Maize Journal (October 2022) 11(2): 129-138

RESEARCH PAPER

Innovative approaches to enhance maize growth and yield *via* residue and nitrogen management in conservation agriculture practices

Praveen V. Kadam[1,2] · S. L. Jat[1] · A. K. Singh[1] · C. M. Parihar[2] · D. M. Mahala[1] · B. Kumar[1] · Radheshyam[1,2] · S. R. Padhan[2] · Anup Kumar[1] · Manish Kakraliya[1] · Ramniwas[1]

Abstract: A field experiment was conducted during the *kharif* season of 2018 and 2019 for exploring the influence of differential residue and nitrogen management practices on growth parameters and physiological indices of maize under conservation agriculture on a sandy loam soil at New Delhi. The treatments consisted of two cropping systems: maize-mustard-mungbean (MMuMb) and maize-wheat-mungbean (MWMb); two residue management practices of with (WR) and without residue (WoR) and four precise N management practices of recommended dose of nitrogen (RDN), 33% N at basal with green seeker (GS), 50% N at basal with GS, and 70% N at basal with GS arranged in split-split plot design and replicated thrice. The results of the study indicated that growth parameters, physiological indices and yield attributes in maize were increased significantly with residue retention and 50% N at basal with green seeker in MWMb. Higher dry matter accumulation (177.2 and 172.2 g/plant), and LAI (3.07 in second year) was recorded under 50+GS compared to RDN application. Based on pooled data of yield attributes, the highest number of cobs (65.4 10^3/ha) and cob length (19.3 cm) values were observed with the 50+GS at 90 DAS, whereas barrenness (9.2%) followed by WR (9.1%) compared with irrespective treatments. The highest grain rows per cob (17.8), grains per row (36.1) and grains per cob (453.6) in maize plants were recorded under 50+GS followed by WR (16.2, 34.6 and 414.2) as compared to other treatments.

Keywords: Conservation agriculture · Growth and yield attributes · Green seeker · Residue · Maize · Nitrogen

Introduction

Maize is grown throughout year in India and third most important cereal after wheat and rice. India needs to produce 40-45 million tons of maize to support the needs of ethanol production, growing demand from poultry. Presently maize is grown in 155 nations around the world across the agro ecologies. Maize is grown in an area of around 10 m ha, with average productivity of 3.5 tons ha^{-1} and total production of 34.15 MT (DACNET, 2022). Majority of maize produced in India 47 per cent, is used by poultry. Due to the government policies and depletion of non-renewable fuels there is boom in ethanol production increasing the demand for maize (IIMR, 2023). To meet out the tremendous need of the various industries there is need to improve the productivity and acreage without affecting the environment. Although, maize is growth throughout year, ~85 per cent of the maize is grown in *kharif* season and national average productivity of maize is low (3.4 ton /ha) compared to global average. This low productivity of maize is mainly governed by the availability of growth promoting factors such as soil moisture, declining soil fertility, poor faulty agronomic practices; lower demand based nutrient supply (Meena *et al.*, 2021; Parihar *et al.*, 2018). An Indo-Gangetic plain (IGP) is food basket of India contributing

✉ S. L. Jat: sliari@gmail.com

[1]ICAR-Indian Institute of Maize Research, Delhi Unit, Pusa Campus, New Delhi-110012, India

[2]The Post Graduate School, ICAR-Indian Agricultural Research Institute, New Delhi-110012, India

Received: 15 May 2022/ Accepted: 13 August 2022

nearly 32 per cent of cereal production. Introduction of high yielding varieties of wheat and rice along with improved production technologies secured the food needs. Monocropping, indiscriminate use of inputs (fertilizers and pesticides) use in dominant rice and wheat lead to malnutrition, diminishing total factor productivity, and natural resource degradation affect sustainability of the agro-ecosystem and economic condition of the small farmers who are already vulnerable to climate change. To break these vicious cropping systems there is need to formulate the crop and cropping system, which are more sustainable in production, economically profitable and ecological friendly. Due to its wide adoptability in various ecologies of the country, maize can be a viable alternative to rice and a potential driver for crop diversification of the rice-wheat system in IGP of India (Parihar *et al.*, 2019; Das *et al.*, 2013). Maize is an exhaustive crop and removes large amounts of plant nutrients from the soil to support high biomass production. Thus, nutrient restoring cropping systems need to be adopted, apart from Maize-wheat cropping system authors have tested various cropping systems across IGP and South East Asia namely maize- mustard (Parihar *et al.*, 2019). Along with these declined crop production and resources, India faces the challenge of factors of production like shortage of labour, shooting up of oil prices and residue burning. Cumulative effect of these constraints, forced the global and Indian farmers to find alternate to these severities. Harvesting residues should be considered as a resource that can be utilized as organic raw material, which could be used to improve soil quality and productivity though soil C sequestration. Conservation agriculture along with precise use of natural resources (water and crop residue) along with judicious use of external inputs improves the soil physical, chemical and biological properties improving the maize production in the region (Jat *et al.*, 2019; Kumar *et al*., 2020). Tillage practices enhances the soil drying and heating/cooling processes (Ussiri and Lal, 2009) as it disturbs the soil surface and thus increases the loss of N from the soil by volatilization and results in lower N use efficiency (NUE).

Nitrogen is vital nutrient requited for growth and development of crop and its deficiency is one of the constraints to growth. Nitrogen application through crop residue along with supplying the nitrogen significantly improves the soil physical, chemical and biological fertility (Gosh, 2015). Indiscriminate use of nitrogenous fertilizers in the RW cropping systems in IGP over last decades caused the land barren and multi-nutrient deficiency. Nitrogen demand in maize is peak during silking to grain filling stage (Adhikari *et al.,* 2016) Use of precision nitrogen management tools such as green seeker, SPAD meter, leaf color chars increase the synchrony between N supply and crop demand throughout the growing season reducing the losses. Precision nitrogen management tools save 10-25 per cent of in season fertilizer N (Jat *et al.*, 2019; Manjunath *et al*., 2021). Conservation agriculture practices coupled with PNM options in Maize-wheat-mungbean and fertilizer N (Meena *et al.,* 2021). Conservation agriculture practices coupled with PNM options in maize-mustard-mungbean cropping systems found to be best in IGP (Jat *et al.,* 2019; Parihar *et al.,* 2019). In IGP noted 32.3 per cent more grains, 57.4 per cent higher economic profitability along with 43.8, 27.5 and 259.8 per cent higher protein, carbohydrate and fat yields, respectively, with maize based cropping systems. Maize growth, leaf N content, chlorophyll and yield are positively correlated and indicate the higher source and sink relations. Using the canopy chlorophyll, nitrogen demand of the crop in season can be determined. Development of critical values for N dosage and relationship between spectral canopy reflectance and yield in maize under CA are limited. Management of N in CA system is new approach involving the interaction of crop residue and nitrogen and its mechanisms in crop production. To achieve the huge demand of maize in India there is a need for proper N management practices for accelerating higher production sustainably. In this view, an attempt has been made to study the response of maize growth to crop residue and PNM options under conservation agriculture.

Materials and methods

The fixed plot experiment was conducted during *kharif* 2018 and 2019 at ICAR-Indian Agricultural Research Institute, New Delhi. The trial was initiated during 2012 and the study was a part of the long-term experiment on maize-wheat-mungbean and maize-mustard-mungbean cropping system under conservation agriculture. The soil was sandy loam, slightly alkaline (pH 7.8) having 0.42 per cent 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). The weather condition was congenial for crop growth, rainfall was well distributed during both seasons. The experiment was laid out in split-split plot design, with treatment combinations of two maize based cropping systems: maize-mustard-mungbean (MMuMb) and maize-wheat-mungbean (MWMb) as main plot; two crop residue management options with residue (WR) and without residue (WoR) as sub plots and four nitrogen management [PNM_1- Recommended dose of nitrogen (RDN), PNM_2- 33% basal RDN+ Green seeker 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)]. Fertilizer application to the treatments done in the form of urea, single super phosphate and muriate of potash. Previous crop (Green gram) residue was placed in the with residue (WR) treatments, while removed from the without residue (WoR). Green seeker was used for in season N requirement calculation at 32 and 42 DAS. Maize (cv. DMH-1) was planted at 67 cm × 45 cm spacing. Recommended package of practices for plant protection, irrigation and weed management done uniformly irrespective of the treatments. The observations are recorded treatment wise and the growth attributes viz., plant height (cm), leaf area index and dry matter accumulation (g/plant) were recorded with standard procedure. The physiological indices *viz.*, crop growth rate (g/plant/day), relative growth rate (mg/g/day) and net assimilation rate (g/cm^2 leaf area/day) were also computed using standard formulae. The yield attributes viz., Cobs (10^3/ha), barrenness (%), cob length (cm), grain rows per cob, grains per row and grains per cob were recorded in maize at harvest.

The data recorded were analyzed with analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for a split-split-plot design using Microsoft excel-2010. The least significant difference tested at 5% level of significance. The Bartlett's homogeneity test was performed before pooled analysis.

Results and discussion

Plant stand at harvest stage

The data pertaining to plant stand at harvest for the individual year and pooled analysis are presented in Table 1. The cropping system (CS), crop residue management (CRM) and precision nitrogen management (PNM) was significantly influenced the final plant stand of maize. However, CS had a non-significant effect in the final plant stand with higher in MWMb (65.7 and 63.7 x10^3 plants/ha) during both the years. The WR (67.1 x10^3

Table 1. Effect of cropping systems, residue and precision nitrogen management options on plant stand of *kharif* maize crop under conservation agriculture in the study

Treatments	Plant stand at harvest (×10^3/ha)		
	2018	2019	Pooled
Cropping system (CS)			
MMuMb	65.5	61.4	63.5
MWMb	65.7	63.7	64.7
SEm±	0.53	0.59	0.40
LSD ($P \leq 0.05$)	NS	NS	NS
Crop residue management (CRM)			
WoR	64.2	57.8	61.0
WR	67.1	67.3	67.2
SEm±	0.67	0.85	0.54
LSD ($P \leq 0.05$)	2.61	3.32	1.75
Precision nitrogen management (PNM)			
RDN	63.5	62.7	63.1
33+GS	65.8	62.6	64.2
50+GS	67.9	62.6	65.3
70+GS	65.2	62.3	63.8
SEm±	2.06	1.08	1.16
LSD ($P \leq 0.05$)	6.00	NS	NS
CS ×CRM	NS	NS	NS
CS×PNM	8.48	NS	NS
CRM×PNM	8.48	4.47	NS
CS×CRM×PNM	12.00	NS	NS
Year			
Year-1	-	-	65.6
Year-2	-	-	62.5
SEm±	-	-	0.40
LSD ($P \leq 0.05$)	-	-	1.55
Y×CS	-	-	NS
Y×CRM	-	-	2.48
Y×CS×CRM	-	-	NS
Y×PNM	-	-	NS
Y×CS×PNM	-	-	NS
Y×CRM×PNM	-	-	NS
Y×CS×CRM×PNM	-	-	NS

Where; CS: Cropping system; CRM: Crop residue management; PNM: Precision nitrogen management; MMuMb: Maize-Mustard-Mungbean; MWMb: Maize-Wheat-Mungbean; WoR: Without residue; WR: With residue; RDN: Recommended dose of nitrogen; GS: Green seeker; NS: Non-significant plants/ha) and 50+GS (67.9 x10^3 plants/ha) had significantly higher final plant stands over MMuMb, WoR and the rest of PNM treatments, respectively. The second year had a significantly lower final plant stand initially compared to the first year. On the pooled basis, the residue application gave 10.2 per cent higher final plant stand over the WoR treatment. The plant population of maize was lower in case of conservation agriculture plots due to the effect of termites and resistance from the crop residue. While after, crop residue had beneficial effect providing the moisture for early growth and development. The use of 50+GS gave significant effect at final plants stand of maize over RDN, 33+GS and 70+GS during first year, while the differences were non–significant during second year (Table 2). The interactions among the treatments found inconsistent throughout the experiment. However, the Y×CRM had an interaction effect with years on the final plant stand of the maize crop indicating beneficial effect of CA on plant growth upon years (Table 1).

Growth attributes

The plant height, leaf area index and dry matter accumulation of maize was responsive to various treatments in the application and are significantly influenced at 90 DAS (Table 2). The plant height of maize shown significant difference due to crop residue and PNM options while CS has not reported a significant difference. Application of 50+GS recorded the highest plant height, RDN and 70+GS being at par with each other. Although the difference in plant height was non-significant in the years while the 2018 cropping season was higher compared to 2019, and similarly, there is no significant interaction between treatment and years.

The photosynthetic efficiency and dry matter accumulation was depends on the leaf characters, which upon depends on the nitrogen supply to the plant through soil. The leaf area index (LAI) reached highest at 60-90 days and declined at 90 DAS (Table 2). Residue added plots (WR) consistently observed the highest LAI during 2018 and 2019 as well as with pooled data at 90 DAS (3.01, 2.87 & 2.94). The congenial conditions, higher soil moisture and lower soil temperature might have favoured the maize to produce higher leaf area and index. Meena *et al.* (2021); Parihar *et al.* (2018); (2019); Jat *et al.* (2019) also observed beneficial effect of crop residue in CA. Further, the effect of PNM the LAI at 90 DAS, 70+GS reported the highest LAI after 50+GS. Higher crop residue addition from the previous crop (Wheat and Mung bean), beneficial effect of Crop residue and higher N at basal might have improved the mineralization of crop residue releasing N for longer time. This resulted in the highest LAI with MWMb × WR and WR×50+GS treatment combinations. The interaction of Y × CS × CRM was significant for 90 DAS of the crop (Table 2).

Similar observations were recorded in dry matter accumulation (DMA), MWMb cropping system, reported higher values of DMA at 90 DAS during both the years and data pooled basis (158.6, 162.8 and 160.7 g/plant) (Table 2 and Figure 1). Among CRM & PNM, the highest dry-matter production on the pooled basis was reported with the treatment combination of WR & 50+GS treatment (163.5 and 174.5 g /plant, respectively) at 90 DAS of the crop. The increase in pooled DMA at 90 DAS due to MWMb, WR, and 50+GS was 4.6, 8.3 and 17.0 per cent over MMuMb, WoR and RDN, respectively. Significant interaction of the treatments were observed among the treatments (Table 3), the MWMb cropping system combined with WR-50+GS gave significantly higher DMA at 90 DAS (197.8 g/plant). The higher value of these growth parameters due to residue application was observed, which enhanced the nutrient supply through its subsequent decomposition coupled with favourable moisture condition created conducive environment for vigorous root growth which ultimately resulted better crop growth and development (Das *et al.,* 2013; Singh *et al.,* 2007). Ram (2005) has also reported that residue retention on soil surface enhanced crop growth parameters at different crop stages as compared to its removal. In contrast to this, in temperate regions negative effect of residue retention on crop growth was noticed probably due to high initial soil organic carbon and slow residue degradation and immobilization of applied nutrients (Rice and Smith, 1984; Thuy *et al.,* 2008). Accordingly, more number of leaves with expanded leaf blade was produced consequently increased leaf area index.

Plant growth rates

The data pertaining to CGR, RGR and NAR in maize plants at 90 DAS are presented in Table 4. The cropping system tested no significant effect on CGR at 60-90 DAS during the both years. However, on the pooled data at 90 DAS,

Table 2. Effect of cropping systems, residue and nitrogen management options on plant height, LAI and DMA of *kharif* maize at 90 DAS (days after sowing) under conservation agriculture

Treatments	Plant height (cm)			LAI			DMA (g/plant)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Cropping system (CS)									
MMuMb	183.9	182.4	183.2	2.75	2.65	2.70	154.7	152.7	153.7
MWMb	187.3	182.4	184.8	2.97	2.81	2.89	158.6	162.8	160.7
SEm±	3.02	2.71	2.03	0.06	0.12	0.07	3.84	2.62	2.32
LSD ($P \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop residue management (CRM)									
WoR	182.8	179.9	181.3	2.71	2.58	2.64	150.2	151.7	150.9
WR	188.5	184.9	186.7	3.01	2.87	2.94	163.1	163.9	163.5
SEm±	2.03	1.00	1.13	0.05	0.07	0.04	1.17	1.99	1.15
LSD ($P \leq 0.05$)	NS	3.94	3.69	0.202	0.284	0.145	4.59	7.80	3.76
Precision nitrogen management (PNM)									
RDN	184.1	180.5	182.3	2.83	2.63	2.73	148.9	149.0	148.9
33+GS	183.4	182.4	182.9	2.68	2.62	2.65	143.9	154.7	149.3
50+GS	191.9	187.9	189.9	2.99	3.07	3.03	177.2	172.2	174.7
70+GS	183.1	178.7	180.9	2.94	2.59	2.77	156.5	155.2	155.8
SEm±	2.36	2.77	1.82	0.07	0.12	0.07	3.52	2.44	2.14
LSD ($P \leq 0.05$)	6.88	NS	5.17	0.21	0.35	0.20	10.27	7.11	6.09
CS ×CRM	NS	5.6	NS	NS	0.40	NS	6.49	NS	NS
CS×PNM	NS	NS	NS	0.299	NS	NS	NS	10.05	NS
CRM×PNM	NS	NS	NS	0.299	NS	NS	14.53	10.05	8.61
CS×CRM×PNM	NS	NS	NS	0.424	NS	NS	20.55	14.22	12.17
Year									
Year-1	-	-	185.6	-	-	2.86	-	-	20.7
Year-2	-	-	182.4	-	-	2.73	-	-	19.3
SEm±	-	-	2.03	-	-	0.066	-	-	2.32
LSD ($P \leq 0.05$)	-	-	NS	-	-	NS	-	-	NS
Y×CS	-	-	NS	-	-	NS	-	-	NS
Y×CRM	-	-	NS	-	-	NS	-	-	NS
Y×CS×CRM	-	-	NS	-	-	0.289	-	-	7.52
Y×PNM	-	-	NS	-	-	NS	-	-	NS
Y×CS×PNM	-	-	NS	-	-	NS	-	-	12.17
Y×CRM×PNM	-	-	NS	-	-	NS	-	-	12.17
Y×CS×CRM×PNM	-	-	NS	-	-	NS	-	-	17.21

Where; CS: Cropping system; CRM: Crop residue management; PNM: Precision nitrogen management; MMuMb: Maize-Mustard-Mungbean; MWMb: Maize-Wheat-Mungbean; WoR: Without residue; WR: With residue; RDN: Recommended dose of nitrogen; GS: Green seeker; NS: Non-significant

CGR was significantly higher in MWMb cropping system. Crop growth was maximum with WR treatment and consistently increased with the age of the crop during both years (19.8 g/plant/day). Surprisingly, the CGR was significantly influenced by PNM options at 90 DAS on pooled basis. Among PNM options, the highest CGR was recorded with 50+GS treatment at 90 (Table 4).

Relative growth rate of maize under CA was significantly influenced unlike CGR. The difference in RGR due to the cropping system and CRM was significant

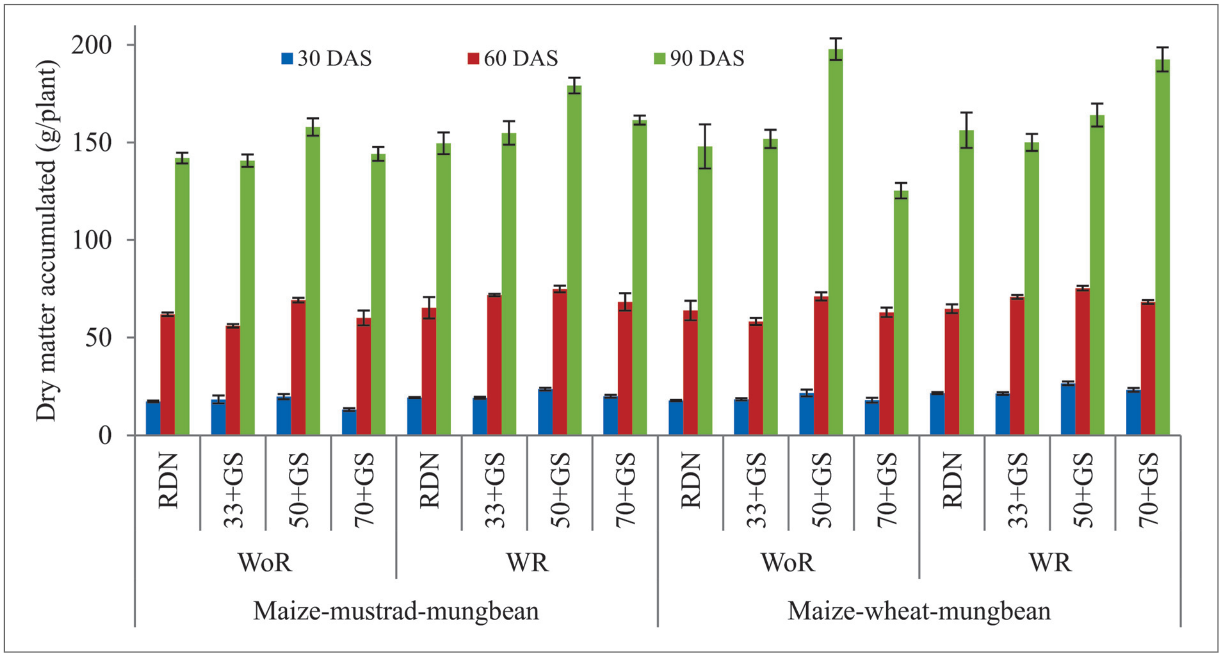

Figure 1. Dry matter accumulation in maize at different intervals as influenced by cropping systems, crop residue and PNM options under conservation agriculture (pooled mean of 2 years). The vertical bars represent the standard deviation

Table 3. Interaction effect of cropping system, residue and nitrogen management options on dry matter accumulation (DMA) of maize under conservation agriculture

CS×CRM×PNM	Pooled DMA (g/plant) at 90 DAS			
	RDN	33+GS	50+GS	70+GS
MMuMb-WoR	142.0	140.6	157.9	144.1
MMuMb-WR	149.6	154.8	179.1	161.5
MWMb-WoR	147.9	151.8	197.8	125.3
MWMb-WR	156.3	150.0	164.0	192.5
LSD *(P≤0.05)*	12.17			

at 60-90 DAS during both the years and on pooled basis (Table 4). Among PNM options, 50+GS treatment (72.9 mg/g/day) followed by RDN (71.1 mg/g/day) recorded higher RGR. The difference in mean NAR was significant only on pooled basis. No significant difference in NAR was noted due to crop residue addition during both the years as well as combined analysis. Meena *et al.* (2021) noted similar observations under maize based cropping systems under CA. Effects of residue retention's enhancement in crop growth were also reported by many workers in varied ecologies (Campbell *et al.*, 2000).

Yield Attributes

The conservation agriculture supported the robust growth of maize, which inturn positively influenced the yield attributes (Table 5 and 6). The MWMb non-significantly reported higher cobs/ha compared to MMuMb (64.9; 53.4 and 59.1×10^3). However, 11.32 per cent higher cobs/ha were produced in residue retained treatment (WR) over residue removal (WoR). Among PNM options, 50+GS treatments produced significantly higher cobs per ha, followed by 70+GS on a pooled basis. Due to PNM options, 14.38% more cobs are recorded compared to RDN and among PNM 10.9 per cent higher cobs are noted compared to 70+GS. There was a significant difference in cobs per ha due to growing seasons of 2018 and 2019, on average 20 per cent higher cobs are obtained during the 2018 cropping season compared to 2019. The failure of a plant to produce a normal ear is termed as bareness in maize. The MMuMb cropping system resulted higher barrenness (8.6%) compared to MWMb (8.0%) in the study (Table 6). Similarly, WoR recorded significantly higher barrenness (7.4%) compared to WR. Among PNM options, the lowest barrenness was recorded with 50+GS treatment (7.0%). No significant effect was observed in cob length by cropping systems while WR resulted in significantly lengthy cobs (18.4 cm) compared to WoR (17.9 cm). Application of 50+GS produced higher cob length (19.2 cm) however, 70% basal + GS treatment (18.4 cm) and 33% basal + GS (PNM2) and RDN were found statistically at par (Table 4). Yield attributes are mostly governed by the genetic

Table 4. Effect of cropping systems, residue and nitrogen management options on CGR, RGR and NAR of *kharif* maize at 60-90 DAS under conservation agriculture

Treatments	CGR (g/plant/day)			RGR (mg/g/day)			NAR (mg/cm^2 LA/day)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Cropping system (CS)									
MMuMb	17.5	17.7	17.6	71.2	70.3	70.8	4.47	4.34	4.41
MWMb	20.3	19.8	20.0	72.7	71.9	72.3	4.64	4.62	4.63
SEm±	0.78	0.55	0.48	0.17	0.25	0.15	0.051	0.078	0.047
LSD (P≤0.05)	NS	NS	1.87	1.05	1.52	0.60	NS	NS	0.184
Crop residue management (CRM)									
WoR	17.3	18.2	17.8	71.2	70.5	70.9	4.5	4.4	4.5
WR	20.5	19.3	19.9	72.7	71.7	72.2	4.6	4.6	4.6
SEm±	0.63	0.45	0.39	0.17	0.17	0.12	0.045	0.052	0.034
LSD (P≤0.05)	2.47	NS	1.26	0.67	0.66	0.39	NS	NS	NS
Precision nitrogen management (PNM)									
RDN	20.5	18.2	19.3	73.1	70.2	71.7	4.96	4.03	4.50
33+GS	15.1	17.7	16.4	69.7	70.9	70.3	4.09	4.69	4.39
50+GS	20.9	21.3	21.1	73.5	72.4	72.9	4.84	4.63	4.74
70+GS	19.2	17.8	18.5	71.5	70.9	71.2	4.33	4.57	4.45
SEm±	0.80	0.52	0.48	0.15	0.22	0.14	0.1	0.1	0.1
LSD (P≤0.05)	2.34	1.51	1.36	0.44	NS	0.38	NS	NS	0.152
CS ×CRM	NS	NS	NS	NS	NS	NS	NS	0.291	0.159
CS×PNM	NS	NS	NS	NS	NS	0.54	NS	NS	0.215
CRM×PNM	3.31	2.14	1.92	NS	NS	0.54	NS	NS	0.215
CS×CRM×PNM	4.68	NS	2.72	NS	NS	0.77	NS	NS	0.304
Year									
Year-1	-	-	18.9	-	-	72.0	-	-	4.56
Year-2	-	-	18.8	-	-	2.0	-	-	4.48
SEm±	-	-	0.48	-	-	0.15	-	-	0.047
LSD (P≤0.05)	-	-	NS	-	-	0.60	-	-	NS
Y×CS	-	-	1.87	-	-	NS	-	-	NS
Y×CRM	-	-	NS	-	-	NS	-	-	NS
Y×CS×CRM	-	-	NS	-	-	NS	-	-	0.224
Y×PNM	-	-	1.22	-	-	0.54	-	-	0.215
Y×CS×PNM	-	-	1.73	-	-	0.77	-	-	0.304
Y×CRM×PNM	-	-	NS	-	-	0.77	-	-	0.304
Y×CS×CRM×PNM	-	-	NS	-	-	1.09	-	-	0.430

Where; CS: Cropping system; CRM: Crop residue management; PNM: Precision nitrogen management; MMuMb: Maize-Mustard-Mungbean; MWMb: Maize-Wheat-Mungbean; WoR: Without residue; WR: With residue; RDN: Recommended dose of nitrogen; GS: Green seeker; NS: Non-significant

factors and seldom influenced by the management factors might be the reason for non-significance response of maize to cropping system followed.

The difference in the mean value of grain rows/cob due to the cropping system and CRM options were non-significant during both the years and in the pooled analysis (Table 6). Application of N as 50+GS significantly improved grains row/cob (36.1) on pooled analysis. Similarly, another important yield trait grains/row was significantly differed with cropping system and residue application, highest reporting from MWMb and WR (34.3 and 34.6) compared to MMuMb and WoR on pooled

Table 5. Effect of cropping systems, residue and nitrogen management options on cob parameters of *kharif* maize under conservation agriculture in the study

Treatments	Cobs (10^3/ha)			Barrenness (%)			Cob Length (cm)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Cropping system (CS)									
MMuMb	64.9	53.4	59.1	9.6	7.6	8.6	17.9	18.0	17.9
MWMb	65.1	54.4	59.8	8.0	8.0	8.0	18.0	18.6	18.3
SEm±	0.59	0.66	0.44	3.20	0.93	1.67	0.30	0.22	0.19
LSD (P≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop residue management (CRM)									
WoR	61.2	51.4	56.3	7.4	7.5	7.4	17.8	17.9	17.9
WR	68.9	56.4	62.6	10.2	8.1	9.1	18.1	18.7	18.4
SEm±	0.48	0.59	0.38	1.26	1.28	0.90	0.32	0.12	0.17
LSD (P≤0.05)	1.87	2.31	1.23	NS	NS	NS	NS	0.49	NS
Precision nitrogen management (PNM)									
RDN	64.4	49.9	57.1	8.7	7.6	8.2	17.4	17.5	17.5
33+GS	61.6	51.2	56.4	9.6	8.0	8.8	17.4	17.4	17.4
50+GS	70.0	60.7	65.4	6.6	7.3	7.0	18.7	20.0	19.3
70+GS	64.0	53.9	58.9	10.2	8.2	9.2	18.5	18.3	18.4
SEm±	1.50	0.78	0.85	4.12	3.07	2.57	0.34	0.28	0.22
LSD (P≤0.05)	4.39	2.27	2.41	NS	NS	NS	0.99	0.81	0.62
CS ×CRM	2.65	NS	1.75	NS	NS	NS	NS	NS	NS
CS×PNM	NS	3.22	NS	17.02	NS	NS	NS	NS	NS
CRM×PNM	NS	3.22	3.41	NS	NS	NS	NS	NS	0.88
CS×CRM×PNM	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year									
Year-1	-	-	65.0	-	-	8.8	-	-	18.0
Year-2	-	-	53.9	-	-	7.8	-	-	18.3
SEm±	-	-	0.44	-	-	1.67	-	-	0.19
LSD (P≤0.05)	-	-	1.73	-	-	NS	-	-	NS
Y×CS	-	-	NS	-	-	NS	-	-	NS
Y×CRM	-	-	1.75	-	-	NS	-	-	NS
Y×CS×CRM	-	-	NS	-	-	NS	-	-	1.12
Y×PNM	-	-	NS	-	-	NS	-	-	NS
Y×CS×PNM	-	-	NS	-	-	NS	-	-	NS
Y×CRM×PNM	-	-	NS	-	-	NS	-	-	NS
Y×CS×CRM×PNM	-	-	NS	-	-	NS	-	-	NS

Where; CS: Cropping system; CRM: Crop residue management; PNM: Precision nitrogen management; MMuMb: Maize-Mustard-Mungbean; MWMb: Maize-Wheat-Mungbean; WoR: Without residue; WR: With residue; RDN: Recommended dose of nitrogen; GS: Green seeker; NS: Non-significant

analysis, respectively. Grains /row were also observed highest in 50+GS (PNM3) treatment, lowest numbers of grains/row were reported from RDN. No significant differences were found in interaction for grains/row (Table 6). On pooled basis grains/cob was significantly affected by treatments except cropping system. Application of residue (WR) improved the grains/cob (414.2). The PNM options also increased the grains/cob, 50+ GS (PNM3) treatments reporting higher number of grains/cob (453.6) on pooled basis. In fact, crop residue retention improves water and nutrient availability to crop and inhibit crop-weed competition for nutrients, ultimately produced higher yield (Saad *et al.*, 2015; Radheshyam *et al*., 2021).

Table 6. Effect of cropping system, residue and nitrogen management options on yield attributes of *kharif* maize under conservation agriculture in the study

Treatments	Grain rows /Cob			Grains/row			Grains/cob		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Cropping system (CS)									
MMuMb	15.1	15.8	15.4	32.2	33.2	32.7	425.3	380.4	402.8
MWMb	15.8	16.5	16.2	33.5	35.0	34.3	427.3	377.1	402.2
SEm±	0.40	0.31	0.25	0.29	0.14	0.16	6.22	5.70	4.22
LSD ($P \leq 0.05$)	NS	NS	NS	NS	0.85	0.62	NS	NS	NS
Crop residue management (CRM)									
WoR	14.9	15.8	15.4	31.4	33.2	32.3	419.8	362.0	390.9
WR	16.0	16.5	16.2	34.3	35.0	34.6	432.8	395.5	414.2
SEm±	0.32	0.22	0.19	0.29	0.33	0.22	5.78	2.95	3.24
LSD ($P \leq 0.05$)	NS	NS	0.63	1.13	1.29	0.71	NS	11.58	10.58
Precision nitrogen management (PNM)									
RDN	14.5	15.8	15.2	31.1	31.6	31.4	399.3	340.2	369.7
33+GS	15.0	15.4	15.2	32.2	34.5	33.4	406.8	365.7	386.2
50+GS	17.6	17.9	17.8	35.9	36.2	36.1	459.6	447.5	453.6
70+GS	14.7	15.4	15.1	32.2	34.1	33.1	439.5	361.7	400.6
SEm±	0.40	0.33	0.26	0.36	0.35	0.25	10.22	11.14	7.56
LSD ($P \leq 0.05$)	1.17	0.97	0.74	1.06	1.02	0.72	29.82	32.51	21.49
CS ×CRM	NS	NS	NS	NS	NS	NS	NS	NS	NS
CS×PNM	NS	NS	1.05	NS	NS	NS	NS	NS	NS
CRM×PNM	1.65	NS	1.05	NS	NS	NS	NS	NS	30.39
CS×CRM×PNM	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year									
Year-1	-	-	15.5	-	-	32.9	-	-	426.3
Year-2	-	-	16.2	-	-	34.1	-	-	378.8
SEm±	-	-	0.25	-	-	0.16	-	-	4.22
LSD ($P \leq 0.05$)	-	-	NS	-	-	0.62	-	-	16.57
Y×CS	-	-	NS	-	-	NS	-	-	NS
Y×CRM	-	-	NS	-	-	NS	-	-	NS
Y×CS×CRM	-	-	NS	-	-	NS	-	-	NS
Y×PNM	-	-	NS	-	-	1.01	-	-	30.39
Y×CS×PNM	-	-	NS	-	-	NS	-	-	NS
Y×CRM×PNM	-	-	NS	-	-	NS	-	-	NS
Y×CS×CRM×PNM	-	-	NS	-	-	NS	-	-	NS

Where; CS: Cropping system; CRM: Crop residue management; PNM: Precision nitrogen management; MMuMb: Maize-Mustard-Mungbean; MWMb: Maize-Wheat-Mungbean; WoR: Without residue; WR: With residue; RDN: Recommended dose of nitrogen; GS: Green seeker; NS: Non-significant

Conclusion

Maize could be a scalable alternative to rice-wheat cropping system in the IGP for higher yield and profitability under CA. It was concluded that the 50% basal application of N with Green seeker (GS) and residue retention in the MWMb system was found significantly superior for enhancing growth attributes, yield and yield attributes in maize under conservation agriculture.

References

Adhikari, P., Baral, B. R. & Shrestha, J. (2016). Maize response to time of nitrogen application and planting seasons. *Journal of Maize Research and Development*, **2**(1): 83-93.

Campbell, C. A., Zentner, R. P., Liang, B. C., Roloff, G., Gregorich, E. C. & Blomert, B. (2000). Organic C accumulation in soil over 30 years in semiarid south-western Saskatchewan–effect of crop rotations and fertilizers. *Canadian Journal of Soil Science*, **80**: 179–192.

DACNET (2023). Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. https://eands.dacnet.nic.in/, Accessed on 24th July, 2023.

Das, T. K., Bhattacharyya, R., Sharma, A. R., Das, S., Saad, A. A. & Pathak, H. (2013). Impacts of conservation agriculture on total soil organic carbon retention potential under an irrigated agro-ecosystem of the western Indo-Gangetic Plains. *European Journal of Agronomy,* **51**: 34-42.

Gomez, K. A., & Gomez, A. A. (1984). Statistical procedures for agricultural research. Second Edition of An International Rice Research Institute Book, A Wiley-Inter-science Publication, John Wiley & Sons, New York.

Gosh, A. (2015). Tillage and nutrient management effects on productivity and nutrient use efficiency of maize. A M.Sc. thesis submitted to PG School, IARI, New Delhi.

IIMR, Ludhiana (2022). Indian Maize Scneario. https://iimr.icar.gov.in/india-maze-scenario/ Accessed on 24th April, 2022.

Jat, H. S., Datta, A., Choudhary, M., Sharma, P, C. & Jat, M. L. (2021) Conservation Agriculture: factors and drivers of adoption and scalable innovative practices in Indo Gangetic plains of India– a review. *International Journal of Agricultural Sustainability,* **19**(1): 40-55.

Jat, S. L., Parihar, C. M., Dey, A., Nayak, H. S., Ghosh, A., Parihar, N., Goswami, A. K. & Singh, A. K. (2019). Dynamics and temperature sensitivity of soil organic carbon mineralization under medium-term conservation agriculture as affected by residue and nitrogen management options. *Soil and Tillage Research*, **190**: 175–185.

Kumar, N., Suby, S. B., Parihar, C. M., Jat, S. L. & Gambhir, G. (2020). Earthworm activity under contrasting tillage practices and cropping pattern. *Maize Journal*, **9**(1): 56-58.

Manjunath, H., Jat, S. L., Parihar, C. M., Meena, B. R., Radheshyam, Kadam, P. V., Kumar, B. & Kumhar, B. L. (2021). Precision nutrient management influences growth, yield attributes and yield of *kharif* maize (*Zea mays* L.). *Maize Journal,* **10**(1): 46-52.

Meena, B. R., Jat, S. L., Parihar, C. M., Kumhar, B. L., Kadam, P. V., Manjunath, H., Chunendra, P., Saroha, S., Radheshyam & Kumar, A. (2021). Growth and physiological indices changes in maize with differential residue and nitrogen management under conservation agriculture. *Maize Journal*, **10**(1): 38-45.

Parihar, C. M., Yadav, M. R., Jat, S. L., Singh, A. K., Kumar, B., Pooniya, V., Pradhan, S., Verma, R. K., Jat, M. L., Jat, R. K., Parihar, M. D., Nayak, H. S. & Saharawat Y. S. (2018). Long-term conservation agriculture and intensified cropping systems: effects on growth, yield, water, and energy-use efficiency of maize in north-western India. *Pedosphere*, **28**(6): 952–963.

Parihar, M. D., Parihar, C. M., Nanwal, R. K., Singh, A. K., Jat, S. L., Nayak, H. S., Ghasal, P. C., Jewlia, H. R., Choudhary, M. & Jat, M. L. (2019). Effect of different tillage and residue management practices on crop and water productivity and economics in maize (*Zea mays*) based rotations. *The Indian Journal of Agricultural Sciences,* **89**(2): 360–366.

Radheshyam, Jat, S. L., Parihar, C. M., Kadam, P. V., Manjunath, H. & Prakash, C. (2021). Post-emergence herbicides enhance yield and profitability in Kharif maize (*Zea mays* L.). *Maize Journal,* **10**(2): 74-82.

Ram, H. (2006). Micro-environment and productivity of maize–wheat and soybean–wheat sequences in relation to tillage and planting systems. *Ph.D. Thesis,* Punjab Agricultural University, Ludhiana, Punjab, India.

Rice, C. W. & Smith, M. S. (1984). Short-term immobilization of fertilizer nitrogen at the surface of no-till and plowed soils. *Soil Science Society of American Journal,* **48**(2): 295-297.

Saad, A. A., Das, T. K., Rana, D. S. & Sharma, A. R. (2015). Productivity, resource-use efficiency and economics of maize (*Zea mays*)–wheat (*Triticum aestivum*)-greengram (*Vigna radiata*) cropping system under conservation agriculture in irrigated north-western Indo-Gangetic plains. *Indian Journal of Agronomy,* **60**(4): 502–510.

Singh, V. P., Barman, K. K., Singh, R., Singh, P. K. & Sharma, A. R. (2015). Weed management in conservation agriculture system. 2015. ICAR - Directorate of Weed Research, Jabalpur, India, 60p.

Thuy, N. H., Shan, Y., Wang, K., Cai, Z. & Buresh, R. J. (2008). Nitrogen supply in rice-based cropping systems as affected by crop residue management. *Soil Science Society of American Journal,* **72**(2): 514-523.

Ussiri, D. A. N. & Lal, R. (2009). Long-term tillage effects on soil carbon storage and carbon dioxide emissions in continuous corn cropping system from an alfisol in Ohio. *Soil Tillage & Research,* **104**: 39–47.