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Research Paper

Enhancement of productivity potential of wheat (*Triticum aestivum*) under different tillage and nitrogen-management strategies

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ABSTRACT

A field experiment was carried out during 2015–16 and 2016–17 at Kalyani, West Bengal, to evaluate the productivity potential of wheat (*Triticum aestivum* L.) in relation to tillage and timing of nitrogen application. The highest grain yield was obtained with reduced tillage (3.8 t/ha), being statistically superior to other options. This was followed by zero (3.4 t/ha) and conventional tillage (3.2 t/ha). Sowing of wheat under reduced tillage showed yield superiority of 23.86, 19.43 and 11.14%, respectively, to the surface seeding, conventional and zero tillage owing to better utilization of available resources with minimum disturbance of soil, and higher values of yield-attributing components. Results indicated that increasing the number of splits cannot compensate for basal nitrogen application. Application of nitrogen in 3 splits [one-half before sowing + one-fourth at 21 days after sowing (DAS) + one-fourth at 42 DAS] resulted in significantly taller plants, more dry-matter accumulation, higher leaf-area index and grain yield (3.6 t/ha). This treatment showed parity with one-third N before sowing + one-third at 21 DAS + one-third N at 42 DAS (3.4 t/ha). Reduced tillage resulted in higher net returns (₹51 × 10^3/ha) and benefit: cost (B:C) ratio (2.22) than the other tillage practices. Time of nitrogen application revealed that, one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS resulted in more net returns (₹42.8 × 10^3/ha) and B:C ratio (2.06) and was followed by zero tillage for net returns (₹43.9 × 10^3/ha) and B:C ratio (2.18).

***Key words*: Nitrogen, Time of application, Tillage, Wheat, Yield

Food security dilemma is the problem of the future for countries like India where resources are getting stretched to the limits. There is no doubt that intensive agriculture in irrigated areas has brought out substantial enhancement in foodgrain production but has also threatened the environmental safety and promoted the degradation and inefficient use of basic resources and production inputs. In the present situation, the only option left is to shift towards environment suitable technology and efficient utilization of production resources, especially soil, water and nutrients. This becomes more imperative in the context of wheat crop. Wheat is one of the most important cereal crops, occupying the prime position among food crops in the world and important constituent of food security. This is an important crop contributing 40% in the total food grain production, and is next only to rice. Importance of wheat crop may be understood from the fact that it covers about one-fifth of total area under food grains and accounts for about one-third (40%) of the total food grain production in India. (Mukherjee, 2017). After the introduction of high-yielding varieties wheat became an important crop in West Bengal. In West Bengal, wheat is grown on 0.22 million ha area and contributes 0.31 million tonnes food grain (Mukherjee, 2016). Sowing of wheat in these areas gets delayed due to late harvesting of medium- to long-duration rice, the previous crop in the rotation. Wet soil conditions further enhance the delayed sowing of wheat, as it takes another 20–25 days to reach working condition. Delayed sowing result in a reduction of yield to the tune of 37.5 kg/ha/day (Jat *et al*., 2013). The adoption of resource-conservation technologies (RCTs) as no-till is considered vital for improving the wheat productivity, and prime driver for zero and reduced tillage, is not the water saving or natural resource management but also for the higher monetary gain (Ereinstein *et al*., 2008). In most crop- production systems, soil tillage is one of the expensive aspect and thus an economically important factor. It influences the physical, chemical and biological processes and also the long-term productivity with effective control of weeds (Choudhary *et al*. 2017). However, tillage is not a growth factor for plants and its effects are

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mainly indirect. Adoption of zero and reduced tillage for sowing of wheat with zero-till drill or behind country plough advances the sowing time 10–15 days and also saves the time and cost involved in field preparation. It has been observed that tillage reduces the problem of weed infestation and improves fertilizer and water-use efficiency which can enhance the yield up to 40–60% (Mukherjee, 2008). Even some low land rice fallows with restricted irrigation facilities can be brought under cultivation with this technology. In India, the demand for nutrient resources particularly NPK, is exceeding the supply and the competition for this scarce resource, is becoming intense in agriculture. Nitrogen is the key input amongst all primary nutrients as it is directly involved in plant photosynthetic system. This is important for all recommended agronomic practices and therefore efficient utilization of nitrogen is essential for wheat. Imbalanced and improper time of use of nitrogen fertilizers warrants their judicious use to maximize fertilizer-use efficiency. Technological advances are needed to reduce excess nutrient application by improving use efficiency and reducing losses in new alluvial region of West Bengal. Recovery of added fertilizer nitrogen is only 50% or less in most of the arable soils owing to volatilization, leaching and denitrification losses (Mukherjee, 2014). So, appropriate time of nitrogen application in suitable proportion becomes very important under present context. As the concept of tillage in wheat is recent in India and West Bengal in particular, and information regarding proper time of N application in split form is scanty, the present investigation was carried out to assess the performance of wheat under different tillage options with correct time and suitable proportion of nitrogen relevance.

MATERIALS AND METHODS

Present investigation was conducted during the winter season of 2015–16 and 2016–17 at the Bidhan Chandra Krishi Viswavidyalaya, Kalyani (22° 56´ N, 88° 32´ E with an average altitude of 9.75 m above mean sea-level) in upland situation. The soil was sandy clay loam in texture (sand 48.4 ± 0.2, silt 29.9 ± 0.1 and clay 21.7 ± 0.1), slightly alkaline (*p*H 7.75 ± 0.05), low in available N (KMnO4-N, 281.3 ± 2.1 kg/ha), medium in available P (Olsens-P, 22.1 ± 0.6 kg/ha) and high in available K (NH4OAC-K, 226.8 ± 4.2 kg/ ha). A total of 16 treatments were tested in a split-plot design with 3 replications by allocating tillage options in the main plots and timings of N application to the subplots. The treatments comprised 3 methods of tillage as main plot, viz. conventional tillage, reduced tillage (RT), zero tillage (ZT) and surface seeding, with 4 methods of N application in split form as subplot, viz. one-half N before sowing + one-half at 21 DAS (N_1), one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2), one-third before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3) and one-third at 21 DAS stage + one-third at 42 DAS+ one-third at 63 DAS (N_4).Wheat cv. 'K 0307' was sown 5 m × 5 m plot size with row spacing of 20 cm apart on 18 and 22 November 2015 and 2016 respectively, at 5–6 cm seeding depth using 100 kg seed/ha in all main plot treatment except in conventional tillage where sowing was delayed by 10 days to conventional practice. In surface seeding, seeds were soaked properly, and planting of soaked seeds treated with fresh cowdung was made in the afternoon to save seeds from bird damage. Under zero tillage, stubbles were buried before sowing and seed drill were used to allow planting of wheat seed into fields after rice harvesting without ploughing the field. In reduced tillage, 2 disc harrowing was done at 10–15 cm depth in row zone only after harvesting of rice. Conventional tillage was prepared by having 4 ploughing (harrowing and cultivation) with a depth of 40–50 cm followed by planking. Recommended dose of fertilizer was 150 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha. Dose of nitrogen was applied as per treatments in split form, whereas phosphorus (diammonium phosphate (DAP), 18% N and 46% P_2O_5) and K (muriate of potash, 60% K_2O) was drilled uniformly as basal dose across all the treatments. Basal dose of N was applied through DAP, whereas remaining N dose was top-dressed as urea (46% N) depending on the treatments. Irrigations and plant-protection measures were applied as per the crop need. Pre-emergence application of pendimethalin @ 1 kg a.i./ha was done 2 days after sowing (DAS) followed by 1 hand-weeding at 30 DAS for complete check of weeds during critical period of crop-weed competition. The crop was harvested on 1 and 3 April during 2016 and 2017, respectively. The data on growth and yield attributing characters were recorded on 10 selected plants at the time of harvesting, whereas leaf-area index (LAI) was recorded 60 days after sowing, as per normal procedure. The crop was threshed plot-wise and grain yield thus obtained from net plot was converted into kg/ha. Crop samples were analysed for uptake of nitrogen, phosphorus and potash as per standard laboratory procedures (Jackson, 1973). The experimental data were analysed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F-test and conclusions were drawn at 5% probability level. Benefit: cost ratio (B:C) was obtained by dividing the gross income with cost of cultivation. The effect of treatments was evaluated on pooled analysis basis on growth, yield attributes and yields.

RESULTS AND DISCUSSION

Growth characters

Conventional tillage (CT) resulted in the maximum plant height and proved statistically better to the other tillage options (Table 1). Split application of nitrogen, revealed that one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2) showed the highest plant height, and was at par with the one-third at before sowing + one-third at 21 DAS stage + one-third at 42 DAS (N_3) and notably better to other treatments. Dry-matter accumulation was the highest with CT, and was at par with the reduced tillage (RT) and statistically more than ZT and surface seeding. The highest dry-matter accumulation, registered with the 3 split doses of nitrogen, one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2), was significantly superior to the other options of nitrogen management. The leaf-area index (LAI) was the highest with the CT, being statistically more to all the other treatments except surface seeding option. Further, split doses of nitrogen revealed that, one-third before sowing + one-third at 21 DAS stage + one-third at 42 DAS (N_3) showed utmost LAI and showed parity only with the one-half before sowing + one-fourth 21 DAS + one-fourth at 42 DAS (N_2), and better to the other subplot assignments.

Yield attributes

Number of effective tillers/m^2 was found more with the RT, and showed parity with all main plot treatments except ZT (Table 1). This increase was primarily owing to faster growth, better root development and aeration because of more free space available due to minimum disturbance of soil. These results are in line with those of Mukherjee (2008) and Majeed *et al.* (2015). Nitrogen management revealed that, application of nitrogen as one-third before sowing + one-third at 21 DAS stage + one-third at 42 DAS (N_3) produced the highest number of effective tillers and showed parity only with the one-half before sowing + one-fourth 21 DAS + one-fourth at 42 DAS (N_2) and statistically more to the others. Ear length failed to produce any significant response with various main and subplot treatments, however, the highest ear length observed with the ZT and 3 split dose of nitrogen use (one-half before sowing + one-fourth at 21 + one-fourth at 42 DAS). Grains/ear were the maximum with the RT and significantly better to the other methods of tillage. Split dose of nitrogen revealed that, grains/ear were found more with 2 split dose of nitrogen (one-half at before sowing + one-half at 21 DAS), and showed parity with all the treatments except N_3. Various tillage options failed to exhibit any significant response with grain weight; however, the highest

Table 1. Growth and yield attributes of wheat as influenced by tillage and nitrogen management options (pooled data of 2 years)

Treatment	Plant height (cm)	Dry matter (g/m)	LAI (60 DAS)	Effective tillers/m^2 (Nos.)	Ear length (cm)	Grains/ ear (Nos.)	Grain weight/ ear(g)	Filled grains/ ear (Nos.)	Test weight (g)	Days to 50% heading	Days to physio-logical maturity
Tillage options											
Zero tillage (ZT)	91.2	269.7	2.05	247.2	9.1	41.0	2.40	34.8	41.2	67.1	109.5
Reduced tillage (RT)	94.6	283.9	2.11	307.1	8.0	43.9	2.99	36.3	43.3	69.0	111.0
Conventional tillage (CT)	96.3	293.3	3.24	301.9	8.4	40.1	2.19	30.2	40.7	69.4	113.7
Surface seeding	91.8	243.1	3.02	303.3	8.2	38.1	2.08	28.5	41.7	70.2	
SEm±	0.42	5.56	0.21	2.01	0.83	0.35	0.89	0.36	0.98	1.02	0.56
CD (P=0.05)	1.12	16.35	0.67	6.11	NS	1.11	NS	1.03	NS	NS	1.69
Time of nitrogen application											
One-half at before sowing + one-half at 21 DAS (N_1)	86.3	276.3	2.09	246.5	8.3	45.4	1.98	33.7	40.1	70.2	113.4
One-half at before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2)	96.3	251.3	2.87	308.6	9.01	43.2	2.78	37.1	39.1	64.3	111.5
One-third at before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3)	94.7	281.0	3.11	317.3	8.8	38.7	2.65	37.4	41.4	63.3	113.3
One-third at 21 DAS stage + one-third at 42 DAS + one-third at 63 DAS (N_4)	86.3	244.3	2.15	225.5	8.9	44.3	1.88	32.2	41.6	67.8	113.5
SEm±	0.65	6.36	0.17	4.21	0.58	1.02	0.32	1.02	0.84	0.39	1.23
CD (P=0.05)	1.84	19.05	0.53	12.13	NS	2.98	0.92	2.87	NS	1.09	NS

DAS, Days after sowing; NS, non-significant

grain weight/ear was registered with the reduced tillage. Further observation revealed that, amongst various subplot, more grain weight/ear were found with the split dose of nitrogen, mainly, one-half at before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2) and was statistically alike with the one-third before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3). The filled grains/ear were observed higher with CT, being appreciably better to all other main plot treatments. Filled grains/ear, observed higher with one-third at before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3), were at par only with the one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2) and significantly better to all other methods of nitrogen use. This could be owing to the fact that nitrogen played a vital role in increased sink size (Mukherjee, 2016a). Nitrogen is required throughout the grand growth period and hence adequate and regular supply might have a great role towards increased number of major yield attributes and filled grains/ear too. Dou and Hons (2006) reported similar crop growth under different tillage systems. As test weight is basically a genetic character it was not influenced by tillage methods and time of nitrogen application. As a result, test weight did not vary significantly with different treatments. However, ZT and N_3 gave more test weight than the other treatments of main and subplot respectively. Further observations on days to 50% heading failed to produce any statistical difference within themselves, however least time observed with the zero tillage and was followed by reduced tillage options. With various subplot treatments, least time of 50% heading registered with the N_3 was at par with N_2. Days to physiological maturity took least time with zero tillage, and were at par only with RT. These could be owing to various favourable factors under zero tillage like proper placement of seed in a narrow slit made by zero till drill as well as emergence of wheat seedlings under favourable moisture content with right time of nitrogen application in split doses. Subplot treatments did not produce any statistical difference, moreover N_2 took minimum time for crop physiological maturity.

Nutrient uptake

Nutrient-uptake pattern significantly differed with various main and subplot treatments. The highest nitrogen in grain and straw was observed with the RT and notably better to the other treatments. The uptake of nitrogen in wheat was the highest with reduced tillage mainly due to more crop economic and biomass production. Table 2 revealed that, the maximum nitrogen uptake found with N_2, was statistically at par with N_3 only for grain and total uptake,

Table 2. Effect of tillage and nitrogen management options on nutrient uptake pattern of wheat (pooled data of 2 years)

Treatment	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)			Total nutrient uptake (kg/ha)
	Grain	Straw	Total uptake	Grain	Straw	Total uptake	Grain	Straw	Total uptake	
Tillage options										
Zero tillage (ZT)	76.3	37.2	113.5	15.3	10.4	25.8	31.0	78.1	109.2	248.5
Reduced tillage (RT)	81.1	49.6	130.7	18.7	12.9	31.6	34.4	83.8	118.3	280.7
Conventional tillage (CT)	70.1	35.0	105.1	12.0	8.6	20.6	29.2	73.6	102.8	228.6
Surface seeding	65.3	32.3	97.7	11.1	7.3	18.4	28.6	67.5	96.1	212.4
SEm±	1.4	0.9	1.6	0.8	0.7	0.9	1.1	1.8	3.8	3.0
CD (P=0.05)	4.8	2.3	4.2	2.4	2.1	2.3	3.1	5.0	10.2	9.1
Time of nitrogen application										
One-half at before sowing + one-half at 21 DAS (N_1)	73.3	32.7	106.0	13.1	9.9	23.0	27.0	74.2	101.2	232.3
One-half at before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2)	79.1	46.8	125.9	15.6	11.0	26.7	32.9	80.2	113.1	265.8
One-third at before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3)	75.6	36.0	111.7	15.0	9.7	24.7	29.9	77.1	107.1	243.6
One-third at 21 DAS stage + one-third at 42 DAS + one-third at 63 DAS (N_4)	60.4	30.7	91.2	10.9	7.1	18.0	26.3	69.3	95.7	207.0
SEm±	1.9	1.2	5.6	1.0	1.3	1.1	1.4	2.3	2.0	3.3
CD (P=0.05)	5.6	3.9	15.9	2.9	4.1	3.0	4.2	6.4	6.1	10.1

DAS, Days after sowing; NS, non-significant

and notably to other treatments for grain, straw and total uptake. Split application of nitrogen caused a corresponding increase in tissue contents of N in wheat plants (Ishaq *et al*., 2001). Reduced tillage registered the highest uptake of phosphorus by grain, straw and total uptake and appreciably better than other tillage options. Application of nitrogen, one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2) took more phosphorus for grain and straw, and showed similarity only with the one-third before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3), and considerably better than the other method of nitrogen split. Total uptake of phosphorus by wheat crop was the highest with N_2, and was at par only with N_3. Potassium uptake by grain and straw utmost observed with the RT and was statistically better than all the other main plot treatments for grain, straw and total uptake. Moreover, subplot treatments revealed that, highest grain and straw uptake observed with the N_2 was at par only with N_3 for straw uptake and statistically better than the other treatment. Total potassium uptake by crop being maximum with the split doses of nitrogen, N_2, was statistically superior to the other methods of nitrogen used. Further, total nutrient uptake by crop was the maximum with RT, being statistically better than the other main plot treatments. With various split doses of nitrogen use, the highest total nutrient uptake observed with N_2 and notably better than all the other options. Higher dry-matter production with increased tissue N content may attribute to this higher uptake. Kharub and Chander (2010) reported higher uptake of total nutrient with number of splits application of nitrogen.

Yield

The highest grain yield obtained with the reduced tillage was statistically superior to the other options (Table 3). This was followed by zero and conventional tillage. Reduced tillage resulted in 23.86, 19.43 and 11.14% more grain yield than the surface seeding, conventional and zero tillage treatments. This increase in yield could be accredited to higher numbers of effective tillers/m^2, grain/ear, grain weight/ear and 1,000-grain weight under RT system. These findings are in confirmation with those of Mukherjee (2008). Time of nitrogen application revealed that, N_2 resulted in the highest grain yield (3.6 t/ha), and was at par only with the split use of nitrogen, one-third at before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3) (3.4 t/ha). Yield increment was 19.05, 6.97 and 9.38 % more in N_2 over the N_4, N_3 and N_1. More availability, less leaching losses and effective use of applied N could be responsible for yield advantage of N_2 over the all other treatments. Similar advantages of N placement have also been reported by Majeed *et al*. (2015). More straw yield noticed with the reduced tillage (5.1 t/ha) was statistically superior to the other treatments. This was followed by zero tillage and surface seeding. Reduced tillage registered 6.41, 18.39 and 14.23% more yield over the zero and

Table 3. Effect of tillage and nitrogen management options on yield, harvest index and economics of wheat (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)	Economics		
				Cost of cultivation (×10^3 ₹/ha)	Net Returns (×10^3 ₹ /ha)	Benefit: cost ratio
Tillage options						
Zero tillage (ZT)	3.4	4.8	41.5	37.1	43.9	2.1
Reduced tillage (RT)	3.8	5.1	42.6	41.9	51.0	2.2
Conventional tillage (CT)	3.2	4.3	42.4	46.1	39.1	1.8
Surface seeding	3.1	4.5	40.7	41.3	37.6	1.9
SEm±	0.05	0.04	1.01			
CD (P=0.05)	0.14	12	NS			
Time of nitrogen application						
One-half at before sowing + one-half at 21 DAS (N_1)	3.3	4.6	42.2	38.0	28.5	1.7
One-half at before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2)	3.6	4.9	42.3	40.3	42.8	2.0
One-third at before sowing + one-third at 21 DAS + one-third at 42 DAS (N_3)	3.4	4.8	41.4	40.1	33.1	1.8
One-third at 21 DAS stage + one-third at 42 DAS + one-third at 63 DAS (N_4)	3.0	4.3	41.5	39.3	27.0	1.6
SEm±	0.08	0.07	0.89			
CD (P=0.05)	0.23	0.21	NS			

DAS, Days after sowing; NS, non-significant

conventional tillage, and surface seeding respectively. The modified microclimatic conditions within the field due to the lesser disturbance of soil in reduced tillage resulted in reduced crop lodging and decreased insect-pest incidence owing to reduced canopy humidity which contributed towards enhanced crop straw yield (Fahong *et al.,* 2004). Use of nitrogen in split form, one-half at before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS (N_2) gave maximum straw yield (4.9 t/ha), and was at par only with N_3 (4.8 t/ha), and significantly superior to the other split doses. Treatment N_2 registered 19.05, 6.97, and 9.38% additional straw yield over the N_4, N_3 and N_1. The harvest index did not fail to produce any statistical difference either with main or subplot treatments, moreover, the highest harvest index found with the reduced tillage and split dose of nitrogen, one-half at before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS.

Economics

With various tillage options, reduced tillage exhibited a higher net returns (₹51 × 10^3/ha) and benefit: cost (B:C) ratio (2.22) over the other treatments. It was mainly owing to less operational cost, as there was no cost incurred towards land preparation and other expenses as conventional tillage. The B:C ratio (1.90) was higher with surface seeding than conventional tillage (1.85) despite lesser yield. Huge curtailment in the cost of land preparation resulted in such improvement of B:C ratio. Time of nitrogen application revealed that, N_2 gave more net returns (₹42.8 × 10^3/ha) and B:C ratio (2.06) owing to better crop harvest.

Reduced tillage technology was supposed to be the most promising tillage options in wheat over conventional and zero tillage operations. Split application of nitrogen one-half before sowing + one-fourth at 21 DAS + one-fourth at 42 DAS was beneficial for wheat under new alluvial condition in terms of yield, nitrogen use efficiency and net returns.

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