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Effect of nitrogen point placement on energetic and soil enzymatic activities on long-term conservation agriculture based maize (*Zea mays*) - wheat (*Triticum aestivum*) system of western Indo-Gangetic plains

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ABSTRACT

A field experiment was done in the long term conservation agriculture (CA)-based plots at ICAR-Indian Agricultural Research Institute (IARI) during 2018–19 with the treatments of nitrogen (N) point/line placement to compute the energy budgeting and soil enzymatic activity. There were four land management practices in main plots and in sub plots there were three nitrogen placement methods. Results of present study showed that the energy use efficiency was higher in the CA-based PB plots by 7.14% and 9.4% than CT plots in maize and wheat respectively. The energy output from the CA-based maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) plots was significantly higher by 9.1–11.2% and 8.8–14.4% than CT plots. However, N point placement treatments i.e. NPM3 and NPM2 had 14.8% and 8.8% higher energy output than NPM1 plots in maize respectively. Similarly in wheat, NPM2 and NPM3 plots had 4.2% and 7.0% higher energy output than NPM1. The CA-based plots recorded an increase in soil microbial biomass carbon (SMBC) by 8.7–15.6% in maize and 10.1–17.2% in wheat. The SMBC content remained statistically similar across N placement methods at flowering of maize and wheat crops. In maize and wheat, at the surface soil layer urease activity was found higher than CT by 11.7–20.2% and 13.2–22.4% in the CA-based plots. However, the urease activity was not affected by subsurface point or line placement of nitrogen at both the soil layers in both the crops. Therefore, the findings of present study suggest that the adoption of CA-based practices with point/line placement of split applied N in maize-wheat system of western Indo-Gangetic plains is favourable for improving the energy use efficiency and soil enzymatic activity.

Key words: Energy use efficiency, Soil microbial biomass carbon, Soil urease activity, Zero tillage.

There are multiple benefits of conservation agriculture (CA) adoption like enhanced productivity, resource use efficiency, profitability, reduced environmental foot prints and better soil health in western Indo-Gangetic Plains of India (Jat *et al.* 2019 and Parihar *et al.* 2018). Nitrogen (N) management is an important aspect in CA, as it can synergizes the benefits from better soil health. The right placement of N in the vicinity of crop roots is important as it assures better N supply and can enhance the crop productivity. Traditionally any agronomic management is evaluated based on crop productivity and profitability. But in the era of energy intensive agriculture, energy budgeting needs to be done to evaluate the efficiency of any management practice for lowering the energy need. In recent past, many researchers (Pratibha *et al.* 2015, Jat *et al.* 2019) have evaluated the various scenario of crop production on the basis of energetics. In present study, the energy budget in point/line placement vs. surface application of N in a decade long CA was calculated. The soil urease enzyme activity is responsible for urea hydrolysis in the soil. The soil enzymatic activity is highly dependent on soil microbial carbon. Although the increment in soil organic carbon (SOC) with adoption of CA has been reported by many researchers (Parihar *et al.* 2018), how it alters the soil microbial carbon (SMBC) and soil urease activity has been evaluated in few studies that too under short or medium term CA. Present research addressed whether one season right placement of N under a decade long CA can alter the SMBC and soil urease activity.

MATERIALS AND METHODS

A field experiment was conducted to examine the

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influence of point/line placement of split applied nitrogen on energy budgeting and enzymatic activity under decade long land management plots at the experimental farm of ICAR-Indian Agricultural Research Institute, New Delhi situated (28°4' N latitude, 77°12'E longitude, 228.6 m amsl) during the rainy and the winter season of 2018–19. Maize (*Zea mays* L.) variety PMH 1 and wheat (*Triticum aestivum* L.) variety HD 2967 were grown during rainy season and winter season, respectively. There were 4-land management practices in main plots, i.e. CA-based permanent beds with residue (PB+R), zero tilled flat with residue (ZT+R), conventional tilled flat with residue (CT+R) and first time zero till flat sowing on a 10-year fallow land with residue (FZT+R) and in sub plots there were 3-nitrogen placement methods, viz. both the N splits surface applied along the crop rows (NPM1), only 1st split of N sub surface point placed in maize/line placed in wheat and 2nd split of N surface applied along the crop rows (NPM2), both the N splits sub surface point placed in maize/line placed in wheat (NPM3). The basal N application method was similar in all the sub plots. The N point/line placement was done manually.

The energy coefficients given in Table 1 were used for estimation of energy inputs and outputs (expressed in MJ/ha) for every crop management practice, by using the primary data.

All inputs energy equivalents were summed to get an estimated total energy input (MJ/ha) under every crop establishment and N placement treatment. The energy output (MJ/ha) from the biomass (grain and stover/straw) yield of maize and wheat was computed using corresponding energy coefficients given in Table 1. The energy efficiency indices were computed by below mentioned formulae:

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy output (MJ/ha)}}$$

$$\begin{array}{c}\text{Energy productivity}\\ \text{(kg/MJ)}\end{array} = \frac{\text{Out put of Grain and byproduct (kg/ha)}}{\text{Energy output (MJ/ha)}}$$

$$\begin{array}{c}\text{Energy intensity}\\ \text{(MJ/USD)}\end{array} = \frac{\text{Energy output (MJ/ha)}}{\text{Cost of cultivation (USD/ha)}}$$

Fumigation extraction method was used to determine soil microbial biomass carbon (Voroney *et al.* 1993). The assay of urease activity involves estimation of urea hydrolysis in soils (Kandeler and Gerber 1988). It was done by estimating the remaining urea after incubation at 37°C temperature for 2 h.

Table 1 Energy equivalents used for estimation of energetic in present study.

Particulars	Equivalent energy (MJ)
Inputs	
Human labor (R)[1]	
Adult man[1] (manhour)	1.96
Women[1] (womanhour)	1.57
Diesel[1] (Litre)	56.31
Farm machinery[1] (kg)	62.70
Chemical fertilizer	
N[1,2] (kg)	60.60
P_2O_5[1,2] (kg)	11.10
K_2O[1,2] (kg)	6.70
Chemicals	
Herbicides[1,2] (kg/l)	254.45
Insecticides[1,2] (kg/l)	184.63
Seed of crops	
Maize/wheat[3,4] (kg)	14.70
Outputs	
Maize/wheat grain[3,4] (kg)	14.70
Stover/straw[3,4] (kg)	12.50

[1]Mittal and Dhawan (1988), [2]Lal (2004), [3]Wang *et al.* (2015), [4]Parihar *et al.* (2018a).

RESULTS AND DISCUSSION

Energy budgeting: Energy input in maize cultivation under different tillage and N placement treatments is presented in Table 2. Energy output in maize cultivation was significantly affected by the tillage ($P<0.05$) and N placement methods ($P<0.001$), while the interaction effect was non-significant (data not presented). The CA-based PB and ZT along with the FZT plots had similar energy outputs. The smallest energy output of 1,71,578 MJ/ha was observed in the CT based maize plots (Table 2). The energy output in PB and ZT plots was 11.2% and 9.1% more than the energy output of CT based maize plots. All the three N placement methods had significantly different energy outputs. The surface crop row application of both the split applied N (NPM1) had smallest energy output of 1,71,079 MJ/ha (Table 2). However, N point placement treatments, i.e. NPM3 and NPM2 had 14.8% and 8.8% higher energy output than NPM1 plots in maize respectively. Among the interaction effects the energy output varied between 154850 MJ/ha in CT-NPM1 to 207477 MJ/ha in FZT-NPM3 (data not presented).

Tillage and N placement methods resulted in significantly different energy use efficiency (EUE), energy productivity (EP) and energy intensity (EI) in maize cultivation. The CA-based PB and ZT plots had similar EUE, whereas the EUE and EP of FZT plots were significantly lower than PB plots. The smallest EUE (3.12) and EP (0.258) were observed in the FZT plots. The EUE, EP and EI of PB and ZT were higher by 2.17–7.2%, 0.74–6.0% and 23.4–23.7% than the CT based maize plots respectively. Among the N placement methods, NPM3 had largest EUE (3.48), EP (0.286 kg/MJ) and EI (464.2 MJ/USD) followed by NPM2 and NPM1. All the three N placement methods differed significantly and NPM3 and NPM2 had 8.6–14.5%, 7.9–13.5% and 6.6–8.6% higher EUE, EP and EI than NPM1 treatment respectively (Table 2).

Similarly in wheat crop, among the tillage treatments,

Table 2 Energy budgeting of maize as affected by long-term tillage practices and N placement methods

Treatment	Input energy ($\times 10^3$ MJ/ha)	Gross output energy ($\times 10^3$ MJ/ha)	Energy use efficiency (output/input ratio)	Energy productivity (kg/MJ)	Energy intensity (MJ/USD)
Tillage & crop establishment practice					
PB+R	55.3	190.9	3.45	0.284	471.6
ZT+R	56.9	187.2	3.29	0.270	470.3
CT+R	53.3	171.5	3.22	0.268	381.2
FZT+R	60.4	188.4	3.12	0.258	472.9
SEm±	-	2.95	0.052	0.003	7.48
CD (P=0.05)	-	10.2	0.18	0.014	25.9
Nitrogen placement method					
NPM1	56.4	171.1	3.04	0.252	427.3
NPM2	56.4	186.1	3.30	0.272	455.5
NPM3	56.4	196.4	3.48	0.286	464.2
SEm±	-	2.27	0.041	0.004	5.48
CD (P=0.05)	-	6.8	0.12	0.012	16.4
Interaction (P value)		0.100	0.146	0.463	0.093
Control (CT-R) mean	6.305	134.8	21.4	1.839	336.5

PB and FZT had highest energy input (50.4×10^3 MJ/ha), followed by ZT (49.8×10^3 MJ/ha) and CT (48.3×10^3 MJ/ha). Among N placement methods, NPM2 and NPM3 had 2.9 and 4.5×10^3 MJ/ha higher energy input than NPM1, respectively (Table 3). The energy output from wheat was significantly affected by tillage and N placement methods ($P<0.01$), whereas the interaction between tillage and N placement methods was found non-significant. The energy output from the CA-based wheat plots was significantly higher by 8.8–14.4% than CT plots. The lowest energy output of 159.8×10^3 MJ/ha was observed in the CT-based wheat plots. Among N placement methods, NPM2 and NPM3 had 4.2% and 7% higher energy output than NPM1 (Table 3). The least energy output was observed in the NPM1 treatment plots of wheat (167.7×10^3 MJ/ha).

The energy use efficiency (EUE), energy productivity (EP) and energy intensity (EI) in the wheat was significantly affected by tillage practices, whereas the impact of N placement methods and interaction was non-significant. The least EUE (3.31), EP (0.248 kg/MJ) and EI (278 MJ/USD) were observed in the CT based wheat plots. The EUE, EP and EI in the PB, FZT and ZT plots of wheat was 5.5–9.4%, 5.2–8.9% and 20.6–25.2% higher than the CT, respectively (Table 3).

Table 3 Energy budgeting of wheat as affected by long-term tillage practices and N placement methods

Treatment	Input energy ($\times 10^3$ MJ/ha)	Gross output energy ($\times 10^3$ MJ/ha)	Energy efficiency (output/input ratio)	Energy productivity (kg/MJ)	Energy intensity (MJ/USD)
Tillage & crop establishment practice					
PB+R	50.5	182.8	3.62	0.270	348.0
ZT+R	49.8	173.8	3.49	0.261	335.3
CT+R	48.3	159.8	3.31	0.248	278.0
FZT+R	50.4	179.3	3.57	0.266	345.8
SEm±	-	2.67	0.05	0.003	5.07
CD (P=0.05)	-	9.24	0.184	0.013	17.5
Nitrogen placement method					
NPM1	47.3	167.7	3.54	0.265	321.4
NPM2	50.2	174.7	3.48	0.260	329.7
NPM3	51.8	179.4	3.46	0.258	329.3
SEm±	-	2.02	0.04	0.003	3.79
CD (P=0.05)	-	6.05	NS	NS	NS
Interaction (P value)		0.468	0.244	0.248	0.494
Control (CT-R) mean	10.25	86.96	8.49	0.636	165.2

There is an additional human energy input in the point/line placed treatments. Under CT, inter-cultivation (including weeding) and herbicide application involved additional human energy input and the land management in CT involved additional diesel consumption/input by ~four fold than CA. This increased the non-renewable energy inputs in CT. The largest contributor to total energy input was crop residue management (retention/incorporation). But this is a renewable form of energy. As the total stover/straw yield of both the crops was lesser in the CT plots than CA, and 1/3[rd] of the residue was incorporated in CT plots, so the renewable energy input in the CT was less than CA. Although the total energy input without inclusion of energy input from residue was higher in CT, while, with inclusion of energy inputs from residue the total energy input was lesser in CT. This is because the higher non-renewable energy input in CT being compensated by lesser renewable energy input, decreased the overall energy input in CT. The output energy was solely based on grain and straw yield multiplied by energy coefficients. So, the energy output was also observed less in the CT plots associated with lesser grain and stover/straw yield.

Soil microbial biomass carbon: The soil microbial biomass carbon (SMBC) at the flowering of maize in both the soil depths (0-10 and 10-25 cm) was significantly affected by tillage practices, whereas N placement methods did not alter the SMBC. At the surface soil layer (0-10 cm) SMBC was observed higher in the plots of ZT, PB and FZT, which was 8.7–14.3% higher than CT plots at flowering of maize. The SMBC in CT based maize plot was 408.5 µg C/g of soil (Table 4). The SMBC remained similar across N placement methods and ranged between 437.54 in NPM1 to 449.2µg C/g of soil in NPM3 plots. Across the treatments, the SMBC content at second soil layer was lower than the surface soil layer. The trend for SMBC content among tillage practices remained similar at second soil layer too. The CA-based tillage practices had 9.7–15.6% higher SMBC than CT plots during flowering of maize. The lowest SMBC was observed in the CT and NPM1 plots of maize (Table 4).

The SMBC at both the soil depths (0–10 and 10–25 cm) during winter wheat was also significantly affected by tillage practices, whereas the effect of N placement methods and interaction effects of tillage and N placement methods was non-significant. The SMBC during winter season wheat was less than the *kharif* season maize. The CA-based plots had 10.1–17.2% higher SMBC than CT wheat plots at upper soil layer. Among the N placement methods, at flowering of wheat the SMBC at surface soil layer ranged between 400.5 and 410.6 µg C/g of soil (Table 4), which was statistically similar. At the second soil layer too, the trend of SMBC was similar across the tillage treatments. Contrary to maize, where a higher reduction in SMBC was observed in the second soil layer, in wheat only a small difference in SMBC was observed between first and second soil layers. The CA-based wheat plots had 10.8–16.4% higher SMBC than CT plots at second soil layer. Across N placement methods, at second soil layer, it ranged between 383-399 µg C/g soil. With addition of crop residue the microbes get more labile pools of carbon, which they can assimilate for their growth easily. Minimum soil disturbance under the CA-based plots increases the mean residence time of various carbon pools and more special in the very labile and labile pools in the soil (Six *et al.* 2002). Availability of higher substrate under

Table 4 Soil microbial biomass carbon and urease activity in maize and wheat as affected by long-term contrasting tillage practices and N placement methods.

Treatment	Maize		Wheat		Maize		Wheat	
	SMBC (µg C/g soil)				Urease (µg NH_4^+/g soil/2 h)			
	0–10 cm	10–25 cm	0–10 cm	10–25 cm	0–10 cm	10–25 cm	0–10 cm	10–25 cm
Tillage & crop establishment practice								
PB+R	455.3	409.8	420.9	407.7	62.5	50.7	55.2	46.6
ZT+R	444.2	396.4	403.6	392.5	60.1	48.0	53.1	44.1
CT+R	408.5	361.2	366.5	354.0	53.8	44.1	46.9	39.4
FZT+R	466.9	417.7	429.6	412.1	64.7	51.3	57.4	47.3
SEm±	9.55	10.30	11.49	10.14	1.59	1.18	1.74	1.26
CD (P=0.05)	33.0	35.6	39.8	35.1	5.5	4.1	6.0	4.4
Nitrogen placement method								
NPM1	449.2	390.3	410.6	383.7	58.6	49.8	51.2	45.3
NPM2	444.5	396.5	404.4	392.1	60.3	48.5	53.3	44.3
NPM3	437.5	402.0	400.5	399.0	61.9	47.2	55.0	43.5
SEm±	8.18	11.98	8.02	11.07	1.43	1.42	1.21	1.34
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (P value)	0.999	1.000	1.000	1.000	0.415	0.774	0.221	0.776
Control (CT-R) mean	350.4	280.9	320.8	269.4	48.6	40.9	42.4	39.3

CA-based plots in form of very labile and labile carbon pools (Parihar *et al.* 2019), increases the microbial biomass carbon in the plots. The lesser SMBC in wheat might be due to lower soil temperature in the winter and types of crop residue retained in the soil. In the maize crop, legume residue, i.e. mungbean was retained/incorporated, while in the wheat crop, residue of cereal crop i.e. maize was retained/incorporated.

Soil urease activity: The urease activity at the flowering stage of maize and wheat was significantly affected by the tillage practices at both the soil layers (0–10 and 10–25 cm); urease activity was not affected by the subsurface point or line placement of nitrogen at both the soil layers. In maize, at the surface soil layer urease activity was found higher by 11.7–20.3% in the CA-based plots than CT. Urease activity was largest in the PB plot (31.25 µg NH_4^+/g soil/h) (Table 4). Across the N placement methods urease activity was observed similar at both the soil depths, but the activity at lower soil layer was lesser than the surface soil layer. Similarly, the urease activity during the flowering of wheat was lesser than the *kharif* season maize. The urease activity at surface soil in winter wheat was also higher in the CA-based plots than CT by 13.2–22.4% (Table 4). The urease activity at lower soil depth was lesser than the surface layer during the winter season wheat. Urease is mainly found in the intracellular and extracellular form in the soil. Extracellular urease enzyme productions by microbes depend on soil properties which influences the soil microbial activity (Soil organic matter content and microbial biomass carbon). Under the CA-based plots, a steady supply of carbon ensures a higher microbial activity and consecutively higher enzymatic activity. Contrary to this under the CT plots, there is rapid breakdown of organic form of carbon and dilution of SOC within the soil plough zone. This decreases the SMBC and urease activity under CT. Similar to our finding Roscoe *et al.* (2000), observed that soil urease enzyme activity was affected by the tillage practices which influence the soil property more. They had observed similar urease activity over a range of N doses. So it can be concluded that higher localized N availability for one year couldn't influence the soil enzymatic activity and SMBC significantly.

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