N; 0, 60, 120 and 180 kg N/ha). Results showed that leaf area index, relative growth rate, spike length, grains/spike, 1000-grains weight, biological yield, nutrient uptake and gross returns were recorded relatively high under ZT practices along with or without crop-residues over the CT practices, though difference among the treatments were non- significant. The biological yield, nutrient uptake (NPK) and gross returns were improved with CA practices (ZT-F+R/ZT-B+R) by 5.3-8.1, 4.8-10.1 and 7.3-10.9 %, respectively over the CT practices. The B:C ratio was recorded the maximum under ZT practices (ZT-F/ZT-B) which was significantly higher by 18.3-24.0 % over the CT practices. Significantly higher values of most of the growth, yields, nutrient uptake and economic parameters were recorded at 120 kg N/ha. Nevertheless, ZT-F+R/ZT-B+R resulted the maximum response of wheat to N-fertilization (169-172 kg/ha) and also produced the maximum grain yield (4.81-4.86 t/ha) which signifying the importance of crop-residues and ZT technology in realizing the highest yield of wheat. Therefore, the study recommends that CA (ZT-F+R/ZT-B+R) systems along with additional 50 kg N/ha in addition to the presently recommended dose of N (120 kg/ha) should be promoted among the farmers of the Indo Gangetic Plains for improving productivity, profitability and long-term sustainability of the wheat in maize-wheat cropping system.

## Introduction

Wheat (*Triticum aestivum* L.) being the important cereal crop of India, providing the food and nutritional security to the country by contributing around 35 % in the national food grain production. The conventional wheat cultivation technologies primarily involving deep and intensively repeated tillage operations, over and indiscriminate use of water and fertilizer resources have significantly contributed in the occurrence of many ill-effects, though these have made the India self-sufficient in wheat production. The ill-effects of these technologies mainly include the soil health deterioration, ground water depletion and environmental pollution (Sharma *et al.,* 2012; Jat *et al.,* 2013).

Over-relaying on these technologies and over increasing input-costs have resulted the wheat cultivation non-profitable and unsustainable (Jat *et al.,* 2019a; Jat *et al.,* 2019b, Choudhary and Behera, 2020a). The conventional tillage (CT) practices are not only the major source of input energy consumption but also increase the costs of production, destroy the soil structure and lower the benefit: cost ratio (Choudhary and Behera, 2013; Singh *et al.,* 2019; Choudhary and Behera, 2019, 2020b).

To obtain a good seed bed in CT system the repeated ploughings not only involve high expenditure but also consume time which many a times delay the sowing of the crops resulting in low yields in intensive cropping system where gap between the harvest of one crop and sowing of the next crop is very short.

Further, crop-residue burning is a common problem in CT-based production systems. Open-field burning of these crop-residues releases the soot-particles, green-houses gases in addition to loss of plant nutrients (Gathala *et al.,* 2011; Jat *et al.,* 2013; Choudhary *et al.,* 2017).

In contrast to burning, retention of crop residue on soil surface as mulch helps in maintaining favorable hydrothermal regimes through modification of soil temperature and act as barrier against the loss of water. It improves the water and nutrient supply to crops and ultimately the crop productivity (Choudhary and Behera, 2014, 2019; Jat *et al.,* 2019b).

The minimal soil movement by reduction in tillage intensity and retention of crop-residues on the soil surface along with crop rotations and diversification to economically benefit the farmers are the key principles of CA (Verhulst *et al.,* 2011). The CA systems are being increasingly adopted in wheat-based cropping systems to reduce variable cultivation cost, enhance the resource-use efficiency and for restoration soil fertility (Jat *et al.,* 2013; Jat *et al.,* 2019c).

The zero-tillage (ZT) is cost effective, energy efficient and beneficial to environment as compared to CT practices of crop production (Jat *et al.,* 2019c; Choudhary *et al.,* 2020). Being the cereal, wheat is a heavy feeder of all nutrients in general, and nitrogen (N) in particular. Therefore, provision for an adequate supply of N throughout the growing season is necessary for realizing the potential yields (Singh *et al.,* 2009).

Further, it has also been observed that cereal crops exhibit reduced yields during the early phase of conversion of production technologies from CT to CA because of lesser N availability due to slower soil N mineralization, and greater immobilization, denitrification and $NH_3$ volatilization losses in the latter systems (Patra *et al.,* 2004). However, adoption of CA for long-run can enhance the supplying power of soil that leads to higher soil available N as compared to CT (Thuy *et al.,* 2008).

All these complexities with N under CA indicate the need for more research to understand the response of N to wheat under CA systems so as optimal supply of N could be ensured. Accordingly, this study was conducted with the objective to investigate the effect of tillage, crop establishment techniques, and N management practices on agronomic productivity and profitability of wheat grown in sequence with maize.

## Materials and Methods

### Experimental location, soil and climatic conditions

The study was conducted at the ICAR-Indian Agricultural Research Institute, New Delhi (28.4° N, 77.1° E, 229 MASL) during the winter seasons (November to April) of 2009-10 and 2010-11. The mean annual rainfall of the site is 672 mm out of which more than 80 % generally occurs during the monsoon season (July-September) with mean annual evaporation 850 mm. At the start of the experiment, the soil was sandy loam in texture had 1.57 g/cm$^3$ bulk density, 17.48 % (w/w) field capacity and 1.26 cm/hr infiltration rate. The organic carbon, $KMnO_4$ oxidizable N, 0.5 N $NaHCO_3$ extractable P, 1.0 N $NH_4OAc$ exchangeable K, pH and electrical conductivity of the soil were observed 0.37 % 147.6 kg/ha, 11.8 kg/ha, 235.1 kg/ha, 7.5 and 0.31 dS/m, respectively.

### Treatment detail and crop cultural practices

Field experiment was planned in split-plot design with three replications in a fixed layout. There were six main-plot treatment combinations of different tillage and crop establishment techniques: conventional tillage-flat (CT-F), zero tillage-flat (ZT-F), conventional tillage-bed (CT-B), zero tillage-bed (ZT-B), ZT-flat with residue (ZT-F+R) and ZT-bed with residue (ZT-B+R), while four levels of nitrogen (N) viz., 0, 60, 120 and 180 kg/ha were superimposed in each main-plot. The CT consisted of two pass of a disc harrow, followed by two pass of cultivator with planking in the last pass. Raised beds (fresh bed) were made with a bed planter which made beds at distance of 26.57″ from bed to bed with a bed height of 8″. The ZT consisted of no-tillage with minimum soil disturbance and one pass of ZT seed drill for sowing of crop. In ZT-beds, one pass of bed planter was made for sowing of crop and reshaping of beds. The fresh and permanent raised beds were of 26.57″ width having 14.76″ top and 11.81″ furrow, which was used for irrigation purposes. The wheat crop (var. PBW 550) was sown at a spacing of 18 cm from row to row with 100 kg seed/ha in flat planting, while three rows of wheat crop was established on top of the raised beds by keeping plant spacing of 5 cm. The chopped residue of the previous maize crop was applied at 5.0 t/ha as per the treatments. Before sowing, weeds were controlled using tank mix paraquat + glyphosate (each 0.5 kg *a.i.*/ha) in ZT practices. In standing wheat crop, tank mix solution of isoproturon (75 WP at 1 kg *a.i.*/ha) and 2,4-D sodium salt (80 WP at 0.5 kg *a.i.*/ha) was applied to control grassy as well as broad leaf weeds after 35 DAS. Full dose of P (26.2 kg/ha) and K (33.3 kg/ha) applied at the time of sowing in both the crops. Full dose of P (26.2 kg/ha) and K (33.3 kg/ha) applied at the time of sowing, while, N was applied in two equal splits (one at sowing and other after first irrigation) as per the treatments. The other standard and recommended practices of CA and CT were followed to harvest good crops.

### Monitoring of growth and yield parameters

In flat sown wheat, 0.25 m$^2$ areas was selected after leaving the first row from either side of the plot and the same area was selected from second bed of plot from the bed sown plots for the measurement of leaf area and dry matter accumulation. The crop leaves were stripped off from their base and total area of all the leaves was determined at 30, 60 and 90 DAS with the help of a Leaf Area Meter (Model LI-COR-3100). LAI was expressed as the ratio of leaf area to the land area occupied by the plant. The samples were sun dried first and then in an oven at 65°C till the constant weight arrived.

The accumulated dry matter ($g/m^2$) was used to calculate the relative growth rate (RGR, $g/g_/day$) between 0-30, 30-60 and 60-90 DAS. The length of ten spikes were measured on a measuring scale and then their average value was expressed as length of spike in cm. Ten ear-heads (spikes) from sampled plants were randomly selected, threshed and numbers of grains were counted. The average was worked out to obtain the number of grains/spike. A representative sample of grains was taken from the produce of each plot after drying and cleaning and weight of 1000-grains recorded and was expressed in grams. Total biomass of each net plot was harvested, weighed and expressed as biological yield in t/ha. Harvest index was computed by dividing the grain yield by the total biological yield and was expressed in percentage.

## Response functions of N-fertilization and economics

The economics of cultivation was worked out on the basis of prevailing market price of produce and cost of inputs. Gross returns were estimated by multiplying the grain yield and straw yields with their respective prices. While the cost: benefit ratio (B:C ratio) was calculated by dividing the net returns with total variable costs. Price of wheat produce was ₹ 11.00 and 11.50 per kg grain and ₹ 1.0 kg/straw during 2009-10 and 2010-11, respectively. Response functions of N-fertilization and their economics were calculated as described by Choudhary and Behera (2019).

## Nutrient uptake

Plant samples collected at harvest were dried in hot air oven at 67°C for 24 hours. The oven dried plant sample and grain samples were ground in a Macro-Wiley Mill and used for the determination of total nitrogen (N), phosphorus (P) and potassium (K) contents. Concentrations of N, P and K in grain and stover samples were determined by modified Kjeldahl method, vanadomolybdophosphoric acid yellow colour method (spectro-photometer) and flame photometer, respectively (Prasad *et al.,* 2006). Accordingly, nutrient uptake by crop was calculated by multiplying nutrient concentration with respective grain and stover yields.

## Statistical analysis

Analysis of variance was used to determine the effect of each treatment. When F ratio was significant, a multiple mean comparison was performed using Fisher's LSD Test ($p \leq 0.05$ probability level). The data were analyzed by two-way ANOVA technique using the PROCMIXED procedure of SAS package (*ver.* 9.3).

## Results and Discussion

## Growth parameters

The leaf area index (LAI) and relative growth rate (RGR) were found statistically similar under different tillage and crop establishment techniques at all the growth stages of wheat during both the years (Table 1 & 2). However, the maximum values of these parameters at most of the growth stages were recorded under ZT-F+R, while the minimum under CT-F. ZT practices have resulted marginally higher values of these parameters than corresponding CT practices. LAI was increased significantly with the advancement of the crop growth. It increased about 2.60 and 1.61 times at 60 and 90 DAS over the 30 and 60 DAS, respectively. However, RGR of wheat was decreased with advancement of crop growth and the maximum was recorded at 0-30 days interval, while the minimum between 60-90 days. Relatively higher values of growth parameters under ZT-F+R/ZT-B+R might be due to improved soil health and micro-environment created by continuous recycling of crop-residue and ZT practices. The growth parameters of wheat responded significantly to different levels of N in both the years. LAI was increased significantly up to 120 kg N/ha at all the growth stages, except at 30 DAS where it responded significantly only up to 60 kg N/ha. RGR was increased significantly up to 120 kg N/ha at 30 DAS, and only up to 60 kg N/ha at rest of the growth stages. The overall improvement in growth of wheat with the addition of N could be ascribed to its pivotal role in several physiological and biochemical processes (Kibe *et al.,* 2006).

## Yield attributes

The effect of different tillage and crop establishment practices on the yield attributes *viz.* spike length, grains/spike and 1000-grain weight of wheat was non-significant during both the years (Table 3). However, most of these yield traits were recorded the maximum under ZT-F+R, while minimum under CT practices. Yadav *et al.,* (2005) have reported that ZT led to improvement in growth and yield attributes, viz. plant height, effective tillers, grains/ear and 1000-grain weight due to better establishment of plants as a result of less weed competition under ZT. The yield

attributes were significantly influenced due to different levels of N, except grains/spike during 2009-10 and 1000-grain weight during both the years. The spike length was responded significantly up to 120 kg N/ha, while other traits were improved significantly only up to 60 kg N/ha. Though, the maximum values of these parameters were recorded at 180 kg N/ha, except 1000-grain weight; which was recorded the maximum at 60 kg N/ha. Our findings are also in agreement with Kumar *et al.,* (2007), they reported that yield attributing characters of wheat, spikes/m row and grains/spike enhanced significantly with each increase in N level up to 150 kg N/ha.

## Yield performance

The biological yield and harvest index of wheat were also not influenced significantly due to different tillage and crop establishment technique during both the years (Table 4). However, the maximum biological yield was recorded under residue applied treatments (ZT-F+R/ ZT-B+R), which were recorded 5.3-8.1 % higher over CT practices. Moreover, ZT without residue also registered the higher biological yield than the corresponding CT practices. Marginally higher biological yield was observed during 2010-11 than 2009-10 due to favourable weather conditions. Sayre *et al.,* (2005) have reported that in the first 5 years of the experimentation, no significant differences in wheat yield were found between different tillage management systems.

However, comparatively higher yield of wheat under ZT-F+R/ZT-B+R might be due to moderated soil temperature, improved soil moisture and soil fertility with recycling of crop-residues. Ram *et al.,* (2010) have reported higher yields under ZT with residue due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture, tillers, grains/ear and 1000-grain weight than no-residue application under ZT and CT practices.

Biological yield of wheat was significantly influenced due to different levels of N. Biological yield was increased significantly with each successive levels of N from 0 to 120 Kg /ha. However, highest values were obtained at 180 kg N/ha, which was significantly higher than 0 and 60 kg N/ha, but remained statistically similar with 120 kg N/ha. Being the cereal, wheat responded well up to 120 kg N/ha might also be due to that N supply boosts the crop growth and developmental processes because it involves in numbers of physiological and biochemical processes in plant system (Stitt and Krapp, 1999). Consequently, benefit derived by the crop in vegetative and reproductive developments due to optimal N supply might be the reason for higher yield of wheat at higher levels N. The harvest index values were varied between 40.23 to 42.85 %, but it did not differ significantly. Similarly, harvest index was also not influenced significantly due to different levels of N.

## Economics

Gross returns were found statistically similar under different tillage and crop establishment techniques (Table 4). However, the maximum gross returns were recorded under residue applied treatments (ZT-F+R/ ZT-B+R), which were recorded 7.3-10.9 % higher over CT practices. The higher gross returns under ZT-F+R/ ZT-B+R were due to comparatively higher yields of wheat.

In contrast to other parameters, those did not influence significantly due to different tillage and crop establishment techniques, but the benefit: cost ratio (B:C ratio) was differed significantly (Table 4). The B:C ratio was recorded the maximum under ZT practices (ZT-F/ZT-B) which was significantly higher by 18.3-24.0 % over the CT practices.

The higher B:C ratio under ZT practices was due to comparatively higher yields and lesser cost incurred in crop establishment, weed control and manpower costs. This was in agreement with the findings of Zentner *et al.*, (2002) and Choudhary and Behera (2020a). However, recycling of high value crop-residues under ZT practices reduced the B:C ratio significantly over the CT practices. Gross returns were also increased with increase in N levels from 0 to 180 kg/ha, but it improved significantly up to 120 kg N/ha. While B:C ratio was increased significantly only up to 60 kg N/ha.

## Nutrient uptake

The total nutrient uptake (N, P and K) in grain and straw of wheat crop were not influenced significantly due to different tillage and crop establishment techniques during both the years (Table 5). However, the maximum uptake of N, P and K was recorded under residue applied ZT treatments (ZT-F+R/ZT-B+R), which were found 5.0-9.9, 8.1-10.1 and 4.8-5.5 % higher over the CT practices, respectively.

The recycling of maize-residues might have contributed in nutrient supply in soil layers and ultimately enhances nutrient availability for wheat which might be the reason for higher uptake of nutrients under CA practices (Choudhary and Behera, 2019).

Unlike, the effect of different tillage and crop establishment techniques on nutrients uptake, various levels of N significantly influenced the nutrients uptake of wheat. The uptake of N, P and K was increased significantly with each increased levels of N up to 120 kg N/ha.

However, the maximum values of N, P and K uptake were recorded at 180 kg N/ha, which remained significantly higher than 0 and 60 kg N/ha, but statistically on par with 120 kg N/ha. Relatively higher concentration of N, P and K in grain and straw and higher biomass yields of wheat might be the reason for higher uptake of these nutrients at higher levels of N.

## Response functions of N-fertilization

Wheat responded differentially to N levels under different tillage and crop-establishment techniques. The response of wheat to N was quadratic (Fig. 1). Almost similar response of N was observed in different CT and ZT without crop-residue practices. However, greater response of N was observed under crop-residue applied ZT treatments. Further, crop-residue applied treatments responded differentially in terms of yield enhancement under varying levels of N, indicating that the beneficial effect of crop-residue recycling was more discernible when N levels were increased from zero to highest.

Beneficial effect of crop-residues under ZT-F+R/ZT-B+R was increased with each successive higher level of N, but at slower pace between 0 and 120 kg N/ha and highest between 120 and 180 kg N/ha. The response functions of N fertilization were worked out by quadratic equations between the grain yields and N levels (Table 6).

The $N_{opt}$ for wheat was observed higher than the recommended dose of N (120 kg N/ha) under all the treatments, indicating that little higher doses of N are needed to achieve higher wheat yields. The $N_{opt}$ for wheat was recorded least under CT-F, followed by other CT and ZT without residue treatments, indicating that yield could not be increased further under these practices even with the application of higher dose of N.

The maximum grain yield of wheat was estimated under ZT-F+R and ZT-B+R treatments were 172.1 and 168.9 kg N/ha ($N_{opt}$), respectively, indicating that wheat require around additional 50 kg N/ha to realize its potential yields under CA systems during the initial years.

Thus, maize residue recycled to wheat under ZT practices had increased the dose of $N_{opt}$ for wheat which led to lower response in kg grain/kg N than CT and ZT without residue-applied treatments, though it produced the maximum grain yield of wheat.

**Table.1** Effect of tillage and crop establishment techniques, and N levels on leaf area index of wheat

| Treatment | 30 DAS | | 60 DAS | | 90 DAS | |
|---|---|---|---|---|---|---|
| | **2009-10** | **2010-11** | **2009-10** | **2010-11** | **2009-10** | **2010-11** |
| ***Tillage and crop establishment*** | | | | | | |
| **CT-F** | 0.69 | 0.73 | 1.95 | 2.01 | 3.20 | 3.27 |
| **CT-B** | 0.69 | 0.86 | 1.96 | 2.12 | 3.32 | 3.41 |
| **ZT-F** | 0.70 | 0.73 | 2.17 | 2.22 | 3.46 | 3.51 |
| **ZT-B** | 0.70 | 0.73 | 2.05 | 2.13 | 3.39 | 3.43 |
| **ZT-F+R** | 0.70 | 0.78 | 2.20 | 2.29 | 3.58 | 3.62 |
| **ZT-B+R** | 0.70 | 0.84 | 2.07 | 2.19 | 3.37 | 3.52 |
| **SEm±** | 0.013 | 0.033 | 0.065 | 0.069 | 0.100 | 0.101 |
| **LSD ($p \leq 0.05$)** | NS | NS | NS | NS | NS | NS |
| ***Nitrogen levels (kg/ha)*** | | | | | | |
| **0** | 0.63 | 0.70 | 1.61 | 1.71 | 2.47 | 2.54 |
| **60** | 0.71 | 0.79 | 2.15 | 2.24 | 3.36 | 3.44 |
| **120** | 0.72 | 0.82 | 2.24 | 2.34 | 3.84 | 3.89 |
| **180** | 0.72 | 0.81 | 2.26 | 2.35 | 3.87 | 3.97 |
| **SEm±** | 0.009 | 0.018 | 0.031 | 0.029 | 0.036 | 0.043 |
| **LSD ($p \leq 0.05$)** | 0.026 | 0.051 | 0.089 | 0.084 | 0.103 | 0.122 |

**Table.2** Effect of tillage and crop establishment techniques, and N levels on relative growth rate (g/g/day) of wheat

| Treatment | 0-30 DAS | | 30-60 DAS | | 60-90 DAS | |
|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 |
| ***Tillage and crop establishment*** | | | | | | |
| **CT-F** | 0.112 | 0.123 | 0.026 | 0.046 | 0.020 | 0.052 |
| **CT-B** | 0.113 | 0.124 | 0.029 | 0.043 | 0.019 | 0.050 |
| **ZT-F** | 0.112 | 0.127 | 0.026 | 0.041 | 0.020 | 0.051 |
| **ZT-B** | 0.113 | 0.123 | 0.028 | 0.044 | 0.019 | 0.051 |
| **ZT-F+R** | 0.112 | 0.129 | 0.026 | 0.039 | 0.019 | 0.051 |
| **ZT-B+R** | 0.114 | 0.128 | 0.028 | 0.038 | 0.019 | 0.050 |
| **SEm±** | 0.001 | 0.002 | 0.001 | 0.002 | 0.001 | 0.001 |
| **LSD ($p \leq 0.05$)** | NS | NS | NS | NS | NS | NS |
| ***Nitrogen levels (kg/ha)*** | | | | | | |
| **0** | 0.104 | 0.118 | 0.029 | 0.046 | 0.017 | 0.047 |
| **60** | 0.113 | 0.126 | 0.026 | 0.041 | 0.019 | 0.050 |
| **120** | 0.116 | 0.129 | 0.027 | 0.040 | 0.020 | 0.052 |
| **180** | 0.117 | 0.130 | 0.026 | 0.039 | 0.021 | 0.053 |
| **SEm±** | 0.0004 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| **LSD ($p \leq 0.05$)** | 0.001 | 0.003 | 0.002 | 0.003 | NS | 0.002 |

**Table.3** Effect of tillage and crop establishment techniques, and N levels on yield attributes of wheat

| Treatment | Spike length (cm) | | Grains/spike | | 1000-grain weight (g) | |
|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 |
| ***Tillage and crop establishment*** | | | | | | |
| **CT-F** | 10.13 | 10.64 | 53.31 | 54.93 | 40.66 | 39.11 |
| **CT-B** | 10.10 | 10.07 | 54.30 | 52.73 | 39.47 | 41.68 |
| **ZT-F** | 10.14 | 10.77 | 58.00 | 57.53 | 39.84 | 42.66 |
| **ZT-B** | 10.17 | 10.76 | 57.48 | 57.43 | 41.16 | 40.59 |
| **ZT-F+R** | 10.18 | 10.69 | 56.03 | 60.33 | 41.45 | 42.84 |
| **ZT-B+R** | 10.14 | 10.56 | 58.70 | 59.47 | 41.16 | 39.84 |
| **SEm±** | 0.163 | 0.208 | 2.433 | 2.846 | 0.725 | 1.403 |
| **LSD ($p \leq 0.05$)** | NS | NS | NS | NS | NS | NS |
| ***Nitrogen levels (kg/ha)*** | | | | | | |
| **0** | 8.84 | 8.90 | 52.96 | 49.50 | 40.90 | 38.96 |
| **60** | 10.44 | 10.12 | 55.77 | 56.30 | 41.27 | 42.46 |
| **120** | 10.62 | 11.54 | 57.63 | 60.41 | 40.34 | 42.13 |
| **180** | 10.66 | 11.75 | 58.85 | 62.05 | 39.98 | 40.93 |
| **SEm±** | 0.129 | 0.195 | 1.549 | 2.355 | 0.631 | 1.252 |
| **LSD ($p \leq 0.05$)** | 0.369 | 0.559 | NS | 6.754 | NS | NS |

**Tanle.4** Effect of tillage and crop establishment techniques, and N levels on yield performance and economics of wheat

| Treatment | Biological yield (t/ha) | | Harvest index (%) | | Gross returns (× $10^3$ ₹/ha) | | B:C ratio | |
|---|---|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 |
| *Tillage and crop establishment* | | | | | | | | |
| CT-F | 9.07 | 9.43 | 41.31 | 40.25 | 49.55 | 51.97 | 1.68 | 2.03 |
| CT-B | 8.94 | 9.66 | 41.24 | 40.23 | 48.46 | 53.24 | 1.60 | 2.06 |
| ZT-F | 9.26 | 9.82 | 42.51 | 40.86 | 51.37 | 54.83 | 2.03 | 2.51 |
| ZT-B | 8.96 | 9.59 | 41.70 | 40.74 | 48.83 | 53.07 | 1.94 | 2.45 |
| ZT-F+R | 9.86 | 10.14 | 42.85 | 41.82 | 55.05 | 57.56 | 1.47 | 1.75 |
| ZT-B+R | 9.72 | 9.86 | 41.50 | 41.77 | 53.06 | 56.04 | 1.42 | 1.71 |
| SEm± | 0.369 | 0.359 | 1.671 | 2.071 | 1.70 | 1.31 | 0.10 | 0.077 |
| LSD ($p \leq 0.05$) | NS | NS | NS | NS | NS | NS | 0.31 | 0.241 |
| *Nitrogen levels (kg/ha)* | | | | | | | | |
| 0 | 6.85 | 6.93 | 40.59 | 41.82 | 36.67 | 39.36 | 1.13 | 1.48 |
| 60 | 9.35 | 9.90 | 42.26 | 41.22 | 51.57 | 55.65 | 1.79 | 2.26 |
| 120 | 10.32 | 10.93 | 42.30 | 40.31 | 56.98 | 60.47 | 1.93 | 2.34 |
| 180 | 10.70 | 11.24 | 42.27 | 40.44 | 58.99 | 62.34 | 1.90 | 2.26 |
| SEm± | 0.156 | 0.181 | 1.270 | 1.242 | 0.85 | 1.03 | 0.05 | 0.063 |
| LSD ($p \leq 0.05$) | 0.448 | 0.519 | NS | NS | 2.44 | 2.96 | 0.14 | 0.180 |

**Table.5** Effect of tillage and crop establishment techniques, and N levels on nutrient uptake (kg/ha) of wheat

| Treatment | Total nitrogen | | Total phosphorous | | Total potassium | |
|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | 2009-10 | 2010-11 | 2009-10 | 2010-11 |
| *Tillage and crop establishment* | | | | | | |
| CT-F | 83.51 | 83.53 | 9.98 | 10.16 | 101.75 | 108.2 |
| CT-B | 85.35 | 88.36 | 9.41 | 10.24 | 100.20 | 108.5 |
| ZT-F | 82.92 | 86.05 | 10.12 | 10.63 | 99.95 | 108.7 |
| ZT-B | 83.32 | 86.93 | 9.52 | 10.13 | 99.74 | 108.2 |
| ZT-F+R | 91.10 | 92.55 | 10.98 | 11.20 | 108.74 | 112.7 |
| ZT-B+R | 89.82 | 92.52 | 10.42 | 10.82 | 108.94 | 109.8 |
| SEm± | 3.709 | 2.146 | 0.41 | 0.370 | 3.412 | 3.890 |
| LSD ($p \leq 0.05$) | NS | NS | NS | NS | NS | NS |
| *Nitrogen levels (kg/ha)* | | | | | | |
| 0 | 55.01 | 56.73 | 7.09 | 7.458 | 75.14 | 74.41 |
| 60 | 85.54 | 89.91 | 10.18 | 10.74 | 103.48 | 110.2 |
| 120 | 99.84 | 102.43 | 11.33 | 11.79 | 115.50 | 124.3 |
| 180 | 103.62 | 104.23 | 11.70 | 12.13 | 118.75 | 128.6 |
| SEm± | 1.746 | 1.749 | 0.19 | 0.233 | 2.460 | 3.180 |
| LSD ($p \leq 0.05$) | 5.008 | 5.018 | 0.55 | 0.667 | 7.055 | 9.121 |

**Table.6** Effect of tillage and crop-establishment techniques on response function of nitrogen fertilization of wheat during 2010-11

| Treatment | Economic optimum dose of N (kg/ha) | Grain yield at economic optimum dose of N (kg grain/ha) | Response at economic optimum dose of N (kg grain/kg N) |
|---|---|---|---|
| **CT-F** | 128.3 | 4395 | 13.4 |
| **CT-B** | 135.3 | 4485 | 12.7 |
| **ZT-F** | 133.1 | 4642 | 13.4 |
| **ZT-B** | 132.9 | 4372 | 10.7 |
| **ZT-F+R** | 172.1 | 4862 | 10.1 |
| **ZT-B+R** | 168.9 | 4805 | 9.5 |

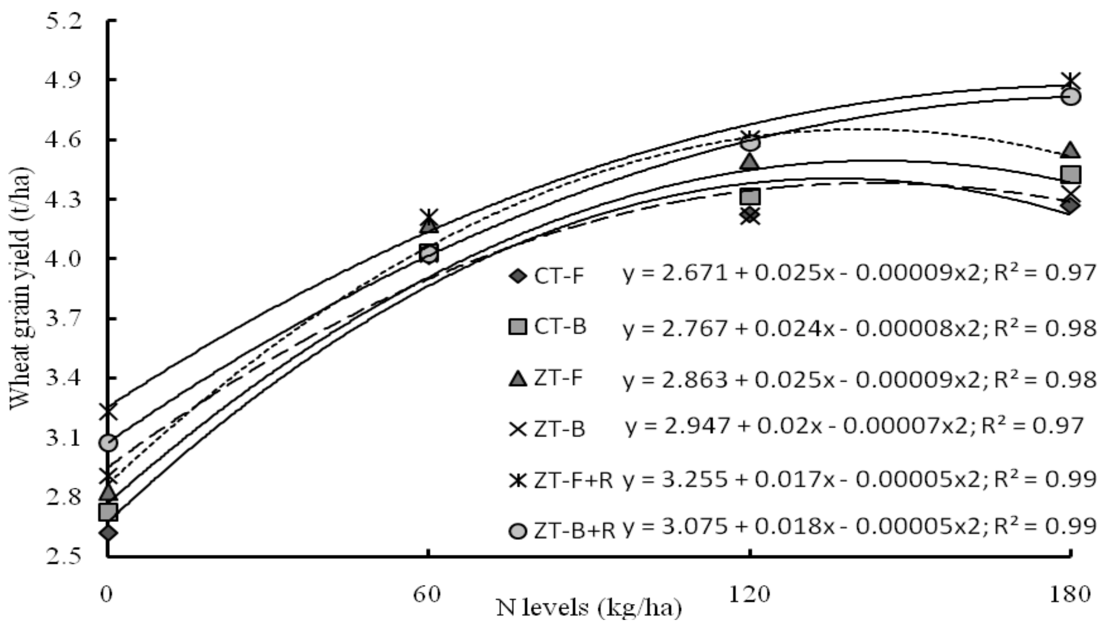


**Fig.1** Response of wheat to varying levels of N as influenced by different tillage and crop-establishment techniques

However, Sharma and Behera (2009) reported that N economy in wheat was 21 kg N/ha owing to residue incorporation of intercropped greengram, cowpea and groundnut; and 49–56 kg N/ha of sole cropped greengram and groundnut. Similarly, Choudhary and Behera (2019) have also reported an N economy of 20-25 kg/ha in maize due to wheat residue recycling under the CA systems.

Thus, it can be concluded that the growth, yield attributes, nutrient uptake and yields of wheat were observed relatively higher under ZT practices along with or without crop residues over the CT practices. However, ZT technology was found most profitable with highest B:C ratio. Recycling of crop-residues under ZT practices resulted the maximum response of wheat to N fertilization and also yielded the maximum which signifying the importance of crop-residues and ZT technology in realizing the highest potential yield of wheat. Therefore, the study recommends that CA (ZT-F+R/ZT-B+R) system along with additional 50 kg N/ha in addition to the presently recommended dose of N (120 kg/ha) should be promoted among the farmers of the Indo Gangetic Plains for improving productivity, profitability and long-term sustainability of wheat in maize-wheat cropping system.

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