



Research Article

Wheat Productivity and Energetics as Influenced by Tillage based Planting Methods and Time of Nitrogen Application

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ABSTRACT

A field experiment was conducted during *rabi* 2015-16 and 2016-17 to study the optimum time of nitrogen application under different resource conservation production technologies in wheat, at Ludhiana, Punjab. The experiment was laid out in split-plot design with 3 replications. The main plot treatments comprised of three tillage based planting methods viz., zero-tillage (ZT), conventional tillage (CT) and bed planting (BP) and sub plots consisted of four different times of nitrogen application i. e. T₁-recommended schedule (full dose of DAP as basal+½ N at sowing & ½ N with first irrigation), T₂-full dose of DAP as basal+ ½ N at 30 days after sowing (DAS) & ½ N at 60 DAS, T₃-full dose of DAP as basal+½ N at 60 DAS & ½ N at 90 DAS and T₄-full dose of DAP as basal+ ⅓ N at 30 DAS, ⅓ N at 60 DAS and ⅓ N at 90 DAS. The results revealed that ZT sowing improved energy use efficiency by 10.58 and 9.52 % over CT sowing and BP, as a result of 10.24 and 4.07 % reduced energy requirement under ZT sowing, respectively. Maximum apparent water productivity (AWP) was obtained in BP (1.95 kg m⁻³). Among the time of N application treatments, treatment T₂ helped in improving the yield attributing characters, yield, AWP, partial factor productivity and energetics significantly. The grain yield was 18.3 % higher in T₂ than T₃. However, T₂ treatment was statistically at par with T₁ and T₄ with respect to all the mentioned parameters.

Key words: Bed planting, Energy use efficiency, Nitrogen, Wheat, Zero-tillage

Introduction

Wheat (*Triticum aestivum* L.) is a dominating crop of India during winter season especially in north-western and central region. In India, wheat productivity is lower (3093 kg ha⁻¹) as compared with many countries of world. India ranked 60th in the world in wheat productivity while Ireland on the top (9539 kg ha⁻¹) and among the G-20 countries, India was at 14th position during 2016 (Anonymous, 2019). It has been estimated that productivity of wheat has stagnated or is declining. Conventional agricultural practices led

to degradation of soil health and environmental quality (soil structure deterioration, soil compaction, low infiltration rate, high use of resources, *etc.*) and thereby, lowering resource-use efficiencies and hence crop yields. The wheat yield can be enhanced by adopting resource conservation production technologies such as zero tillage, bed planting, *etc.* and with optimum use of resources. Zero-tillage helps to improve soil properties, energy-use efficiency and productivity and reduces cost of cultivation and environmental pollution (Kumar *et al.*, 2013; Khan *et al.*, 2017). The furrow irrigated raised bed planting method increase water and nutrient-use efficiency and productivity in wheat (Kumar *et al.*, 2010a,b).

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Optimum use of nitrogen to increase wheat grain yield and nitrogen use efficiency (NUE) is of paramount importance. Excessive use of N may lead to many environmental problems like nitrate leaching, emission of green house gases and also increases cost of cultivation. However, lower use can decrease grain yields and profitability. The nitrogen use efficiency in cereal crops is only about 33% (Raun and Johnson, 1999). However, it depends on various factors viz., soil moisture condition, soil properties, method, source and timing of fertilizer application, planting methods, crop rotation, *etc.* (Halvorson *et al.*, 2001). So, optimum time of N application is critical to enhance crop yield and NUE and minimize environmental damage. The improved NUE might be due to synchronization of availability of N in the soil with plant N demand. Various studies on timing of fertilizer application under different tillage systems showed differential responses of N fertilizer application on grain yield in wheat (Melaj *et al.*, 2003; Iqbal *et al.*, 2005). The timing for N application recommended for conventional sown wheat may not be optimum for wheat sown under ZT and bed planting system. So, the present investigation was carried out with the objective to find out optimum time of N application, energetics and productivity under different tillage based planting methods.

Materials and Methods

A field experiment was conducted during winter (*rabi*) seasons of 2015-16 and 2016-17 at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, India. The experiment was conducted in split-plot design with 3 replications. The main plot treatments comprised of three tillage based planting methods viz., zero tillage (ZT), conventional tillage (CT) and bed planting (BP) and sub plots consisted of four different times of nitrogen application i. e. T₁-recommended schedule (full dose of DAP as basal+½ N at sowing & ½ N with first irrigation), T₂-full dose of DAP as basal+ ½ N at 30 days after sowing (DAS) & ½ N at 60 DAS, T₃-full dose of DAP as basal+½ N at 60 DAS & ½ N at 90 DAS and T₄-full dose of DAP as basal+ ⅓ N at 30 DAS, ⅓ N at 60 DAS and ⅓ N at 90 DAS.

The soil of experimental site was loamy sand, low in available N and medium in P and K with normal soil reaction. The total rainfall during the crop growing season of 2015-16 and 2016-17 was 72.3 and 98.3 mm, respectively. Zero-tillage sowing was done with zero-till drill without preparing the field. Conventional sowing was done with conventional seed-cum-fertilizer drill after ploughing the field once with disc harrow and twice with cultivator followed by planking. In case of bed planting, sowing of wheat was done with tractor operated bed planter after conventional tillage, which makes 37.5 cm wide bed and 30 cm wide furrow between two beds and simultaneously sow two rows of wheat 20 cm apart on top of bed. In case of flat sowing, sowing was done with tractor mounted seed-cum-fertilizer drill with a row to row spacing of 20 cm. Wheat variety 'PBW 658' and 'PBW 677' was sown on 17th December, 2015 and 12th November, 2016 and harvesting was done on 21th April, 2016 and 12th April, 2017 during 2015-16 and 2016-17, respectively. A basal dose of 62.5 kg P₂O₅ ha⁻¹ was applied through DAP (18% N and 46% P₂O₅) as per recommendation. However, nitrogen was applied in the form of urea (46% N) @ 125 kg N ha⁻¹ as per treatments and the dose of urea was reduced accordingly due to application of DAP as phosphorus source. Four and five irrigations were applied during 2015-16 and 2016-17, respectively, keeping 75 mm depth of water in zero tillage and conventional tillage sowing and 50 mm in bed sowing method.

The data on growth and yield attributing characters and biological and grain yields of wheat were recorded at harvest. The bundle weight was recorded after harvesting and was expressed as biological yield in t ha⁻¹. The weight of grains was recorded after threshing. The straw weight was computed by deducting the weight of grains from bundle weight. Grain and straw yields were then reported as t ha⁻¹. The apparent water productivity in kg m⁻³ was calculated by dividing the grain yield (kg ha⁻¹) with irrigation water applied (m³ ha⁻¹). The partial factor productivity (kg grain kg N⁻¹) is the grain yield (kg ha⁻¹) produced from unit quantity of nitrogen applied. The energy input and energy output were

estimated by using the energy equivalents (Table 1) given by Panesar and Bhatnagar (1994). The net energy gain was calculated by subtracting energy input from energy output. Energy use efficiency was calculated by dividing the energy output with energy input as per the formulae given by Demircan *et al.* (2006). The energy productivity (g grain MJ⁻¹) was calculated by dividing grain yield (g ha⁻¹) with energy input (MJ ha⁻¹). All the data were subjected to statistical analysis as per split plot design (Gomez and Gomez, 1984).

Table 1. Energy equivalents for different inputs and outputs

Particulars	Unit	Equivalent energy (MJ)
Input		
Human labour	h	1.96
Diesel (including lubricants)	l	56.31
Tractor	h	64.80
Farm machinery	h	62.70
N	kg	60.60
P ₂ O ₅	kg	11.10
Herbicides	kg	238.00
Insecticides	kg	199.00
Fungicides	kg	92.00
Irrigation water	m ³	0.63
Seed	kg	14.70
Output		
Wheat grain	kg	14.70
Wheat straw	kg	12.50

Results and Discussion

Growth and yield attributes

The data (Table 2) revealed that growth and yield attributing characters viz., plant height at harvest, effective tillers, number of grains per ear and 1000-grain weight were not significantly influenced by tillage based planting methods. The ear length was significantly higher in bed planting (10.1 cm) than that in conventional sowing (9.67 cm) but statistically at par with zero-tillage sowing (9.78 cm). However, it was observed that number of grains per ear and 1000-grain weight

were numerically higher under bed planting as compared with CT and ZT sowing methods due to better row orientation. Similar results were reported by Ram *et al.* (2012).

The time of nitrogen application did not significantly affect the plant height significantly. The effective tillers were significantly more with application of full DAP as basal along with ½ N at 30 DAS and ½ N at 60 DAS (T₂) (309.6 m⁻²) as compared with application of full DAP + ½ N at 60 DAS and ½ N at 90 DAS (T₃) (276.4 m⁻²) but statistically at par with recommended schedule i.e. full DAP + ½ N at sowing and ½ N with first irrigation (T₁) (298.8 m⁻²) and full DAP + ⅓ N at sowing, ⅓ N at 60 DAS and ⅓ N at 90 DAS (T₄) (296.9 m⁻²). The ear length and number of grains per ear were significantly higher in T₂ (10.0 cm and 59.3) as compared with T₃ (9.37 cm and 52.8) but at par with T₁ (9.92 cm and 55.8) and T₄ (10.0 cm and 57.2), respectively. However, 1000-grain weight was not affected with time of N application (Table 2).

Yield

The biological, grain and straw yields were statistically similar under different planting methods viz., zero tillage, conventional tillage and bed planting methods (Table 2). However, among the time of nitrogen application, T₂ treatment gave significantly higher biological yield (11.43 t ha⁻¹) than T₃ (9.98 t ha⁻¹) but statistically at par with T₁ (11.33 t ha⁻¹) and T₄ (11.27 t ha⁻¹). Time of N application affected the grain and straw yield significantly. The maximum grain yield was obtained with T₂ treatment which was 18.3 % higher than T₃ treatment. Straw yield was maximum in T₁ treatment which was significantly higher than T₃ but statistically at par with T₂ and T₄. Non-significant differences were observed in harvest index under different tillage based planting methods and time of N application. Melaj *et al.* (2003) also reported statistically similar grain yields under ZT and CT wheat and also observed significantly higher yield with application of nitrogen at tillering as compared with application at sowing.

Table 2. Effect of tillage based planting methods and time of nitrogen application on growth, yield attributing characters and yield of wheat (pooled data of 2 years)

Treatments	Plant height (cm) at harvest	Effective tillers m ⁻²	Ear length (cm)	Number of grains ear ⁻¹	1000-grain weight (g)	Biological yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
Tillage based planting method									
Zero tillage	91.4	294.1	9.78	56.2	36.40	11.12	4.38	6.88	39.4
Conventional tillage	91.8	302.3	9.67	55.3	34.98	11.29	4.44	6.87	39.3
Bed planting	92.6	289.8	10.1	57.3	37.23	10.60	4.33	6.18	41.0
CD (p=0.05)	NS	NS	0.28	NS	NS	NS	NS	NS	NS
Time of Nitrogen application									
Recommended (Full DAP* as basal + ½ N at sowing & ½ N at 1 st irrigation)	92.5	298.8	9.92	55.8	35.75	11.33	4.51	7.20	39.7
Full DAP as basal + ½ N at 30 DAS** & ½ N at 60 DAS	92.3	309.6	10.0	59.3	36.50	11.43	4.65	6.92	40.5
Full DAP as basal + ½ N at 60 DAS & ½ N at 90 DAS	90.4	276.4	9.37	52.8	35.14	9.98	3.93	5.61	39.7
Full DAP as basal + ⅓ N at 30 DAS, ⅓ N at 60 DAS & ⅓ N at 90 DAS	92.5	296.9	10.0	57.2	37.43	11.27	4.44	6.84	39.7
CD (p=0.05)	NS	15.2	0.31	4.08	NS	0.46	0.26	0.41	NS

*DAP- Diammonium phosphate; **DAS - Days after sowing

Table 3. Effect of tillage based planting methods and time of nitrogen application on apparent water productivity, partial factor productivity and energetics of wheat (pooled data of 2 years)

Treatments	Irrigation water applied (cm)	Apparent water productivity (kg m ⁻³)	Partial factor productivity (kg grain kg N ⁻¹)	Energy input (000 MJ ha ⁻¹)	Energy output (000 MJ ha ⁻¹)	Net energy gain (000 MJ ha ⁻¹)	Energy use efficiency	Energy productivity (g grain MJ ⁻¹)
Tillage based planting method								
Zero tillage	33.75	1.32	87.6	12.98	148.7	135.7	11.5	337.6
Conventional tillage	33.75	1.33	88.8	14.46	150.8	136.4	10.4	307.2
Bed planting	22.50	1.95	86.6	13.53	142.0	128.5	10.5	320.0
CD (p=0.05)	-	0.12	NS	-	NS	NS	0.75	NS
Time of Nitrogen application								
Recommended (Full DAP* as basal + ½ N at sowing & ½ N at 1 st irrigation)	30.0	1.57	90.1	13.64	151.7	138.0	11.1	330.9
Full DAP as basal + ½ N at 30 DAS** & ½ N at 60 DAS	30.0	1.63	92.9	13.64	153.4	139.7	11.3	341.4
Full DAP as basal + ½ N at 60 DAS & ½ N at 90 DAS	30.0	1.38	78.7	13.64	133.4	119.8	9.8	289.1
Full DAP as basal + ⅓ N at 30 DAS, ⅓ N at 60 DAS & ⅓ N at 90 DAS	30.0	1.55	88.8	13.68	150.3	136.6	11.0	325.0
CD (p=0.05)	-	0.10	5.1	-	6.7	6.7	0.48	18.6

*DAP- Diammonium phosphate; **DAS - Days after sowing

Apparent water productivity

Apparent water productivity (AWP) was significantly influenced by tillage based planting methods. The pooled data of 2 years showed that maximum AWP was obtained in bed planting (1.95 kg m^{-3}) which was 46.6 % higher than zero tillage and conventional tillage sowing methods (Table 3). Higher AWP in bed sowing method might be attributed to less irrigation water applied to beds as compared to other methods of sowing. Kaur *et al.* (2018) also reported increase in AWP under bed planting method over flat planting.

Timing of N application significantly affected the AWP (Table 3). Apparent water productivity was significantly higher in T_2 (1.63 kg m^{-3}) than T_3 (1.38 kg m^{-3}) but statistically at par with T_1 (1.57 kg m^{-3}) and T_4 (1.55 kg m^{-3}). Higher AWP due to more grain yield produced with unit quantity of irrigation water applied in T_2 , T_1 and T_4 than T_3 .

Partial factor productivity

The data (Table 3) revealed that tillage based planting methods did not affect the partial factor productivity (PFP) significantly. However, it was significantly affected by time of N application. Maximum PFP was obtained with T_2 ($92.9 \text{ kg grain kg N}^{-1}$) which was significantly higher than T_3 ($78.7 \text{ kg grain kg N}^{-1}$) but was statistically at par with T_1 ($90.1 \text{ kg grain kg N}^{-1}$) and T_4 ($88.8 \text{ kg grain kg N}^{-1}$).

Energetics

The energy requirement was lowest in zero-tillage sowing (12980 MJ ha^{-1}) followed by bed planting (13530 MJ ha^{-1}) and highest in conventional sowing (14460 MJ ha^{-1}) and was 10.24 and 4.07 % lower than conventional sowing and bed planting, respectively (Table 3). The energy output and net energy gain were not significantly affected by tillage based planting methods. However, energy output and net energy gain were highest in conventional tillage sowing followed by zero-tillage sowing and bed planting. Due to lower energy input in ZT, the energy use efficiency of zero tillage sowing was significantly

higher i.e. 10.58 and 9.52 % than conventional and bed planting, respectively. The tillage based planting methods did not affect the energy productivity significantly. However, it was highest under ZT sowing ($337.6 \text{ g grain MJ}^{-1}$) followed by bed planting ($320.2 \text{ g grain MJ}^{-1}$) and conventional sowing ($307.2 \text{ g grain MJ}^{-1}$). Kumar *et al.* (2013) also reported 13% lower energy requirement, 5% higher energy output, 17% lower specific energy use and 20% higher energy use efficiency in zero tillage sowing than conventional sowing in wheat.

The time of N application affected the energy output, net energy gain and energy use efficiency significantly. The energy output was maximum in T_2 ($153400 \text{ MJ ha}^{-1}$) which was 14.99, 2.06 and 1.12% higher than T_3 , T_4 and T_1 , respectively. Similar trend was also observed in net energy gain, energy use efficiency and energy productivity. The energy use efficiency was significantly higher in T_2 (11.3) than T_3 (9.8) but statistically at par with T_1 (11.1) and T_4 (11.0). The energy productivity of T_2 treatment was 18.09% higher over T_3 (Table 3).

Conclusions

The zero-tillage sowing helped in lowering energy requirement and enhancing energy use efficiency and energy productivity without any loss of grain yield. The application of half dose of nitrogen at 30 DAS and half at 60 DAS showed better performance with respect to growth and yield attributing characters and yield and as a result gave significantly higher apparent water productivity, nitrogen productivity, energy use efficiency and energy productivity.

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