Ann. Agric. Res. New Series Vol. 43 (2) : 119-126 (2022)

Crop establishment and nitrogen management effects on growth, physiology and productivity of wheat under rice-wheat system

[1]Sudarshan S, [2]Kapila Shekhawat*, [3]S S Rathore, [4]Rajiv K Singh, [5]Anchal Dass and [6]Mona Nagargade

Division of Agronomy
ICAR- Indian Agricultural Research Institute, Pusa, New Delhi-110012
**Corresponding author e-mail: drrathorekapila@gmail.com*

Received: February 2022; Revised Accepted: May 2022

Abstract

A field experiment was conducted during the winter season of 2020 – 21 at the ICAR–Indian Agricultural Research Institute, New Delhi to evaluate different nitrogen (N) management protocols under various crop establishment methods in wheat. The experiment was conducted in split-plot design with three replications. The treatment consisted of four crop establishment, methods viz. conventional wheat (CT-wheat), zero-tilled wheat (ZT-wheat) + rice residue @ 3t/ha, ZT-wheat without residue and stale-seed bed wheat (SSB-CT-wheat) in the main plot and 4 N management protocols viz., control (No-N), recommended N schedule (RDN), modified N schedule and leaf colour chart (LCC)-guided N scheduling in sub-plot. The growth parameters, like dry matter and indices like CGR, RGR and LAI were observed highest at 90 DAS and decreased thereafter. They remained highest in ZT+R and LCC-guided N application treatments. Various root parameters like, root length, root volume and root surface area were recorded maximum in ZT+R, followed by ZT, SSB-CT and lowest in CT. A 14.2 % increase in grain yield was recorded under ZT+R compared to CT. Also, about 15.4% increase in grain yield was recorded under LCC-guided N application-based N management compared to RDN. Also, under different establishment methods, a saving of 33.3% N under LCC-guided N application was recorded in ZT, SSB-CT and CT.

Key words: Conventional tillage, leaf colour chart, precision nitrogen management,zero tillage

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world. In India, wheat covers approximately 29.6 M ha area and produces 99.7 Mt production per year, with an average productivity of 3.37 t/ha (Anonymous, 2018). Wheat is predominantly grown in India's North-Western plains, including the states of Haryana, Punjab, Delhi, Rajasthan, and Uttar Pradesh, which account for nearly 37% of the country's land area and 45% of total food grain production. The rice–wheat cropping system is critical for global food security because these two main cereals are grown in India on an area of about 43 and 26 M ha, respectively. To meet the rising food demand, the productivity of rice-wheat cropping system must be enhanced on a sustainable manner. However, due to less turn-around period for wheat sowing, wheat sowing is often delayed in rice-wheat systems. Hence, conservation agriculture (CA) based rice-wheat systems are gaining popularity among the farmers, especially the farmers of North-western plains of IGP (Bhatia et al., 2011). Increased productivity and resource conservation can be achieved

[1]Ph.D Scholar, [*]Senior Scientist, [3,4&5]Principal Scientist, [6]Scientist ICAR- Indian Agricultural Research Institute, Pusa, New Delhi-110 012

through the development or implementation of new crop establishment methods, as well as changes in management practises such as nitrogen (N) management.Wheat is a heavy nutrient feeder crop. The crop's immediate and high response to applied nutrients, especially N, has led to increased use of chemical fertilisers, which has resulted in an imbalanced use of nutrients, as indicated by a wider NPK ratio of 8.3:2.7:1. Thus, for sustainable resource management in the world's most intensive cereal systems, an efficient and effective method of nutrient application is needed.

By addressing the problems of late sowing, increased cultivation costs, and weed infestation, zero tillage (ZT) as a resource management technology has a great potential for sustaining wheat production and increasing returns. It can save water, reduce production costs, and increase productivity of wheat after rice (Jat *et al.*, 2014). N management in high-residue no-till farming systems and its impact is a researchable issue. The surface-applied residue decomposes slowly and does not provide N to wheat; instead, it may immobilise soil N. However, the negative effects of N immobilisation can be mitigated by allowing enough time for rice straw to decompose before planting wheat (Dhar *et al.*, 2014). But, the window for sowing wheat is very small. All of these challenges in N fertiliser management in no-tillage (NT) systems point to the need for further studies on how to use N fertiliser more effectively. For optimum nitrogen supply to wheat receiving residues, adjustments in fertiliser N timing and rate are likely to be needed.

The application of N fertiliser at the time of sowing may not always be the most effective way to ensure a consistent grain yield and quality in wheat. The precise timing of N application to wheat at various stages of its growth and development has a significant impact on yield and grain quality. During cycles of rapid growth and decline toward maturity, there is a greater demand for N.N losses from the soil-plant system are high when N fertiliser application is not synchronised with crop demand, resulting in low N fertiliser use efficiency. As a result, plant-based N application is critical for high yield and N usage efficiency (Duttagarnavi *et al.,* 2014).

The most effective fertiliser N management strategy for increasing nitrogen use efficiency (NUE) is to feed crop N according to crop needs. Real-time monitoring of N status through LCC in wheat has the benefit of allowing the plant to incorporate N supply over time and thus reflect N supply as it is influenced by temperature, soil processing, and fertilisation. A leaf-color chart (LCC) is a non-destructive and low-cost alternative to a chlorophyll metre that can quickly and accurately determine a crop's N status based on leaf colour. It can also be used for need-based N management in rice and wheat. The LCC assists in determining the in-situ crop N requirement by indirectly estimating crop N status in the field while accounting for variations in soil N supply and defining the time of N application when it is needed (Gupta *et al.,* 2011).

LCC is used to predict leaf N concentration in wheat, and the threshold LCC value can assist need-based fertiliser N applications. It enables farmers to better match N application to crop demand or to boost the current fixed N recommendation for increased N efficiency(Singh *et al.,* 2013). Despite all benefits of LCC-guided N management in wheat, its wide-scalead option especially under ZT and other crop establishment methods remains a challenge for farmers. Hence, a systematic study on standardizing N management options for different crop establishment methods in wheat under rice-wheat cropping system was planned.

Materials and Methods

The IARI research farm New Delhi, India is located at 28°38′23"N, 77°09′27"E, and 228.6 metres above mean sea level. The experimental site is located in the western Indo-Gangetic Plains (IGP), which receives an average annual rainfall of 714 mm, with 75 percent of that falling during the monsoon season (July to September) and the rest falling during other seasons (October to June).Delhi has a semi-arid, sub-tropical climate with hot, dry summers and cold winters.

Total rainfall received during the study period was 73.6 mm (Fig. 1). The maximum rainfall was received during the 1st week of 2021. Total evaporation during crop growth period was(449.2

mm) between 7.7 to 47.8 mm/day, sunshine hrs/day ranged between 0.6 hrs to 9.5 hrs/day during the study and the mean was 5.8hrs/day. The maximum temperature during crop growth period was ranged between 16.7 ºC to 38ºC being maximum in the 15thweek of 2021 and lowest during 2ndweek of 2021 and the minimum temperature during crop growth period was ranged between 3.3 ºC to 18.4ºC being minimum in the 15thweek of 2021 and lowest during 51ndweek of 2020 (Fig. 1). Mean average wind speed during the cropping period is 3.4 kmph. The average relative humidity during morning is 84.5% and in the evening is 43.2%.The daily weather data described in this chapter has been taken from of the meteorological observatory located in the IARI, Pusa Campus, New Delhi and depicted in Fig.1.

The soil pH varied between 7.5 to 8. Soil organic carbon, available N, P_2O_5 and K_2O was 0.39%, 203.2, 24.4 and 342.2 kg/ha, respectively. The wheat variety HD 2967 which is a double dwarf variety which takes 157 days for maturity and produces 2.4 t/ha.The field experiment was designed in a split-plot design, with 4 different establishment methods, viz. CT-wheat, ZT-wheat,ZT-wheat+ rice residue @ 3t/ha and stale seed bed-CT wheat in the main plots and 3 different nitrogen management options, i.e. control (No N), recommended N schedule(N as schedule as 33% basal, 33% at 20-25 DAS and 33% at 45-50 DAS), modified N schedule (No basal N, 3 split N application at 20-25 DAS, 40-45 DAS and 60-65 DAS) and LCC guided N application (adjustable time N application using LCC matching with irrigation schedule)in the sub-plotswith 3 replications. Full p and K were applied as basal.

For estimating dry matter accumulation, the samples are collected from the second row from the border of each side of the plot. Plants were cut to the floor, oven dried at 60-65°C until they obtained consistent weight. The dry weight was measured in g/plant.The leaf area per plant measured by using leaf area meter was divided by the respective ground area and recorded at 30, 60 and 90 DAS. LAI was calculated using following formula

$$\text{LAI} = \frac{\text{Total leaf area plant}^{-1}(\text{cm}^2)}{\text{Land area plant}^{-1}(\text{cm}^2)}$$

The crop growth ratio measures the growth of the crop per unit area on a daily basis. It measured at 30 days interval and expressed as g/day/m^2. It is given by the formula

$$\text{CGR} = \frac{W_2 - W_1 \qquad 1}{T_2 - T_1 P}$$

P = Ground area in cm^2

W_2 and W_1 are the dry weight of the plant at time T_2 and T_1

The dry weight recorded at 30, 60, 90 and harvest stages are used to calculate RGR as below. It determines the growth rate of the crop on compound interest basis and expressed as g/g/day

$$\text{RGR} = \frac{\text{Ln}W_2 - \text{Ln}W_1}{T_2 - T_1}$$

Ln is the natural logarithm

W_1 and W_2 are the weight of the crop at time T_1 and T_2 respectively.

For recording the root observations, at 60 DAS, soil core samples were taken using a root sampling pipe up to a depth of 15 centimetres. These soil samples were sieved through a nylon mesh of one mm and washed under running water. For plant root estimation, the washed roots were analysed in WinRHIZO Root Scanner.

The harvested crop was weighed after 3-4 days of sun drying to determine biological yield. It was threshed, and the grains were cleaned before being expressed as kg/ha at a moisture content of 14%. The straw yield was calculated by subtracting grain yield from biological yield per plot and expressing the result in kilogrammes per hectare.

Results and Discussion

Plant growth parameters of wheat

The mean dry matter accumulation at 90 DAS were 644.15 g/m^2 respectively. Dry matter accumulation increased substantially from 60 to 90 DAS a significantly higher dry matter accumulation was recorded in ZT+R (680.2g/m^2) which remained statistically at par with ZT. Dry matter accumulation increased substantially at 90 DAS and significantly higher dry matter accumulation were recorded in LCC-guided N application

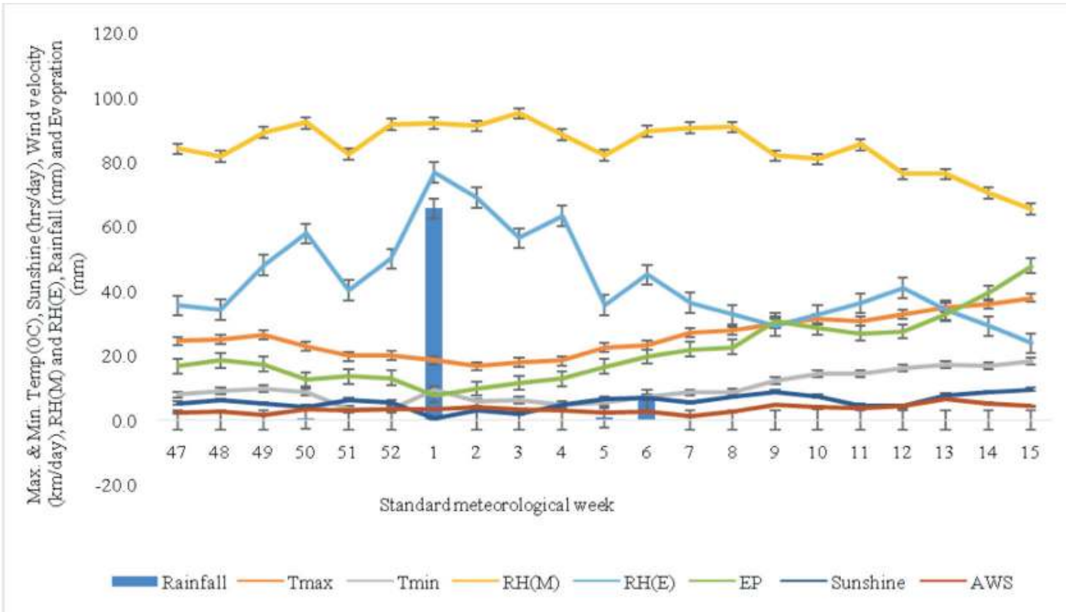

Fig. 1. Daily weather data during crop experimentation period (*rabi* 2020-21)

(672.8g/m^2) and this was statistically at par with Mod N scheduling (Table 1).

The maximum CGR was observed at 60-90 DAS (mean 11.5 g/m^2/day). At this stage, the maximum CGR was observed with ZT+R. However, this was significantly higher over the remaining establishment methods. The lower CGR was observed in CT. The CGR between 90 DAS and harvest decreased sharply over 60-90 DAS, with the mean value of 7.3g/m^2/day, at this stage CGR ranged between 7.0-7.7g/m^2/day with maximum CGR with ZT+R (7.7g/m^2/day) and lowest being with CT (Table 4.4, Fig 4.4). The maximum CGR value was observed at 60-90 DAS (mean value 11.5g/m^2/day). At this stage, the maximum CGR value was observed with LCC-guided N application. However, it remained at par with Mod N scheduling, but was significantly higher over the remaining establishment methods. The CGR between 90 DAS and harvest decreased sharply over 60-90 DAS, with its mean value of 7.3g/m^2/day at this stage CGR ranged between 7.3-7.4g/m^2/day,

Table 1. Effect of crop establishment methods and nitrogen management on different growth indices in wheat

Treatment	DMA (90 DAS)	LAI (90 DAS)	CGR (60-90 DAS)	RGR (60-90 DAS)
Crop establishment methods			g/m^2/day	g/g/day
CT	614.9	2.00	10.55	0.037
SSB-CT	625.2	2.32	10.80	0.038
ZT	656.3	2.57	11.54	0.038
ZT+R	680.2	2.73	11.75	0.038
SEm ±	9.05	0.04	0.03	0.001
LSD (Pd”0.05)	31.94	0.14	0.08	NS
Nitrogen management options				
No-N	602.1	2.18	11.10	0.037
RDN	643.4	2.34	11.15	0.037
Mod N Sch	658.3	2.50	11.17	0.038
LCC-guided N Sch	672.8	2.60	11.23	0.040
SEm ±	7.97	0.04	0.03	0.001
LSD (Pd”0.05)	23.40	0.12	0.08	0.0013

Note: CT: Conventional tillage, SSB: stale seed bed, ZT: zero tillage, R: crop residue, N: nitrogen, RDN: recommended N application, Mod N: Modified N scheduling, LCC: leaf colour chart guided N application with the maximum CGR with LCC-guided N application (7.4g/m^2/day) and lowest being with RDN (Table 1).

At 90 DAS, the RGR reduced further and the minimal value was recorded at 90 DAS. The maximum RGR at 90 DAS was recorded at ZT+R which, although was found statistically at par with other establishment methods. At 60-90 DAS, the maximum RGR was observed with LCC-guided N application, which is statistically higher over other nitrogen management options. At 90 DAS, the RGR reduced further and the minimal value was recorded at 90 DAS, however maximum RGR at 90 DAS was at LCC-guided N applicationwhich was statistically at par with Mod N scheduling and higher over other nitrogen management options. The results are in corroboration with Gupta *et al.,* 2011.

However, at 90 DAS, LAI ranged between 2.0-2.70 at 90 DAS, the maximum being at ZT+R establishment method. The LAI ranged between 2.18-2.60 at 90 DAS, the maximum being at LCC-guided N application nitrogen management which is significantly at par with Mod N scheduling.

Root studies

The rootparameters like root length density, root volume and root surface area of wheat varied significantly under different crop establishment methods, except root diameter.

The root length density of wheat varied significantly under different crop establishment methods and nitrogen management options (Table 2). Under different crop establishment methods, the maximum root length density was 3174.8 cm/cm^3 under ZT+R which remained significantly higher over SSB-CT and CT but statistically at par with ZT. Under different nitrogen management options, the maximum root length density was 3188cm/cm^3 under LCC-guided N application which remained significantly higher over RDN and No-N but statistically at with Mod N scheduling method of nitrogen management. The variation in root diameter of wheat was not significantly under different crop establishment methods but varied significantly under various N management options (Table 2). Under different nitrogen management options, the maximum root diameter was 0.80 mm under LCC-guided N application which remained significantly higher over RDN and No-N but statistically at par with Mod N scheduling method of nitrogen management. The enhanced growth with LCC-guided N application has been reported by Kumar *et al.,* 2014.

The maximum root length density was 211.6 cm/cm^3 under ZT+R which remained significantly

Table 2. Effect of crop establishment methods and nitrogen management on root parameters at the maximum flowering stage in wheat

Treatment	Root length density (cm/cm^3)	Root diameter (mm)	Root volume (cm^3/cm^3)	Root surface area (cm^2/cm^3)
Crop establishment methods				
CT	2016.2	0.67	11.5	566.0
SSB-CT	2371.2	0.68	11.6	586.8
ZT	2813.5	0.73	13.0	653.4
ZT+R	3174.8	0.75	14.2	718.3
SEm±	224.98	0.03	0.51	28.1
LSD (Pd”0.05)	793.65	NS	1.78	99.1
Nitrogen management options				
No-N	1965.4	0.55	10.78	524.3
RDN	2348.7	0.72	12.50	596.9
Mod N	2873.7	0.77	13.46	681.6
LCC	3188.0	0.80	13.60	721.5
SEM±	232.11	0.02	0.60	31.4
LSD (Pd”0.05)	681.52	0.07	1.77	92.2

Note: CT: Conventional tillage, SSB: stale seed bed, ZT: zero tillage, R: crop residue, N: nitrogen, RDN: recommended N application, Mod N: Modified N scheduling, LCC: leaf colour chart guided N application higher over SSB-CT and CT but statistically at with ZT method of establishment, maximum root volume was 14.2 cm^3 under ZT+R which remained significantly higher over SSB-CT and CT but statistically at par with ZT method of establishment. The maximum root surface area was 718.25 cm^2 under ZT+R at with ZT method of establishment. This may be due to better growth and development of crop in ZT+R. Wheat root length and growth increased more than above ground growth in ZT than in CT, and roots penetrated deeper into the soil than in conventional and minimal till (Singh *et al.,* 2013).

The root parameters varied significantly under nitrogen management options. The maximum root length density was 212.5 cm/cm^3 under LCC-guided N application which remained significantly higher over RDN and No-N but statistically at par with Mod N scheduling method of nitrogen management. Maximum root diameter (0.80 mm) under LCC-guided N application remained significantly higher over RDN and No-N, but statistically at with Mod N scheduling method of nitrogen management. The maximum root volume was 13.6 cm3 under LCC which remained significantly higher over No-N but statistically at with Mod N scheduling and RDN method of nitrogen management. Maximum root surface area was 721.52 cm^2 under LCC-guided N application which remained significantly higher over RDN and No-N but statistically at with Mod N scheduling method of nitrogen management. This may also due to better growth and development in LCC guided N applications. A lower bulk density and higher microbial activities facilitate easy penetration of roots to the pulverized deeper soil layers.

The root volume of wheat varied significantly under different crop establishment methods and nitrogen management options (Table 2). Under different crop establishment methods, maximum root volume was 14.2 cm^3 under ZT+R which remained significantly higher over SSB-CT and CT but statistically at with ZT method of establishment. Under different nitrogen management options, the maximum root volume was 13.6 cm^3 under LCC-guided N application which remained significantly higher over No-N but statistically at with Mod N scheduling and RDN method of nitrogen management.The root surface area of wheat varied significantly under different crop establishment methods and nitrogen management options (Table 2). Under different crop establishment methods, the maximum root surface area was 718.25 cm^2 under ZT+R par with ZT method of establishment.Under different nitrogen management options. Maximum root surface area was 721.52 cm^2 under LCC-guided N application which remained significantly higher over RDN and No-N but statistically at par with Mod N scheduling method of nitrogen management.

Wheat yield attributes and yield

The grain yield of wheat was significantly influenced by different crop establishment methods. The highest grain yield under ZT+R method of establishment (4.99 t/ha) which remained statistically at par with ZT method of establishment but was found significantly higher over SSB-CT and CT (Fig. 2). ZT+R has 14.2% higher grain yield than CT, 10.9% higher than SSB-CT and 5.5% higher than ZT. The maximum total biological yield was recorded under ZT+R method of establishment which remained statistically at par with ZT, but significantly higher over SSB-CT and CT. ZT+R has 12% higher than CT, 9.7% higher than SSB-CT and 4.7% higher than ZT. The straw yield remained maximum under ZT+R method of establishment which remained significantly higher over SSB-CT, CT and ZT (Fig 2). The seed placement in the zero-tilled field is ensured at the right depth by the zero-tillage drill, which responds in terms of good crop yields (Gupta *et al.,* 2011). The soil organic matter was exposed to direct sunlight in conventional tillage, which enhanced the rate of mineralization, but zero-tillage provides a cover to the soil organic matter, causing slower breakdown of organic matter and providing nutrients to the plants.

The total biological yield varied with in the range of 11.62-13.02t/ha, whereas the straw yield under different crop establishment methods ranged between 7.26-8.03t/ha. ZT+R has 10.6% higher straw yield than CT, 9.1% higher than SSB-CT and 4.2% higher than ZT. The mean grain, straw, total biological yield is 4.65, 7.59 and 12.23 t/ha, respectively. The harvest index of wheat was not affected by different crop establishment methods. The harvest index ranged from 37.5-38.4%. Since yield is a function of various yield components that are dependent on the complimentary interaction of the crop's vegetative and reproductive growth. Most of these growth and yield qualities have a significant positive correlation with

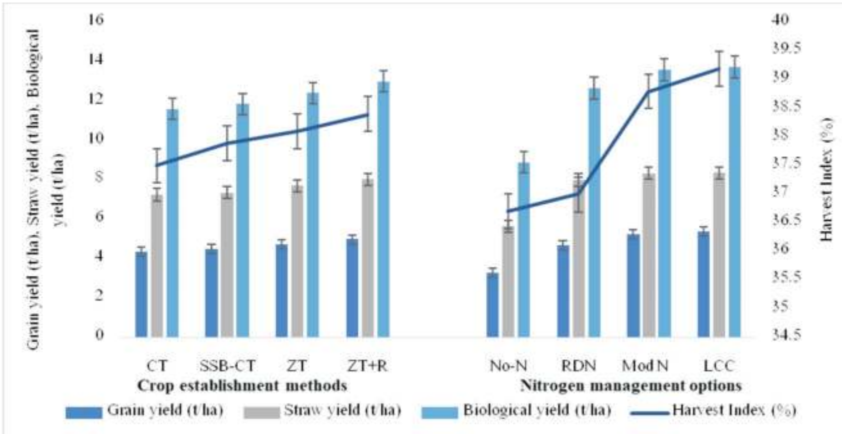

Fig 2. Effect of crop establishment methods and nitrogen management on yield of wheat

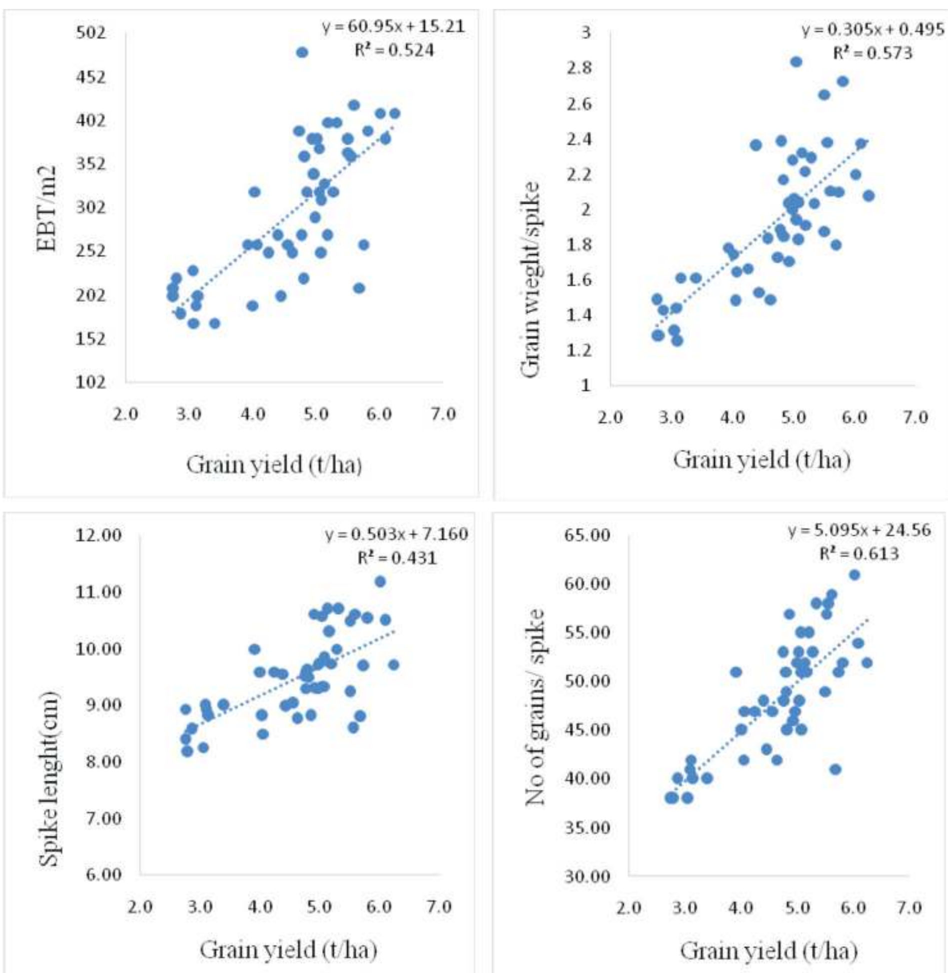

Fig 3. Effect of crop establishment methods and nitrogen management on correlation studies between grain yield different yield parameters.

wheat grain yield, resulting in increased yield in ZT+R treatments (Fig. 3). Crop residue management can help to improve nutrient cycling and increase crop yields (Cruse *et al.*, 2009; Tripathi *et al.*, 2013).

Therefore, a combination of ZT+R and LCC-guided N application, may be recommended for better growth, productivity, soil health and higher returns in wheat under rice-wheat system.

References

Anonymous 2018. Agricultural Statistics at a glance, Ministry of Agriculture and Farmers' Welfare, GoI.

Bhatia, A., Pathak, H., Jain, N., Singh, P. K. and Tomer, R. 2011. Greenhouse gas mitigation in rice-wheat system with leaf color chart-based urea application. *Environmental Monitory Assessment*, doi:10.1007/s10661-011-2174-8.

Dhar, D., Datta, A., Basak, N., Paul, N., Badole, S. and Thomas, T. 2014. Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice-wheat cropping system. *Indian Journal of Agricultural Research*, **48**(5), 373-378.

Duttarganvi, S., Channabasavanna, A., Rao, S. and Halepyati, A. 2014. Effect of LCC and SPAD based nitrogen management on growth and yield of lowland rice (Oryza sativa L.). *The Bioscan*, **9**(2), 663-665.

Gupta, M., Bali, A. S., Kour, S., Bharat, R. and Bazaya, B.R. 2011. Effect of tillage and nutrient management on resource conservation and productivity of wheat (*Triticum aestivum*). *Indian Journal Agronomy*. **56**, 116-120.

Jat, R. K., Sapkota, T. B., Singh, R. G., Jat, M. L., Kumar, M. and Gupta, R. K. 2014. Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: yield trends and economic profitability. *Field Crops Research*,**164**, 199-210.

Kumar, R. and Singh, U.P. 2018. Performance of zero-till wheat (*Triticum aestivum* L.) with residue and weed management techniques under rice-wheat cropping system. *Agricultural Science Digest-A Research Journal*, **38**(2), 113-117.

Singh, Y. P., Singh D., Tomer, S. S. Gupta. and Raj K. 2013. Effect of the time of pre-irrigation and tillage practices on Wheat (*Triticum-aestivum*) under pigeonpea (*Cajanuscajan*)- Wheat cropping sequence. *Indian Journal of Agricultural Sciences*. **83**(12), 1317-21.

Tripathi, R.S., Raju, R., and Thimmappa, K. 2013. Impact of Zero Tillage on Economics of Wheat Production in Haryana. *Agricultural Economics Research Review*. **1**(26), 101- 108.

Cruse, R.M. and Herndl, C.G. 2009. Balancing corn stover harvest for biofuels with soil and water conservation. *Journal of soil water conservation*,**64**(4), 286-291.