Indian Journal of Agricultural Sciences **92** (5): 637–42, May 2022/Article
https://doi.org/10.56093/ijas.v92i5.124789

Effect of residue and nitrogen management in maize (*Zea mays*) on mustard (*Brassica juncea*) productivity and profitability under conservation agriculture

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Received: 02 November 2021; Accepted: 27 December 2021

ABSTRACT

A field experiment was conducted during 2018–19 and 2019–20 to assess the influence of precision nitrogen management options in preceding maize (*Zea mays* L.) on succeeding mustard (*Brassica juncea* L.) under conservation agriculture in sandy loam soil of Delhi. The experiment had two main plots of with residue (WR) and without residue (WoR) retention and four sub-plot treatments of N management applied in maize {recommended dose of N (RDN), 33, 50 and 70% basal RDN +green seeker (GS) based N application} and uniform recommended dose of 90 kg N/ha was applied for mustard in all treatments. A positive response to residual plus directly applied N and residue application was observed on growth, dry matter accumulation, yield attributes, yield and nutrient uptake of mustard. On a pooled mean basis, crop residue mulching enhanced 7.1 and 8.3% in seed and stalk yield of mustard with 9.4 and 5.2% higher net returns and B:C ratio. The 50% basal RDN + GS guided N applied treatment on pooled basis gave 5.9 and 5.2% higher seed and stalk yield and 7.7 and 7.9% higher net returns and B:C ratio compared to conventional RDN. The highest land productivity in mustard was also obtained with residue retention (₹654/day) and 50% RDN +GS (₹674/day). Overall, the study concluded that zero tillage with maize residue mulching and recommended nitrogen application in mustard in rotation with 50% basal RDN+GS guided N applied maize improves the crop growth, yield attributes, yield and net returns of mustard, and could be implemented in maize-mustard cropping system under resource-poor semi-arid conditions.

Keywords: Conservation agriculture, Economics, Maize-mustard system, Precision nitrogen management, Yield

Mustard (*Brassica juncea* L.) is an important oilseed crop in India contributing nearly 23% to the oil basket but mostly grown on resource constraint moisture and nutrient-deficient areas. The mustard productivity increased from 1121 kg/ha in 2011–12 to 1331 kg/ha in 2019–20 with a range of 1083–1511 kg/ha. This inter-seasonal variation in mustard yield can be minimized with the adoption of improved management practices to match the global productivity (1980 kg/ha). The intervention of the maize-mustard cropping system has promising results in enhancing the productivity of mustard in Indo-Gangetic plains (Jat *et al.* 2019). Thus, maize-mustard is an upcoming cropping system in India and has prospects of increasing production of both crops.

India generates ~700 mt of crop residue each year of which 50 mt is being surplus (Devi *et al.* 2017) and conservation agriculture (CA) could utilize this surplus. It is gaining importance for its resource conservation, environmental sustainability and higher production of crops. Maize-mustard rotation gives better yield, soil health and profitability under conservation agriculture in western IGP (Jat *et al.* 2019 and Pooniya *et al.* 2021). Additionally, nitrogen use efficiency in agriculture ranges from 30–45%, the partial factor productivity of nitrogen (PFP_N) continuously declining due to unscientific and faulty nitrogen management practices. Therefore, precise nutrient management practices in CA and their implementation using modern tools have to play a major role not only in bridging yield gaps but also in improving nutrient use efficiency, economic profitability and reducing losses and addressing climate change issues. The use of green seeker (GS) guided *in situ* precision nitrogen management in rice and wheat has increased nutrient use efficiency and profitability in India. However, there is no/meagre information on the use of this technology in maize systems in the Indian context. Similarly, the benefit of residue retention in maize-mustard especially on the mustard crop is also not widely studied. Therefore, a study was carried out to evaluate the carryover effect of precision nitrogen management options followed

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in maize and its interaction with mustard growth, yield and economics under residue management options.

MATERIALS AND METHODS

Field experiments were conducted at the experimental farm of ICAR-Indian Institute of Maize Research, Pusa, New Delhi during the winter 2018–19 and 2019–20. The soil was sandy loam, slightly alkaline (*p*H 7.8) having 0.42% organic carbon, low in available N (240 kg/ha), medium in available P (15.2 kg/ha) and high in available potassium (240.8 kg/ha). Rainfall was well distributed during both seasons, total rainfall received during the study period was 142.9 and 306.5 mm during 2018–19 and 2019–20, respectively (effective rainfall was computed from the Cropwat model was 130.3 and 246.1 mm, respectively). The mustard crop was being grown exclusively under zero tillage since 2012 and was sown on 5th November 2018 and 25th October 2019. The experiment was designed in a split-plot with three replication having two crop residue management options [WoR-without residue and WR-with residue mulching] as main-plot treatments, and four nitrogen management [PNM_1- Recommended dose of nitrogen (RDN), PNM_2 - 33% basal RDN+ Greenseeker guided N application (33+GS), PNM_3- 50% basal RDN + GS guided N application (50+GS), PNM_4- 70% basal RDN + GS guided N application (70+GS)] as sub-plot treatments to maize. Mustard was grown as a succeeding crop after maize and was uniformly fertilized with 90 kg N/ha irrespective of treatments. Both the carry over and direct effect of N on mustard, applied in maize as PNM treatments were assessed. Mustard (cv. NRCDR-2) was planted at 45 cm × 10 cm spacing. At the initiation of the experiment, mungbean residues were applied @1.5 Mg dry residues/ha before sowing of the *kharif* maize during 2012, in all the residue added treatments (WR). Similar residue management practices were followed during successive cropping seasons, approximately lower 1/3rd of available residues of maize were anchor retained in residue added treatments (WR) in *rabi* mustard. Other recommended crop husbandry practices were used uniformly irrespective of the treatments. Observations were recorded on various growth parameters, yield components and yield by tagging five plants in each plot, destructive samples were collected for dry matter estimation on a constant oven-dry weight basis. Leaf area was measured and LAI was calculated at 30-day intervals. The crop was harvested with a sickle from the net plot area on 23rd March 2019 and 17th March 2020. The harvested part was threshed and weighed treatment wise, and grain yield was calculated at 12% moisture content and converted to kg/ha.

Statistical analysis: Data were statistically analysed using the analysis of variance technique applicable to the split-plot design. The significance of the treatment effect was determined using F-test; the means of the treatments are tested using the least significant differences (LSD) at the 5% probability level. Error variances across the years were tested for their homogeneity using Bartlett's test of variance and were found homogenous. Pooled analysis was performed considering two years of mean data. Regression analyses were carried out using MS-Excel.

RESULTS AND DISCUSSION

Growth attributes of mustard: Growth and yield attributes of mustard, viz. crop growth rate (CGR), leaf area index (LAI) and dry matter accumulation at various stages were significantly influenced by reside and precision nitrogen management (PNM) treatments applied in maize (Table 1). The year as environment significantly affected the CGR at 0–30 and 30–60 DAS where the first year had higher CGR at an early stage while in mid-stage the second year increased CGR significantly. With residue (WR) mulching, the CGR reached its peak during 30–60 DAS (8.69 g/m^2/day) and declined towards harvest. This increase in CGR in WR might be due to higher nutrient availability and optimum moisture under residue mulching as reported by Amgain and Sharma (2013). As a residual effect of the PNM applied in maize, higher growth of the crop was noticed with 50+GS and 33 + GS that was at par with RDN. The low evaporation rate due to residue and moderate N content might have influenced the crop growth.

Similarly, dry-matter accumulation (DMA) increased sharply and reached a maximum rate at 60 days after sowing thereafter it increased at slower rate (Table 1). The crop residue mulching had a non-significant effect on the DMA of mustard but had slightly higher values under residue retention (WR). This could be ascribed to the good rainfall that occurred during both the years. As a residual effect of the PNM applied in maize, higher DMA was noticed in 50+GS (31.03 g/plant on pooled basis) followed by 33+GS while consistently lower DMA was observed in 70+GS. Between 60–90 DAS, the increase in DMA by 70+GS was 33.1% only compared to 58.9, 44.0 and 40.9% in RDN, 33+GS and 50+GS, respectively. Residual soil N, not utilized by the previous crop and congenial climate created by residue might have led to a synergistic effect on crop growth rate thus resulting in higher DMA. Hariom *et al.* (2013) reported increased DMA in mustard due to nutrients applied for preceding crops. In the pooled analysis, significant interaction effects were found in Y×PNM for DMA at 30 and 60 DAS. This could partly ascribe to the addition of the residue over the years which might have enhanced the soil nutrient and moisture availability under CA. Similarly, interaction effects of CRM×PNM were also observed at 90 DAS for both years and pooled basis. The differential availability of nutrients with and without residue retention could lead to a variable performance in mustard DMA at 90 DAS.

Similar to CGR and DMA, the influence of crop residue on leaf area index (LAI) was non-significant, except the initial stage of crop LAI was remained higher in WR treatment. LAI declined towards maturity due to defoliation and foliage senescence at 90 DAS (Table 1). As a residual effect of nitrogen applied in maize, 50+GS recorded higher LAI followed by 33+GS across the phases. Higher CGR during 30–60 days coupled with higher LAI indicated higher photosynthates accumulation. This was reflected in DMA registering higher values, as LAI reached the peak after 60 DAS up to 90 DAS. Favourable growing conditions created by crop residue by supplying optimum moisture for residue decomposition, which in turn added nutrients might have increased the dry matter accumulation at later crop stages. Interaction of CRM and PNM was non-significant across the stage of the crop. Year as a source of variation had non-significantly higher LAI during the year 2019–20 at 30 and 60 DAS, while at 90 DAS 2018–19 had higher LAI.

Yield attributes of mustard: The primary and secondary branches with residue (WR) were significantly higher over WoR. Similarly, a significantly higher number of siliqua/plant and seeds/siliqua (420 and 17.1, respectively) was found in WR (Table 1). Residue improved soil fertility and conserved soil moisture might be attributed to improved yield attributes. Among PNM options a higher number of siliqua/plant and seeds/siliqua was reported in 50+GS, mostly due to higher primary and secondary branches in the same treatment. Improvement of reproductive parts in 50+GS and 33+GS might be due to efficient partitioning nutrients, photosynthates, demand-based availability of N in this treatment, which in turn, led to higher yield attributes. These findings on yield attributes are in agreement with Hariom *et al.* (2013). Interaction of CRM×PNM was significant for secondary branches and siliqua/plant. The yield attributes were not differed significantly across the years, while higher yield attributes were recorded during 2019–20.

Yield of mustard: Significantly higher mustard seed yield (2.12 t/ha) in with residue (WR) compared to without residue (WoR) was observed based on the pooled mean. This increased yield due to residue retention by 7.1% higher over WoR (Table 2). Jakhar *et al.* (2018) reported higher mustard seed yield by 11–23% due to maize crop residue applied at 4 t/ha compared to non-residue treatment. Similarly, Amgain and Sharma (2013) observed preceding crop and residue mulch increased mustard yield. Amongst the residual effect of PNM based N applied treatments in maize; higher seed yield was noticed in 50+GS (1.8 t/ha) followed by 33+GS (2.07 t/ha) and RDN (2.05 t/ha) and were at par with each other. The lowest yield of mustard was obtained in 70% basal+ GS (1.9 t/ha). However, the pooled increase in mustard seed yield under 50+GS was 5.9 and 4.8% higher compared to RDN and 33+GS, respectively. Our results are in line with the results of the response of mustard obtained to residual fertility levels in maize by Jat *et al.* (2019), in pearl millet by Hariom *et al.* (2013) and Amgain and Sharma (2013) in cluster bean. Similarly, stalk yield was higher in WR treatment over WoR was 8.3% lower than WR treatment. The mustard stalk yield differed from the N application options applied in maize where it was higher by 8.8% in 50+GS compared to 70+GS. However, the harvest index was non-significantly influenced by various treatments. The conducive effect of crop residue and previous PNM treatments could be attributed to the supply of N through mineralization, which might have improved the growing conditions for mustard. The increased yield could be explained by the positive and significant correlation of dry matter found in our study (Fig 1). A significantly higher yield (16.8%) was reported during 2019–20 and Y×PNM interaction was found to be significant indicating the accumulated residual effect of fertility on mustard seed yield. Mitra and Mandal (2012) also reported increased vegetative growth and yield attributes led to improvement in seed and stover yields.

Economics and profitability of mustard: The economic analysis of mustard cultivation revealed higher net returns and B:C ratio in WR treatments across the years by 9.4 ad 5.2% on pooled basis over WoR (Table 2). The net returns were lower during 2018–19 due to lower economic yield and as well as lower market prices while higher net returns were due to higher yield and higher market price during 2019–20. Among the PNM options, applying 50+GS in maize fletched higher net returns and B:C ratio (~17% higher) compared to 70+GS. On the pooled basis, 50+GS gave 7.7 and 7.9% higher net returns and B:C ratio compared to conventional RDN. Thus, maize fertilization with 50% RDN as basal + GS and in succeeding mustard, residue retention with recommended RDN helped in improving the crop yield and profitability under conservation agriculture. Significantly

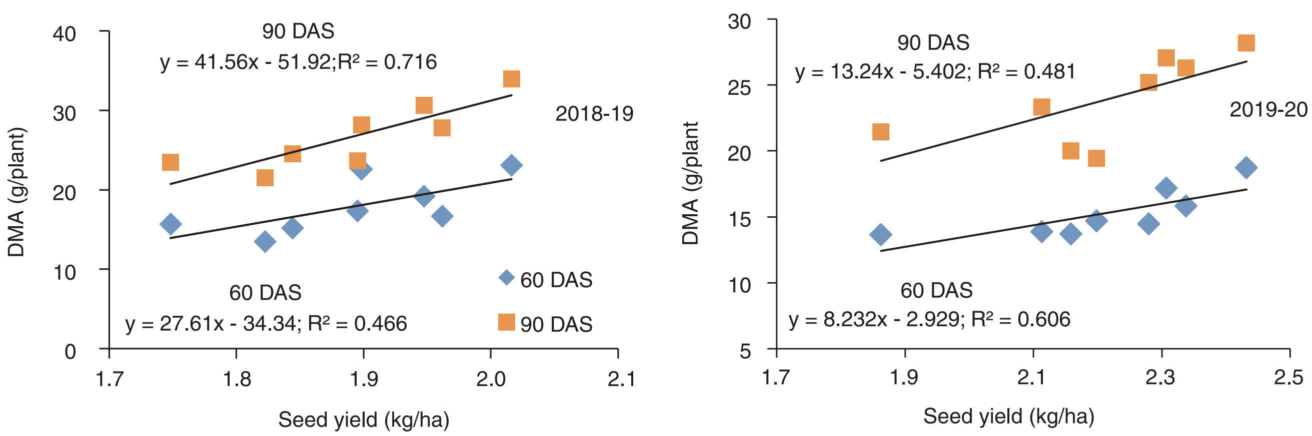

Fig 1 Correlation of dry matter accumulation and seed yield of mustard under conservation agriculture.

Table 1 Effect of crop residue and precision nitrogen management options in maize on growth and yield attributes of mustard under conservation agriculture (pooled data of two years).

Treatment	Crop growth rate (CGR) ($g/m^2/day$)			Leaf area index (LAI)			Dry matter accumulation (DMA) (g/plant)			Yield attribute			
	0-30 DAS	30-60 DAS	60-90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	Primary branches/plant	Secondary branches	Siliqua/plant	Seeds/siliqua
Crop residue management (CRM)													
WoR	1.38	7.65	3.97	1.23	2.60	2.14	2.8	18.2	25.7	3.9	19.6	374	15.3
WR	1.44	8.69	5.45	1.16	2.69	2.24	2.7	19.5	28.6	5.1	23.0	420	17.1
SEm±	0.01	0.02	0.05	0.014	0.053	0.044	0.03	0.28	0.53	0.08	0.06	7.5	0.22
LSD (P≤0.05)	NS	NS	0.21	NS	NS	NS	NS	NS	NS	0.33	0.23	NS	0.86
Precision Nitrogen Management in maize (PNM)													
RDN	1.34	7.24	5.78	1.19	2.59	2.03	2.6	17.0	27.1	3.9	19.5	357	15.3
33+GS	1.34	7.58	4.40	1.15	2.48	2.14	2.7	18.4	26.5	4.7	20.8	381	15.4
50+GS	1.47	10.29	5.28	1.22	2.90	2.38	2.7	22.0	31.0	5.4	24.5	449	18.2
70+GS	1.48	7.57	3.39	1.22	2.62	2.23	2.8	18.0	24.0	4.1	20.3	401	15.9
SEm±	0.11	0.71	0.67	0.049	0.117	0.089	0.14	1.01	0.96	0.42	0.95	22.7	0.74
LSD (P≤0.05)	NS	2.08	1.96	NS	0.341	0.259	NS	2.95	2.79	1.22	2.76	66.2	2.17
CRM×PNM	NS	NS	NS	NS	NS	NS	NS	NS	2.28	NS	1.74	54.1	NS
Year													
Year-1	1.80	8.90	4.6	1.03	2.68	2.10	2.7	18.1	25.8	4.5	19.2	363	15.9
Year-2	1.06	7.40	4.8	1.36	2.61	2.29	2.8	19.6	28.5	4.6	23.4	432	16.5
SEm±	0.028	0.12	0.26	0.014	0.053	0.044	0.03	0.28	0.53	0.08	0.06	7.5	0.22
LSD (P≤0.05)	0.023	NS	NS	0.053	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y×CRM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y×PNM	NS	NS	NS	NS	NS	0.211	0.34	2.41	NS	NS	1.84	NS	NS
Y×CRM×PNM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

WoR, Without residue; WR, With residue; RDN, Recommended dose of nitrogen (150 kg N/ha for maize), 33+GS, 50+GS and 70+GS- 33%, 50 and 70% N as basal followed by Greenseeker guided N application.

Table 2 Effect of crop residue and precision nitrogen management options in maize on yield and economics of mustard under conservation agriculture

Treatment	Seed yield (t/ha)			Stalk yield (t/ha)			Harvest Index (%)			Net returns (×10^3 ₹/ha)			BC ratio			Net returns ₹/day		
	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled	2018–19	2019–20	Pooled
Crop residue management (CRM)																		
WoR	1.83	2.13	1.98	6.89	7.34	7.11	20.98	22.50	21.74	73.4	95.3	84.3	2.37	2.99	2.68	531.8	666.4	599.1
WR	1.96	2.29	2.12	6.85	8.56	7.70	22.23	21.16	21.69	77.4	107.0	92.2	2.41	3.24	2.82	560.6	748.3	654.4
SEm±	0.027	0.031	0.004	0.163	0.066	0.088	0.331	0.202	0.0194	0.50	0.91	0.11	0.002	0.034	0.004	3.60	6.34	0.74
LSD (P≤0.05)	NS	NS	0.081	NS	0.402	0.345	NS	1.230	NS	0.70	1.28	0.41	0.003	0.049	NS	5.10	8.96	2.92
Precision Nitrogen Management in maize (PNM)																		
RDN	1.90	2.20	2.05	6.88	7.75	7.32	21.68	22.11	21.90	76.0	99.6	87.8	2.41	3.06	2.74	550.7	696.7	623.7
33+GS	1.89	2.25	2.07	6.77	8.31	7.54	21.78	21.44	21.61	74.7	104.6	89.7	2.37	3.22	2.79	541.3	731.6	636.5
50+GS	1.96	2.38	2.17	6.97	8.43	7.70	21.94	22.04	21.99	78.5	111.0	94.7	2.48	3.42	2.95	568.5	776.0	672.3
70+GS	1.82	2.01	1.92	6.85	7.30	7.07	21.03	21.72	21.38	72.4	89.4	80.9	2.29	2.75	2.52	524.3	625.2	574.8
SEm±	0.029	0.051	0.051	0.099	0.167	0.168	0.398	0.391	0.483	0.71	0.95	1.03	0.024	0.033	0.035	5.13	6.65	7.27
LSD (P≤0.05)	0.091	0.156	-0.148	NS	0.515	0.491	NS	1.204	NS	1.00	2.93	3.00	0.034	0.101	0.103	7.25	20.50	21.23
CRM×PNM	NS	NS	NS	NS	0.193	NS	NS	NS	NS	NS	1.10	2.45	NS	0.038	0.084	NS	7.68	17.34
Year																		
Year-1			1.89			6.9			21.6			75.4			2.39			546.2
Year-2			2.21			7.9			21.8			101.2			3.11			707.4
SEm±			0.021			0.09			0.19			0.52			0.017			3.64
LSD (P≤0.05)			0.0811			0.35			NS			0.52			0.068			14.31
Y×CRM			NS			NS			0.933			NS			NS			NS
Y×PNM			0.121			0.401			NS			2.45			0.137			17.34
Y×CRM×PNM			NS			0.568			NS			3.46			0.068			24.52

WoR, Without residue; WR, With residue; RDN, Recommended dose of nitrogen (150 kg N/ha for maize), 33+GS, 50+GS and 70+GS- 33%, 50 and 70% N as basal followed by Greenseeker guided N application.

higher daily net returns in mustard were obtained with WR (654 ₹/day) and 50+GS (672 ₹/day). On average, 626 ₹/day was earned in mustard due to PNM options applied in maize. These findings are in line with Hariom *et al.* (2013) and Amgain and Sharma (2013).

Nitrogen fertilizers are the major sources of GHGs emissions, their higher usage also led to crop yield reduction. Conservation agriculture and diversification of traditional cropping systems with agronomic interventions are rosy sides in that direction. Optimum N application through green seeker at right time and recycling the crop residue can mitigate GHGs emission along with improved yield levels. As per the above study, 50% N application as basal + Greenseeker based nitrogen application in maize followed by recommended N application in mustard with crop residue retention lead to robust vegetative growth, thus increasing the yield attributes and yield of mustard with enhanced economic profitability which may be adopted in semi-arid ecologies of India and similar agro-ecological situation elsewhere.

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