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DEVELOPMENT OF LOW INPUT, NO- TILL WHEAT SEEDING TECHNOLOGIES FOR CROP RESIDUES MANAGEMENT IN RICE-WHEAT CROPPING SYSTEM

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A considerable amount of rice stubbles (7-10 ton ha^{-1}) are produced yearly in rice- wheat cropping system. Suitable management of these crop stubbles maintains soil health and natural balance of the cropping systems. Rice stubbles management requires number of tillage operations to prepare the seedbed which ultimately delayed the wheat sowing process. Consecutive two-year trail was conducted at Agriculture Extension and Adaptive Research Farm, Gujranwala, Pakistan i.e. 2012-13 and 2013-14, with the objectives to determine the most profitable economical rice residues management technique for this system. Trail was comprised of seven tillage methods; turbo seeder (TS), happy seeder (HS), zone disc tiller drill (ZDT), zero tillage drill (ZTD), ZTD after physical elimination of rice stubbles, ZTD after straw burning, conventional tillage and three nitrogen application timings; all N application at sowing time; 0.5 N at as basal dose + 0.5 N at first irrigation; 0.5 N at first irrigation + 0.5 N at second irrigation. Statistically, higher plant height was noted in turbo and happy seeded wheat as compare to other wheat sowing methods while nitrogen application timings gave maximum plant height where N fertilization was done, 0.5 N during seed bed preparation and 0.5 N at first irrigation. Turbo seeded treatment gave 265.33 fertile tillers m^2 that were 5%, 7%, 12%, 11%, 6% and 4 % more than HS, ZDT drill, ZTD, conventional ZTD after rice straw removal manually, conventional ZTD after rice straw burning and conventional wheat sowing, respectively. Turbo seeded wheat produced substantial higher spike length compared to other ZT methods. Statistically, maximum grains per spike were recorded in experimental units where wheat cultivation was done with turbo seeder followed by conventional tillage method of wheat sowing. Among nitrogen application timings higher grains per spike were calculated where N fertilizer was applied, 0.5 N during seedbed preparation and 0.5 N at primary watering. Uppermost thousand grain weight (TGW) was recorded in conventional sowing method and it was similar with TS, HS, ZTD, ZTD after physical elimination of rice stubbles and ZTD after straw blazing while, in case of N application timings, utmost TWG was obtained when N fertilization was done half N as basal dose and half at the time of primary irrigation. Turbo seeder treatment gave substantially highest total crop biomass as compared with other sowing methods. Wheat sown with turbo seeder gave 5.69%, 14.95%, 12.18%, 9.33%, 5.1% and 1.99% higher yield than HS, ZDT, zero tillage drill, ZTD after physical elimination of rice stubbles ZTD after straw blazing and conventional method of wheat sowing, respectively. Among nitrogen application timings, higher grain yield was obtained where N fertilization was done with 0.5 N at sowing and 0.5 N at time of primary irrigation. During both year of experimentation, LAI and crop growth rate (CGR) at 75 days after sowing (DAS) and total dry matter (TDM) and leaf area duration (LAD) at 120 DAS was maximum in turbo seeded wheat when N was added 0.5 N dose as a basal and 0.5 N at the time of primary irrigation. Net assimilation rate was higher in turbo seeded wheat when N was added 0.5 N during seedbed preparation and 0.5 N at primary watering. Moreover, highest grain protein contents (12.95%), fat contents (0.85%), and fiber contents (0.14%) were observed in TS experimental unit. Among different zero tillage sowing methods turbo seeder gave better returns and in case of nitrogen application timing the treatment gave better returns when half nitrogen was applied at sowing time and half nitrogen was applied at first irrigation.
Key words: zero tillage, turbo seeder, rice-wheat cropping system, nitrogen fertilization.

INTRODUCTION

Rice-wheat production system is primarily the most significant and world's largest farm production system (Hussain *et al*. 2012). According to Singh and Kaur (2012), total rice cultivation is practiced on an area of 23.5 m ha in Asia and this cultivated area is consisting of China (10 m ha) and in South Asia (13.5 m ha). The South Asia's total area under this system comprised of Bangladesh (0.8 million hectares), Pakistan (2.2 million hectares), India (10 million hectares) and Nepal (0.5 million hectares).

A considerable amount of stubbles (7-10 ton ha^{-1}) are produced yearly in rice-wheat production system, stubbles takes out more than 300 kg potassium (K), 30 kg phosphorus (P) and 300 kg nitrogen (N) per hectare (Mandal *et al*. 2004). Crop residues are regarded as waste materials at the time of harvest that require proper disposal but these are priceless natural reserves and may be managed as an essential constituent of the production system for increasing soil health, nutrient recycling, managing weeds and supporting the natural ecosystem as well as enhancing crop productivity (Kumar and Goh, 2000; Soon *et al*. 2009; Lemke *et al*. 2010; Ailincai *et al.* 2010; Usman *et al.* 2012). Wheat straw is generally cut by the farmers to feed their animals, however, rice straw having markedly higher lignin and silica with smaller quantity of protein contents, is regarded as poor feed for animals. Mandal *et al*. (2004) and Pathak *et al*. (2006) elucidated that farmers generally burn the rice straw to clear the land surface. Nevertheless, burning of rice stubbles helps to control soil borne pathogens, but burning generally contributes to air pollution, mortality of some beneficial soil organisms (Mandal *et al*. 2004) and substantial hammering of plant nutrients that can be re-cycled into the system (Gangwar *et al*. 2006; Gupta *et al*. 2004). Burning of rice stubbles ultimately affects the productivity of soil, which leads to loss of 30-35% P, 80-85% K, 40-50% sulfur and 40% N (Mandal *et al*. 2004). Rice residues elimination and burning did not have any distinction in organic carbon and available nitrogen stuff of soil, but straw burning substantiated its dominance to straw elimination in terms of obtainable phosphorus and potash (Kumar and Goh, 2001). Rice residue burning practice can be reduced by adopting different rice residue management options like soil incorporation, retention on the soil surface, mulching and direct sowing of wheat with conservation tillage implements (Singh *et al*. 2008). All these processes are directly involved in lowering soil temperature and evaporation during summer months, retaining soil moisture for longer period particularly under dry conditions and in that way improve crop productivity (Lobell *et al*. 2006).

The problem of N immobilization is becoming more acute in every next year of rice-wheat cropping system due to greater deposition of higher C: N ratio of rice crop stubbles (Qamar *et al*. 2012). Application of N fertilizer to crop strongly affects the sustainability of cropping system. Nitrogen fertilizer plays important function in wheat crop growth and development (Qamar *et al*. 2012). Mandal *et al*. (2004) observed that crop stubbles retained on earth surface improved the uptake of N by 29%, NO_3 by 46% and yield by 37% as compared to burning. To re-establish soil properties and succeeding output in this production system, appropriate crop residues management has great importance (Kumar and Goh, 2000; Singh *et al*. 2005 and Mandal *et al*. 2004). The productivity of soil in terms of available N, organic carbon, K and P after harvesting of wheat crop got enriched by the crop stubble inclusion or preservation irrespective of tillage type which is more under zero tillage (Kumar *et al*. 2001). Common features of the no till practice are less erosion, constant production, and extra organic matter (OM) contents in the soil (Uri, 2000; Kumar and Yadav, 2001; Brula, 2002). No-till techniques are one of the most potential methods that deposit extra nutrients and organic matter contents into soil than conventional methods of tillage. Availability of appropriate zero tillage drills is considered a main limitation in direct seeding of wheat in rice stubbles, largely due to obstruction in many parts of the zero tillage machines and fails to gain good soil-seed contact. The introduction of happy seeder (HS) technology (zero tillage drill) in the rice-wheat production systems made the wheat sowing easier with both in standing or loose rice straw stubbles. Moreover, Qamar *et al.* (2012) reported that cost for zero tillage wheat crop cultivation with HS is fifty to sixty percent lower than conventional sowing method. Zero tillage technology provides satisfactory replacement of burning of rice straw. The practice of zero tillage managed rice straw allows direct sowing of wheat in spread rice straw (Gathala *et al*. 2009). Major drawbacks pertaining to zero tillage wheat cultivation are weeds influx, retorted crop growth owing to quick drying of upper soil surface and consumption of N by microbes for decomposing the rice residues (Rahman *et al*. 2005). According to McMaster *et al.* (2002) and Hemmat and Eskandari (2004), wheat yield in zero tillage system was considerably higher than or equal to the conventional tillage. Assessment of different straw management practices in rice-wheat cropping system can also provide as an imperative procedure in managing fertilizer application practices.

There is dire need to compare and standardize the numerous zero-till and residue management strategies in rice-wheat cropping system of Pakistan. So the current study was conducted to develop low input and resource saving wheat seeding method with proper residues management technique. The main objective of the experiment was the development of low input technologies for zero tillage wheat seeding for the management of residues in cropping system of rice-wheat.

MATERIALS AND METHODS

***Experimentation*:** This research trial was conducted at Department of Agriculture (AE & AR), at Agriculture Extension and Adaptive Research Farm, Gujranwala, Punjab-Pakistan during Rabi seasons 2012-13 and 2013-14, respectively. The experimental site was located at altitude 226 m, longitude 74°E and latitude 32°N. The type of soil was sandy clay loam (Typic Calciargids, mixed, Hyper thermic, USDA nomenclature fine loamy) by texture. The weather data of two growing seasons is shown in Figure 1.

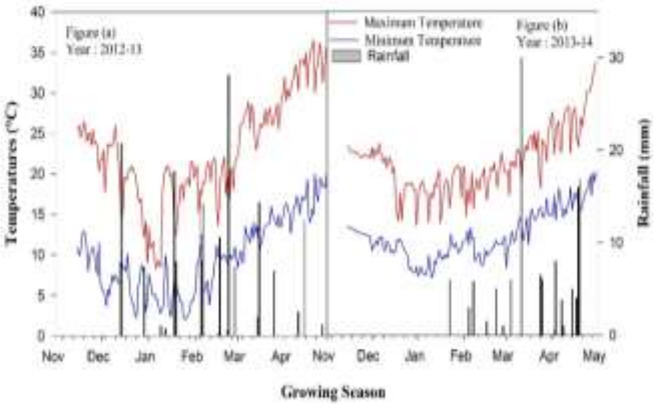

Figure 1. Seasonal weather data for wheat during the years 2012-13 and 2013-14.

The experimental treatments were as follow:

Sowing methods	Nitrogen application timing		
	N1	**N2**	**N3**
TS	N1*TS	N2*TS	N3*TS
HS	N1*HS	N2*HS	N3*HS
ZDT	N1* ZDT	N2*ZDT	N3*ZDT
ZTD	N1*ZTD	N2*ZTD	N3*ZTD
ZTDM	N1*ZTDM	N2*ZTDM	N3*ZTDM
ZTDB	N1*ZTDB	N2*ZTDB	N3*ZTDB
CONV.	N1*C0NV	N2*CONV	N3*CONV

TREATMENTS

Factor: A (Sowing methods/ techniques)

TS: Wheat sowing with Turbo Seeder zero tillage drill

HS: Wheat sowing with Happy Seeder zero tillage drill

ZDT: Wheat sowing with Zone Disc Tiller zero tillage drill

ZTD: Wheat sowing with Zero Tillage Drill

ZTDM: Wheat sowing with Zero Tillage Drill after rice straw manual removal

ZTDB: Wheat sowing with Zero Tillage Drill after rice straw burning

CONV: Wheat sowing with conventional method

Factor: B (Nitrogen application timings, 120 kg ha^{-1})

N_1: Nitrogen application at sowing time

N_2: ½ Nitrogen (at sowing) + ½ Nitrogen (at first irrigation)

N_3: ½ Nitrogen (at first irrigation) + ½ Nitrogen (at second irrigation)

***Crop husbandry*:** In each year, experiment was performed by using randomized complete block design with split-plot arrangement having 3 replications. In main plots, sowing methods while in sub plots, nitrogen application timings were kept. The total plot size of trial was 8.10 m × 15 m. The experimental material comprised of wheat variety Millat 2011 which was sown on 15th and 21th of November in years 2012-13 and 2013-14, respectively at R×R distance 22.5 cm and 36 rows per plot were sown by using the seed rate of 125 kg/ha . Nitrogen from urea, P from DAP and K from SOP were applied at 120, 100 and 60 kg/ha, respectively. All P and K were used at seedbed preparation while N was applied according to treatments of the experiment. After attaining maturity, crop was manually harvested on 27th of April, 2013 and 3rd of May, 2014.

***Experimental data collection Growth analysis*:** After plant emergence, an indiscriminately of 30 cm long row selected area was cut after every fifteen days at about 30 days after sowing (DAS) from each plot. Digital balance was used to measure fresh weight of stem and leaf. Leaf area was measured by taking a sub-sample of five-gram green foliage on leaf area meter (ΔT Area meter MK2) and transformed into per square meter. These sub-samples were then desiccated under sunshine for twenty-four hours and weight of the dried samples were calculated after the use of oven for drying of the samples at 70 ºC for 24 hrs to achieve a constant weight. Dry weights of all the fractions were added to estimate overall dry matter produced per unit area. Subsequent growth parameters were estimated by the measurement of leaf area and dry weight.

***Total dry matter production*:** Plant samples were collected randomly after 15 days' interval. Each plant was divided into various portions i.e. stem and leaf. Fresh weight of every portion was computed individually. Subsample of ten grams of each division was used to find out the dry weight of the sample after drying in the hot air oven (at 70 ºC). Production of the total dry mass-produced was calculated by summation of dry weights i.e. stem and leaf. After that unit was changed to kg/ha.

Leaf area index (LAI): LAI of the green lamina was recorded by applying the formula prescribed by Watson (1952).

LAI = leaf area/land area used

Leaf area duration (LAD): LAD was recorded by using formula given by Hunt (1978).

Leaf area duration (days) = $(LAI_1+LAI_2) \times (T_2 - T_1)/2$

Here, LAI_1 represents the index of leaf area at time T_1 and LAI_2 represents the index of leaf area at time T_2.

Crop growth rate (CGR): By applying formula prescribed by Hunt (1978) CGR was computed which is mentioned below

Crop growth rate (g/m^2 day^1) = $(W_2\text{-}W_1) / (T_2\text{-} T_1)$

Where, W_1 represents the total dried weight at harvested time T_1 and W_2 represents the total dried weight at harvested time T_2.

Net assimilation rate (NAR): NAR was calculated by applying the prescribed formula given by Hunt (1978).

NAR (Net assimilation rate) (g m^{-2} day^{-1}) = TDM / LAD

Yield parameters: At physiological maturity, crop plant height, number of fertile tillers, spike length and number of grains per spike were calculated. The 1000-grains were computed and weighed after drying at 70ºC for 24 h. Biological yield was computed by weighing total above-ground biomass and grain yield was recorded after threshing grains from plants harvested from whole plot. The harvesting index (HI) was computed by formula given below:

$$\mathrm{HI} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Grain quality

Grain protein content (%): Grain quality was determined from 4-5 g grain samples from each experimental unit by grinding samples and storing them in airtight bottles. Nitrogen contents were computed by using Micro Kjeldahl's technique. The protein contents (%) were determined by multiplying the grain sample nitrogen content with 5.7 which is the appropriate factor worked out for wheat.

***Crude fat content* (%):** Crude fat contents were measured by taking three-gram damp free flour samples. Petroleum ether as a solvent was used for 2-3 h in the Soxhlet apparatus as method specified in AACC (1983).

$$\text{Crude fat percent} = \frac{\text{Fat weight (g)}}{\text{Sample weight (g)}} \times 100$$

***Crude fiber Percent* (%):** The crude fiber content was measured from one-gram damp free flour sample. These samples were firstly digested with 1.25% quantity of H_2SO_4 and 1.25% of sodium hydroxide solution, after sample drying, the fiber contents (%) was calculated by using method described by AACC (1983). Following formula was used to compute the crude fiber (%) contents:

$$\text{Crude fiber \%} = \frac{\text{Weight loss on ignition (g)}}{\text{Weight of sample (g)}} \times 100$$

***Statistical analysis and graphics*:** Data collected from two years (2012-13 and 2013-14) experiments were statistically analyzed by using software statistics 10 (analytical software, Tallahassee, Florida, USA). Among the treatment means, differences were compared for checking the significance by using the least significant difference (LSD) test at 5% probability level.

RESULTS

***Growth analysis*:** It was observed that different sowing methods and nitrogen application timings and their combination had prominent impact on NAR, LAI (fig 4.1, 4.2), TDM (fig 4.3,4.4), LAD (fig 4.5,4.6) and CGR (fig 4.7,4.8) of the crop as depicted in graphs. During both the years of experimentation, the highest LAI (5.84 and 5.66) were achieved after 75 DAS in treatment where ½ N was applied at time of seedbed preparation and ½ N at first irrigation. During both growing seasons, highest TDM (1371.0 g/m^2 and 1208.08 g/m^2) was achieved by turbo seeder, happy seeder and the lowest TDM was observed with zero tillage drill when all nitrogen fertilizer application was applied as basal dose at 135 DAS. In turbo seeder treatment where N was applied 50% dose at sowing time and 50% dose at 1st irrigation produced maximum leaf area duration (264.63 and 248.13 days) during both the growing seasons, respectively. Significantly, the lowest LAD was observed in Turbo seeder wheat treatment along with N fertilizer dose when 50% N was added at sowing time and 50% N with first irrigation. During both experimental years, utmost CGR was calculated in turbo seeder treatment (22.96 and 24.29 g m^{-2} d^{-1}), respectively.

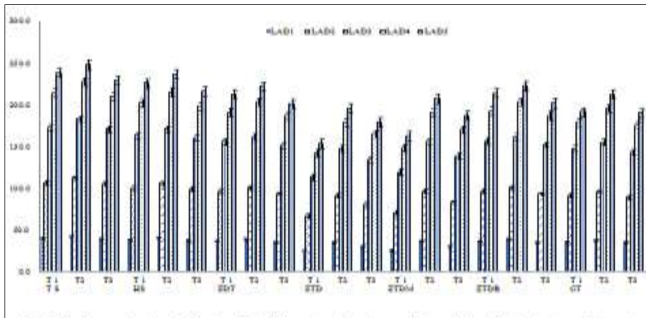

Fig:4.6. Leaf area duration of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2013-14
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw, ZTDR= zero tillage drill after burning of rice straw, CT= Conventional tillage

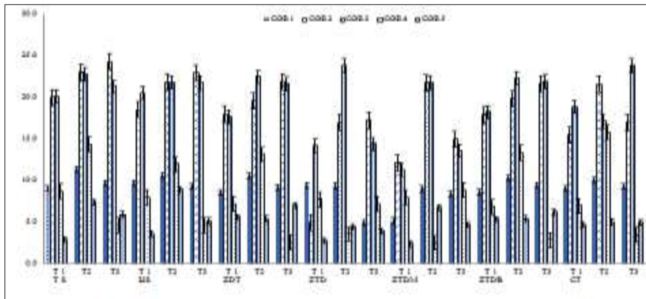

Fig: 4.8. Crop growth rate of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2013-14.
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw, ZTDR= zero tillage drill after burning of rice straw, CT= Conventional tillage

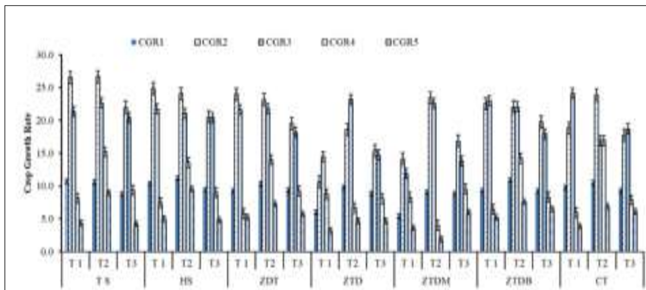

Fig: 4.7. Crop growth rate of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2012-13.
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw, ZTDR= zero tillage drill after burning of rice straw, CT= Conventional tillage

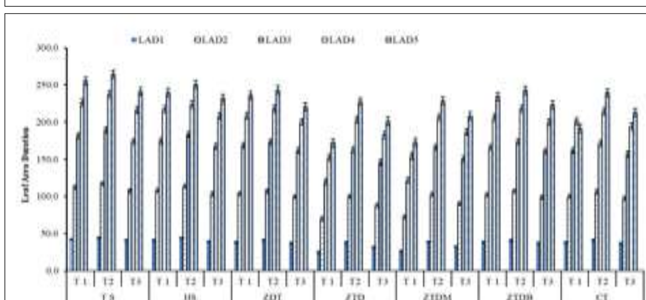

Fig:4.5. Leaf area duration of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2012-13
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw, ZTDR= zero tillage drill after burning of rice straw, CT= Conventional tillage

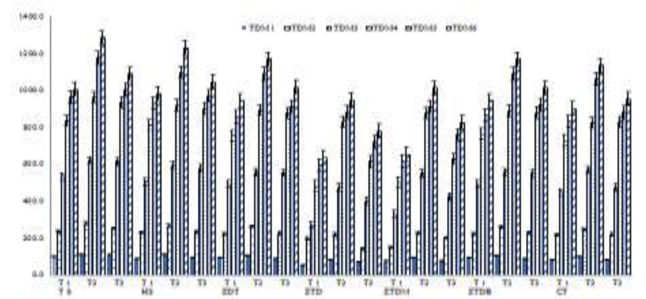

Fig:4.4. Total dry matter of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2013-14
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT=zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw; ZTDB= zero tillage drill after burning of rice straw; CT= Conventional tillage

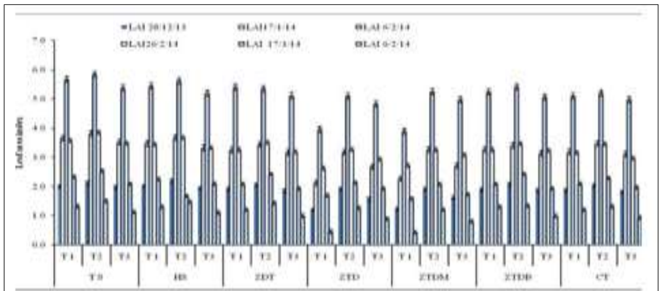

Fig: 4.1 Leaf area index of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2012-13.
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw; ZTDB= zero tillage drill after burning of rice straw; CT= Conventional tillage

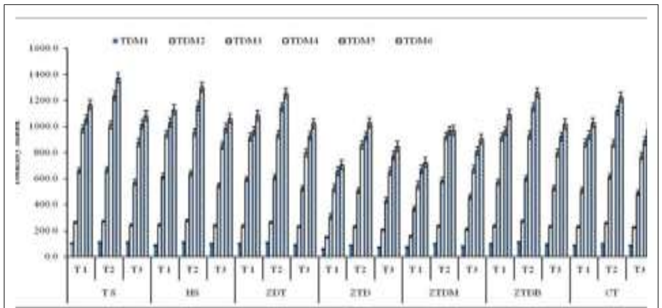

Fig:4.3. Total dry matter of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2012-13.
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw; ZTDB= zero tillage drill after burning of rice straw; CT= Conventional tillage

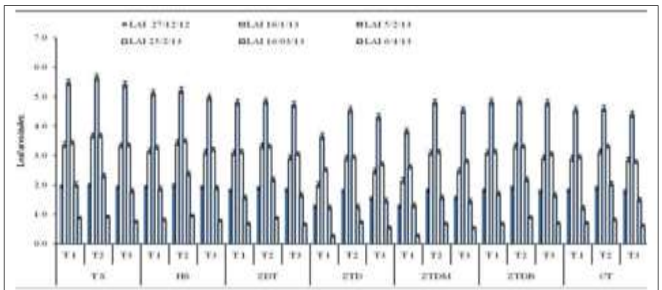

Fig: 4.2. Leaf area index of wheat as affected by sowing techniques and time of N application in rice-wheat system during 2013-14.
T1= all nitrogen as a basal dose T2= 0.5 nitrogen as basal +0.5 nitrogen at first irrigation T3=0.5 nitrogen at first irrigation +0.5 nitrogen at second irrigation TS=turbo seeder, HS= happy seeder, ZDT= zone disc tiller, ZTD= zero tillage drill, ZTDM= zero tillage drill after manual removal of rice straw, ZTDB= zero tillage drill after burning of rice straw, CT= Conventional tillage

***Yield parameters*:** The data regarding plant height, productive tillers, spike length, grain per spike, thousand grain weight, biological yield, grain yield and harvest index are presented in Table 2. Data depicted that different sowing techniques, timing of N application and their interaction have significant effect on these parameters during both the years. During the first year, among various sowing techniques, maximum plant height (100.89 cm) was noted in conventional method of sowing which was statistically similar to sowing with happy seeder (HS) and zero tillage (ZT) drills after rice residues burning during first year of experimentation. Turbo seeded treatment gave 265.33 fertile tillers per m^2 that was 5%, 7%, 12%, 11%, 6% and 4 % higher than happy seeder, zone disc tiller drill, zero tillage drill, conventional zero tillage drill after rice straw manual removal, conventional zero tillage drill after rice straw burning and conventional wheat sowing, respectively. Turbo seeder treatment produced prominently the lengthy spikes (13.72 cm) which was statistically comparable with happy seeder, zero tillage drill, wheat cultivation by using traditional method of sowing and wheat cultivation after burning and manual removal of crop stubbles by using zero tillage drill. Conventional sowing method produced more grain weight per spike which resembled statistically with that recorded in plots sown with turbo seeder, happy seeder, wheat crop sowing after manual rice crop residues removal of by using zero tillage drill, cultivation of wheat after burning of rice crop straw by using zero tillage drill. However, least grain weight per spike was noted when cultivation of wheat was done by using zero tillage drill. The highest total biomass was produced by turbo seeder drill (14.26 Mg ha^{-1}) which was 11%, 18%, 23%, 19%, 11% and 2% higher than zone disc tiller and happy seeder, zero tillage drill, zero tillage drill after straw removal manually, zero tillage drill after rice crop residues burning and traditional sowing method. Maximum seed grain yield (5.1 Mg ha^{-1}) was achieved in turbo seeder wheat cultivation treatment which was 5.69%, 14.95%, 12.18%, 9.33%, 5.1% and 1.99% greater than happy seeder, zone disc tiller, zero tillage drill, zero tillage drill after elimination of rice straw manually, zero tillage drill after burning of rice crop residues and traditional cultivation method, respectively. The highest harvest index (36.56%) was achieved in turbo seeder treatment, that was similar to zone disc tiller, happy seeder, zero tillage drill, zero tillage drill after elimination of rice straw manually, zero tillage drill after rice crop residues burning and conventional method, respectively. While in case of nitrogen application timings, statistically maximum plant height (99.92 cm), productive tillers (254.48 m^{-2}), spike length (13.50 cm), grain per spike (41.89), thousand grain weight (41.90 g), grain yield (4.85 Mg ha^{-1}), harvest index (39.01%) of wheat was recorded when half N was added as basal application and half N was applied at first irrigation followed by treatment when half N fertilizer dose with first irrigation and half N was added with second irrigation. Similar trend was observed for nitrogen application timings during second year of study.

Table 1. Influence of different sowing methods and nitrogen application timings on growth related traits of wheat

Treatments	2012-13				2013-14			
	N_0	N_1	N_2	Mean	N_0	N_1	N_2	Mean
				Net assimilation rate (NAR)				
TS	4.60bc	5.17a	4.47bc-e	4.74 A	4.06ij	5.61b-d	4.82e-h	4.83 B
HS	4.73b	5.20a	4.57bc	4.83 A	4.15h-j	5.70bc	4.92d-g	4.92 B
ZDT	4.60bc	5.17a	4.63bc	4.80 A	4.25g-j	5.81B	6.65A	5.57 A
ZTD	4.10f	4.53b-d	4.20d-f	4.28 B	3.25kl	5.30b-e	4.80e-i	4.45 C
ZTDM	4.17ef	4.47b-e	4.30c-f	4.31 B	3.15k	5.43bc-e	3.87jk	4.15 C
ZTDB	4.70b	5.20a	4.60bc	4.83 A	4.24g-j	5.80b	5.07c-f	5.04 B
Conv.	4.50b-e	5.10a	4.63bc	4.74 A	4.24g-j	5.98ab	4.45f-j	4.89 B
Mean (NS)	4.49 B	4.98 A	4.49 B		3.91 C	5.66 A	4.94 B	
LSD ($p \leq 0.05$)	*Sowing methods=0.096, Nitrogen timings0.067, Interaction=0.17*				*Sowing methods=0.24, Nitrogen timings=0.128, Interaction=0.36*			

Interaction and main effects sharing the same case letter, for a parameter during an experimental year, do not differ significantly ($p \leq 0.05$) by the least significant difference test; Likewise, the figures of main effects and interaction without lettering, do not differ significantly ($p \leq 0.05$) by the least significant difference test; N_0= All nitrogen as a basal dose, N_1= 1/2 nitrogen as basal +1/2 nitrogen at first irrigation, N_2= 1/2 nitrogen at first irrigation +1/2 nitrogen at second irrigation, TS=Turbo seeder, HS= Happy seeder, ZDT=Zone disc tiller, ZTD= Zero tillage drill, ZTDM= Zero tillage drill after manual removal of rice straw, ZTDB= Zero tillage drill after burning of rice straw, CONV= Conventional sowing

Table 2. Influence of different sowing methods and nitrogen application timings on yield related traits of wheat

Treatments	2012-13				2013-14			Mean
	N_0	N_1	N_2	Mean	N_0	N_1	N_2	
				Plant height (cm)				
TS	88.06hi	104.66a	102.29a-c	98.34B	90.06gh	106.84a	105.60ab	100.84AB
HS	91.67g	105.23a	99.88c-e	98.93AB	90.20gh	100.73a-e	98.21c-f	96.38B
ZDT	86.46ij	99.87c-e	86.93h-j	91.09D	89.80gh	100.87a-e	96.27c-g	95.64C
ZTD	79.65k	84.54hi	79.84k	81.35E	86.65h	95.94d-g	89.84gh	90.81D
ZTDM	89.81gh	98.71d-f	95.73f	94.75C	90.81gh	95.71e-g	91.08f-h	92.53D
ZTDB	96.64f	102.89a-c	97.64ef	99.06AB	96.61c-g	103.41a-c	99.38b-e	99.80B
Conv.	97.94ef	103.54ab	101.18b-d	100.89A	100.04a-e	103.41a-c	102.97a-d	102.14A
Mean (NS)	90.04C	99.92A	94.79B		92.02C	100.99A	97.62B	
LSD ($p \leq 0.05$)	Sowing methods=1.99, Nitrogen timings=1.16, Interaction=3.20				*Sowing methods=2.25, Nitrogen timings=1.36, Interaction=3.70*			
				Number of productive tillers (m^{-2})				
TS	261.00a-c	268.67a	266.33ab	265.33A	258.33c-f	273.33ab	266.33b-d	266.00A
HS	247.00d-h	255.67c-e	248.33d-f	250.33BC	250.33e-i	266.33b-d	243.67g-j	253.44B
ZDT	245.33f-h	248.00d-g	242.00f-i	245.11C	235.33jk	252.00e-h	244.00g-j	243.78D
ZTD	229.67jk	237.00h-j	234.00i-k	233.56D	215.00l	241.33h-k	239.00i-k	231.78E
ZTDM	226.00k	246.00e-h	238.00g-j	236.67D	230.67k	249.33e-i	248.33e-i	242.78D
ZTDB	238.33f-j	256.67b-d	246.00e-h	247.00C	238.33i-k	259.67c-e	247.33f-j	248.44C
Conv.	233.67i-k	269.33a	261.67a-c	254.89B	254.00d-g	279.67a	270.67a-c	268.11A
Mean (NS)	240.14 C	254.48 A	248.05 B		240.29 C	260.24 A	251.33 B	
LSD ($p \leq 0.05$)	Sowing methods = 6.68, Nitrogen timings=3.61, Interaction=10.27				*Sowing methods=4.11, Nitrogen timings=2.24, Interaction=6.35*			
				Spike length (cm)				
TS	13.10	14.63	13.44	13.72A	15.33a-c	16.03ab	14.27a-d	15.21A
HS	11.69	14.10	12.38	12.72ABC	13.42a-d	16.50a	13.78a-d	14.57AB
ZDT	11.47	13.62	11.34	12.14BC	13.20a-d	14.69a-d	12.74bcd	13.54B
ZTD	11.30	12.24	11.10	11.55C	12.46cd	12.97a-d	11.36d	12.26C
ZTDM	12.32	12.74	12.48	12.52ABC	13.82a-d	13.97a-d	13.72a-cd	13.84B
ZTDB	12.54	13.34	13.09	12.99AB	13.27a-d	13.93a-d	13.34a-d	13.51B
Conv.	13.27	13.84	13.37	13.49A	14.76a-d	14.88a-d	13.88a-d	14.51AB
Mean (NS)	12.24B	13.50A	12.46B		13.75B	14.71A	13.30B	
LSD ($p \leq 0.05$)	*Sowing methods=1.34, Nitrogen timings=0.57, Interaction=NS*				*Sowing methods=1.18, Nitrogen timings=0.625, Interaction=1.79*			

Treatments	2012-13				2013-14			
	N_0	N_1	N_2	Mean	N_0	N_1	N_2	Mean
				Grains per spike				
TS	40.99	43.72	42.72	42.48AB	41.66	45.06	43.39	43.37A
HS	39.16	42.32	41.22	40.90BC	38.83	45.83	42.56	42.41A
ZDT	37.72	41.36	40.48	39.85CD	39.39	41.37	39.81	40.19B
ZTD	38.06	39.27	38.89	38.74D	38.73	39.94	39.56	39.41B
ZTDM	40.49	41.27	41.09	40.95BC	40.16	40.94	40.26	40.45B
ZTDB	41.20	42.14	42.67	42.00AB	41.54	42.81	42.67	42.34A
Conv.	42.46	43.14	42.54	42.71A	41.47	43.81	42.54	42.60A
Mean (NS)	40.01B	41.89A	41.37A		40.25C	42.82A	41.54B	
LSD ($p \leq 0.05$)	*Sowing methods=1.74, Nitrogen timings=0.53, Interaction=NS*				*Sowing methods=1.31, Nitrogen timings=0.60, Interaction=NS*			
				1000-grain weight (g)				
TS	40.71	43.54	41.38	41.88AB	41.21	42.24	42.05	41.83A
HS	40.26	41.68	41.29	41.08ABC	40.63	42.38	39.99	41.00AB
ZDT	39.71	41.20	40.25	40.39C	38.41	40.50	39.95	39.62AB
ZTD	40.43	40.67	40.40	40.50C	38.25	38.73	39.23	38.74B
ZTDM	40.23	41.65	40.89	40.93BC	40.27	41.35	41.26	40.96AB
ZTDB	40.68	41.92	40.98	41.19ABC	40.48	41.95	40.88	41.11AB
Conv.	42.14	42.68	41.38	42.07A	41.68	42.78	42.98	42.48A
Mean (NS)	40.60B	41.90A	40.94B		40.13B	41.42A	40.91AB	
LSD ($p \leq 0.05$)	*Sowing methods=1.02, Nitrogen timings=0.54, Interaction=NS*				*Sowing methods=2.89, Nitrogen timings=0.899, Interaction=NS*			
				Biological yield (Mg ha^{-1})				
TS	14.47	13.52	14.77	14.26A	12.74bc	14.58a	14.68a	14.00A
HS	13.02	12.41	12.90	12.78C	11.41ef	13.11b	13.07b	12.53B
ZDT	12.96	12.00	12.19	12.38D	10.55g	12.36cd	11.59e	11.50C
ZTD	11.51	10.88	11.11	11.17F	9.81h	10.90fg	11.42e	10.71D
ZTDM	11.98	11.52	11.63	11.71E	10.51g	11.74de	11.85de	11.37C
ZTDB	13.40	13.20	12.54	13.05C	11.31ef	12.89bc	13.18b	12.46B
Conv.	13.96	13.28	14.19	13.81B	12.76bc	14.13a	14.46a	13.78A
Mean (NS)	13.04A	12.40C	12.76B		11.30B	12.82A	12.89A	
LSD ($p \leq 0.05$)	*Sowing methods=0.35, Nitrogen timings=0.16, Interaction=0.50*				*Sowing methods=0.545, Nitrogen timings=0.171, Interaction=0.659*			
				Grain yield (Mg ha^{-1})				
TS	4.79	5.55	5.25	5.20A	4.99cd	5.86a	5.82a	5.56A
HS	4.33	4.89	4.66	4.63C	4.44f-h	5.69ab	4.67d-g	4.93B
ZDT	4.10	4.54	4.28	4.31D	4.01i	4.56e-g	4.37gh	4.33CD
ZTD	3.84	4.11	3.99	3.98E	3.58j	4.30g-i	4.28g-i	4.05D
ZTDM	4.00	4.52	4.27	4.27D	4.07hi	4.79df	4.65d-g	4.50C
ZTDB	4.41	4.92	4.74	4.69C	4.52fg	5.33bc	4.87de	4.90B
Conv.	4.54	5.38	5.08	5.00B	4.95c-e	5.53ab	5.51ab	5.33A
Mean (NS)	4.29C	4.85A	4.61B		4.37C	5.15A	4.89B	
LSD ($p \leq 0.05$)	*Sowing methods=0.17, Nitrogen timings=0.092,Interaction=NS*				*Sowing methods=0.326, Nitrogen timings=0.106, Interaction=0.399*			
				Harvest index (%)				
TS	37.10	41.05	35.54	36.56A	39.24	40.21	39.62	39.69A
HS	36.52	39.40	36.12	36.26A	38.99	43.42	35.75	39.39A
ZDT	31.62	37.81	35.12	34.85B	38.03	36.88	37.69	37.54B
ZTD	33.34	37.74	35.91	35.66AB	36.63	39.50	37.49	37.87B
ZTDM	33.37	39.25	36.75	36.46A	38.75	40.84	39.23	39.61A
ZTDB	32.88	37.32	37.76	35.99AB	39.93	41.31	36.92	39.38A
Conv.	32.50	40.50	35.75	36.25A	38.78	39.17	38.13	38.69AB
Mean (NS)	32.86A	39.01A	36.14A		38.62B	40.19A	37.83C	
LSD ($p \leq 0.05$)	*Sowing methods=0.35, Nitrogen timings=1.26, Interaction=NS*				*Sowing methods=1.47, Nitrogen timings=0.6, Interaction=NS*			

Table 3. Influence of different sowing methods and nitrogen application timings on quality related traits of wheat

Treatments	2012-13				2013-14			
	N_0	N_1	N_2	Mean	N_0	N_1	N_2	Mean
				Total Protein contents (%)				
TS	12.29d	13.55a	13.01b	12.95A	12.29d	13.54a	13.02b	12.95A
HS	12.23de	13.50a	12.94c	12.89B	12.23de	13.51a	12.96bc	12.90B
ZDT	12.22e	13.49a	12.93c	12.88B	12.22e	13.50a	12.95c	12.89B
ZTD	8.40g	12.26de	11.56f	10.74C	8.42g	12.26de	11.58f	10.75C
ZTDM	8.37g	12.22e	11.55f	10.71C	8.38g	12.22e	11.56f	10.72C
ZTDB	12.22e	13.49	12.93c	12.88B	12.22e	13.50a	12.95c	12.89B
Conv.	12.26de	13.52a	12.96bc	12.91B	12.26de	13.53a	12.98c	12.92B
Mean (NS)	11.14C	13.15A	12.55B		11.15C	13.15A	12.57B	
LSD ($p \leq 0.05$)	*Sowing methods=0.0125, Nitrogen timings=0.0120,, Interaction=0.0337*				*Sowing methods=0.0210, Nitrogen timings=0.0210, Interaction=0.0334*			
				Total Fat (%)				
TS	0.83a-c	0.86a	0.85ab	0.85A	0.84	0.86	0.86	0.85A
HS	0.82a-c	0.85ab	0.84ab	0.84A	0.83	0.86	0.85	0.85A
ZDT	0.82a-c	0.84ab	0.83a-c	0.83A	0.82	0.85	0.85	0.84A
ZTD	0.78c	0.82a-c	0.80bc	0.80B	0.78	0.83	0.81	0.81B
ZTDM	0.78c	0.82a-c	0.80bc	0.80B	0.78	0.82	0.80	0.80B
ZTDB	0.82a-c	0.84ab	0.83a-c	0.83A	0.82	0.85	0.85	0.84A
Conv.	0.82abc	0.85ab	0.84ab	0.84A	0.83	0.86	0.85	0.85A
Mean (NS)	0.81C	0.84A	0.83B		0.81B	0.85A	0.84A	
LSD ($p \leq 0.05$)	*Sowing methods=0.0124, Nitrogen timings=0.0105, Interaction=0.0259*				Sowing methods=0.0119, Nitrogen timings = 0.0099, Interaction=NS			
				Total Fiber (%)				
TS	0.13a-c	0.14ab	0.14a-c	0.14A	0.16a	0.15a	0.14ab	0.15A
HS	0.12a-c	0.13a-c	0.13a-c	0.13AB	0.13ab	0.14ab	0.13ab	0.13AB
ZDT	0.11c	0.12a-c	0.12bc	0.12B	0.13ab	0.14ab	0.13ab	0.13AB
ZTD	0.13a-c	0.14a	0.13a-c	0.13A	0.12ab	0.14ab	0.13ab	0.13AB
ZTDM	0.12bc	0.13a-c	0.12a-c	0.12AB	0.11b	0.13ab	0.12ab	0.12B
ZTDB	0.12bc	0.12a-c	0.12a-c	0.12AB	0.12ab	0.14ab	0.13ab	0.13AB
Conv.	0.12bc	0.13a-c	0.12a-c	0.12AB	0.13ab	0.14a	0.14ab	0.14A
Mean (NS)	0.1200B	0.1300A	0.1238AB		0.1286B	0.1398A	0.1321AB	
LSD ($p \leq 0.05$)	*Sowing methods=0.0140, Nitrogen timings=8.296E-03, Interaction=0.0228*				*Sowing methods=0.0150, Nitrogen timings = 0.0122, Interaction=0.0303*			

The interactive effect of sowing methods and nitrogen application timings showed that maximum height of plant (105.23 cm) was recorded in happy seeder treatment where half N fertilizer was added as basal dose and half N was applied with first irrigation and turbo seeder treatment gave maximum productive tillers (268.67m^{-2}) when half N fertilizer was added as basal dose and half N was applied with first irrigation.

During second year of study, conventional sowing treatment produced maximum plant height (102.14 cm), productive tillers (268.11 m^{-2}) and thousand grain weight (42.48 g). While the highest spike length (15.21 cm), grain per spike (43.37), biological yield (14.00 Mg ha^{-1}), grain yield (5.56 Mg ha^{-1}) and harvest index (39.69%) was recorded in turbo seeder treatment.

Maximum height of wheat plant (106.84 cm), its biological yield (14.58 Mg ha^{-1}) and grain yield (5.86 Mg ha^{-1}) were recorded in turbo seeder treatment when half N fertilizer was added as basal dose and half N was applied with first irrigation. Conventional sowing method treatment gave the highest productive tillers (279.67 m^{-2}) where half N fertilizer was added as basal dose and half N was applied with first irrigation.

***Grain quality*:** Data regarding protein, fat and fiber contents are presented in Table 3. The highest grain protein contents (12.95%), fat contents (0.85%) and fiber contents (0.14%) were observed in TS treatment. While in case of nitrogen application timings, statistically maximum protein (13.15%), fat (0.84%) and fiber contents (0.13%) were recorded when 1/2 N was added as basal application and 1/2 N was applied with first irrigation followed by treatment when 0.5 N fertilizer dose with first irrigation and 0.5 N was added at second irrigation. Similar trend was observed in nitrogen application timings during second year of study.

The interactive effect of various sowing methods and nitrogen application timings showed that maximum protein contents (13.55%) and fat contents (0.86%) was recorded in turbo seeder treatment when half N fertilizer was added as basal dose and 0.5 N was applied with first irrigation. During second year of study, conventional sowing treatment produced maximum fat (0.85%) and protein (12.95%), was recorded in turbo seeder treatment.

Maximum protein (13.54%) and fiber (0.15%) contents were recorded in turbo seeder treatment when 0.5 N fertilizer was added as basal dose and 0.5 N was applied at first irrigation.

DISCUSSION

The possible reasons for the highest LAI could be the healthy rooting area and deeper rooting structure that privileged moisture and mineral nutrition utilization effectiveness which eventually had impact on plant growth and development. Obtained consequences are quite same as the outcome of Kosmas *et al.* (2001), Su-Juan *et al.* (2008) and Lopez-Fando and Pardo (2009) who found that turbo seeded wheat had utmost LAI than traditional method of wheat sowing. Privileged TDM in turbo seeded wheat planted treatment was produced owing to more LAI, plant height and vigorous root length than traditional method of wheat sowing. These findings could be correlated with the outcomes of Li *et al.* (2008) and Kosmas *et al*. (2001) who concluded that more LAI in turbo seeded wheat privileged more TDM because of more assimilates addition. Su-Juan et al. (2008) and Lopez-Fando and Pardo (2009) noted that HS crop gave higher TDM when compared with traditional cultivation method owing to more nutrient and moisture accessibility to crop. Higher LAD was measured when 50% N fertilizer dose was added at sowing time and 50% nitrogen was added with 1st irrigation remained. These conclusions are in accordance with the findings of Yan-min *et al.* (2006) who found that LAD was more in the turbo seeder sown plots owing to water and nutrient accessibility that affirmative the crop for better growth. It is noticeable that during each experimental year, there was considerable distinction in LAD in different sowing methods but also between the N fertilizer application timings. Our consequences regarding CGR are contradictory to the results of Gangwar *et al*. (2004) and Salvagiotti and Miralles, (2008) who observed more crop growth rate in conventional method of wheat sowing than other zero tillage sowing techniques.

The maximum plant height in turbo seeded sown wheat crop and conventional method was accredited to more provision of moisture at seeding zone and seed sowing at appropriate depth. These outcomes are in similarity to the conclusions of Dixit *et al.* (2002) who noted that extra height of the plant in no-till cultivated wheat was owing to accumulation of rice straw at top soil surface which enhanced water accessibility to root region and better nutrient position in no tillage at top surface of soil. Wheat with dwarf height of plant in zero tillage fields after rice harvesting with combine harvester was accredited to less presence of water at seeding area owing to existence of profound rice stubbles at top soil surface. More plant height was observed when half nitrogen fertilizer dose was added at sowing and 1/2 N fertilizer was added with first watering. These results substantiated the earlier revealing of Rasheed *et al*. (2004) and Mohsan (1999) who described enhancing nitrogen impact on plant height. In interaction case, utmost height of plant with turbo seeded wheat and N application timing (half N for basal application and half N after first irrigation was linked with good crop stand due to basal nitrogen dose in rice residues for decomposition and higher nitrogen use efficiency.

The utmost fertile tillers number in conventional tillage and turbo seeder treatment was linked with better sprouting of seed and improved root growth owing to more pore spaces that privileged nutrients uptake. More root-zone area improved the nutrients absorption that resulted in healthy root expansion and growth of wheat crop. According to Kumar *et al*. (2014), turbo seeded wheat treatment produced more tillers of wheat crop than other sowing techniques. Higher 1000-grain weight in conventional sowing method was owed to higher pore spaces of soil and feasible environment for crop growth which ultimately improved the root growth. For direct drilling of wheat, there is a requirement of suitable ratio of loose rice crop residues to anchor rice remaining on the soil surface. To fulfill this requirement, no tilling was done in standing rice stubbles (Dixit *et al*. 2002). These outcomes are conflicting to the conclusion of Hemmat and Eskandari (2006) who elucidated that various sowing techniques had no effect on TGW. More spike length in crop sown by using happy seeder was possibly due to improved moisture and nutrient availability in the root zone. These findings can be correlated with Lopez-Fando and Pardo (2009) who observed similar results when they sow crop by using zero tillage. According to Mrabet (2002), zero tillage gave similar and better outcome than other tillage operations. Hemmat and Eskandari (2006) and Gangwar *et al*. (2006) also noted the crop having more spike length sown with zero tillage as compared to traditional method of sowing. Utmost length of spike was noted under crop sown by using turbo seeder drill. The reason for best results could be suitable seed depth and placement and, dense root system owing to less compactness of soil (Dixit *et al*. 2002). When maximum quantity of rice straw is available in field after rice crop harvesting then the performance of seed drill would be outclassing with increased yield. Less spike length in treatment where wheat crop was sown with zero tillage drill and N fertilizer application was done in two splits with first and second irrigations was due to presence of unfastened residues at field surface in more quantity which induce hindrance with sowing process. The seed was distributed irregularly in field during sowing process because aggregation of soil and loose rice crop residues layer was disturbed (Green and Poisson, 1999).

The reason for extra total biomass in turbo seeder wheat sown was healthy and suitable soil environment, subsidiary soil compaction and deeper roots. The results can be correlated with conclusion of Rashidi and Keshavarzpour (2007) who noted that healthy and suitable soil conditions and deeper roots have positive impact on biological yield of wheat. Crop which was cultivated by using zero tillage method produced more biological yield leading to higher grain yield and these findings can be co-related with Sip *et al*. (2009) who found that crop cultivating with zero tillage produced more biological yield leading to utmost grain yield as compare to sown by using traditional method. In case of nitrogen application timings, more total biomass with nitrogen fertilization 0.5 N at sowing time and 0.5 N at 1st irrigation was linked with extra productive tillers per unit of land and utmost thousand grain weight. These results supported the conclusions of Mohsan (1999) and Khan *et al*. (2000) who noted that N fertilizer addition to soil amplified total biomass yield of crop. This increment of total biomass in all different sowing methods at 0.5 N fertilizer dose application at first irrigation and 0.5 N fertilizer application at second irrigation was due to less loss of nitrogen through volatilization, hence more yield was obtained due to higher N use efficiency. More yield was obtained in turbo seeder zero tillage treatment of wheat cultivation. The reason behind augmented yield was more moisture and nutrient availability for plants near soil surface. These findings can be identical with the consequences obtained by Younis *et al.* (2006), Moussa-Machraoui *et al.* (2010), Rashidi and Keshavarzpour (2007), Kumar *et al*. (2014), Jin *et al.* (2007), Fuentes *et al.* (2009) and Lopez-Fando and Paedo (2009) who concluded that to attain good grain yield, no-till sowing with conservation of crop residues is practicable technology. Reason of more grain yield with N fertilizer application with urea fertilizer 0.5 N at sowing and 0.5 N with first irrigation can be the increased productive plants and more thousand grains mass.

Seed protein contents were highest in turbo seeder treatment which was ascribed to deeper root and better nutrient utilization resulting in augmented grain protein contents in turbo sowing wheat sowing. Our consequences could be similar with conclusion of Coventry *et al*. (2011) who demonstrated that protein contents were higher in no-till treatment. While second experimentation year, more seed protein contents was achieved with application of nitrogen 0.5 N dose at sowing time and 0.5 N at first irrigation probably due to deeper roots and better nutrient utilization. These conclusions are similar to the consequences of Hussain *et al*. (2006) and Sameen *et al*. (2002) who concluded that N fertilization had significant impact on seed protein contents.

During both year trials, turbo seeder zero tillage drill treatment produced maximum fat contents. These results can be similar to the findings of Hiltbrunner and Liegdens (2008) who concluded that application of N contents had impact on seed quality due to positive and feasible environment and soil conditions. These results can be identical to those of Lestingi *et al*. (2010) who observed that sowing methods had non-prominent effect on seed fat contents.

Conclusion: Turbo seeder treatment gave highest grain yield during both year of experimentation. Among nitrogen application timings, highest grain yield (4.8 Mg ha^{-1}) was produced when 0.5 N fertilizer was applied at sowing time and 0.5 N dose applied at the time of first Irrigation. Interactive effect of different sowing techniques and N application timings showed that maximum grain yield 5.55Mg ha^{-1} was achieved with turbo seeder when 0.5 N was applied at sowing time and 0.5 N was applied at 1st irrigation. During both year of experimentation, LAI and CGR at seventy-five DAS, TDM and LAD at 120 DAS was maximum in turbo seeded wheat when nitrogen fertilizer was added 0.5 N dose at sowing time and 0.5 N dose at the time of 1st irrigation. Net assimilation rate was higher in turbo seeded wheat treatment when 0.5 N fertilizer was applied at sowing time and 0.5 N at the time of first irrigation. Maximum benefit cost ratio (1.80 and 1.79) were achieved with turbo seeder when 0.5 nitrogen dose was added at the time of sowing and 0.5 nitrogen at the time of first irrigation during both years of field trails. Maximum net returns (Rs. 83905 and Rs.82238), per hectare were achieved with turbo seeder when 0.5 nitrogen fertilizer was applied at sowing time and 0.5 nitrogen at first irrigation during both years of field trails.

On the basis of economic analysis it is recommended that the wheat growers of rice- wheat cropping system of Punjab (Pakistan) should grow wheat with turbo seeder fertilized with nitrogen 0.5 at time of sowing and 0.5 at the time of first irrigation to get higher benefits.

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