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RESEARCH PAPER

Growth and physiological indices changes in maize with differential residue and nitrogen management under conservation agriculture

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Abstract: A field experiment was conducted during *kharif* season 2015 for exploring 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 N management practices of control, prilled urea (PU), sulphur coated urea (SCU) and neem coated urea (NCU) arranged in split-split plot design and replicated thrice. The results of the study indicated that growth parameters, *viz.*, plant height, dry matter accumulation (DMA), leaf area and leaf area index (LAI) and physiological indices *viz.*, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) in maize were increased significantly with residue retention and coated urea application. The yield attributes of maize were also enhanced by the application of WR, MWMb and NCU. After water stress significant decrease in canopy temperature was recorded with WR (-3.39^{o}C) compared to WOR (-1.84^{o}C). The higher dry matter accumulation (218 g/plant) was recorded under MWMb compared to MMuMb (184 g/plant) cropping system. The highest and least leaf area and LAI in maize plants were recorded under NCU application and absolute control, respectively. SCU and PU remained at par with each other with respect to both leaf area and LAI. The highest SPAD values were observed with the NCU at 30 and 90 DAS, which were at par with SCU at 30 DAS and PU and SCU at 90 DAS. Thus, the basal application of NCU and residue retention in MWMb system was could be opted for enchaining growth parameters and physiological indices in maize under conservation agriculture.

Keywords: Coated urea · Conservation agriculture · Growth parameters · Maize · Residue

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Introduction

Maize, an important crop for food, feed and nutritional security in India grown in diverse agro-environments and seasons on an area of about 9.57 m ha with productivity of 3.01 t/ha and total production of 28.77 million tons (DACNET, 2021). India ranks 4th in maize area in the world but has the productivity less than half of the world's average. The bulk of the maize production in India is used as poultry feed (47 per cent). Of the rest, 14 per cent is used in the starch industry, 13 per cent is used as livestock feed, 13 per cent for food purposes, 7 per cent as processed food and 6 per cent for export and other purposes (IIMR, 2021). There is a tremendous need to increase the acreage and productivity of this crop in near future to meet rising feed, food and industrial demands, especially in view of the very fast growth in livestock and poultry sectors in India (Kar *et al.,* 2004 and 2005).

Growth and yield of any crop under a particular environment are largely governed by soil moisture, nutrients, radiation interception and the efficiency of conversion of intercepted radiation and partitioning of dry matter to grain (Kar *et al.*, 2005; Figuerola and Berliner, 2006; Kar *et al*., 2013).

In pre-green revolution era, coarse cereals including maize were the principal crops of rainy season in northern India. But with the introduction of high yielding varieties and expansion of irrigation facilities, rice has become prominent rainy season while wheat as winter crop after green revolution. Hardly less than one tonne organic manure per ha is being added to the soil, which leads to fast decline in organic matter content of soils. The ground water depletion due to over exploitation for planting of rice, as it is done in north-western Indo-Gangetic plains (IGP) two months before onset of monsoon and that has dangerously lowered the ground water level. Rice-wheat cropping system not only threatening sustainability of agro-ecosystem of IGP but also becoming less profitable due to increasing input cost; particularly conventional tillage practices and overuse of nitrogenous fertilizers through conventional method. Recently, conservation agriculture (CA) practices for crop production comprising of minimum soil mechanical manipulation, permanent soil cover and profitable crop rotation found to be useful in reduction in cost of crop production in addition to giving ecological services for lower carbon consumption/ emission and improvement in soil health. The area under CA is increasing due to shortage of labour and escalating input prices in South Asian region and practiced on 180 m ha area worldwide (Kassam *et al.*, 2019). However, in India CA is practiced only on 1.5 m ha during 2015 (Kassam *et al.*, 2019). Adoption of CA in South Asia has skewed distribution, mainly concentrated in Indo-Gangetic Plains (IGP) in India, Pakistan, Nepal and Bangladesh (Somasundaram *et al.*, 2020). Broadcasting of nitrogenous fertilizer over retained crop residue in CA may be an inefficient method of N application, due to immobilization of inorganic N, in association with the microbial breakdown of wider C: N cereal residue (Rice and Smith, 1984; Thuy *et al.*, 2008; Xu *et al.*, 2010) and greater ammonia volatilization (Janssen, 1996; Patra *et al.*, 2004), compared to application on bare soil. Despite more favourable results of CA in research, farmers are not adopting it at their field because of several reasons and one of them is improper nutrient especially N management practices. The five-split application of N in maize with recommended dose of nitrogen in ratio of 10:30:30:20:10 as basal, 4-leaf emergence, 8-leaf emergence, tassel emergence and early grain filling stages, respectively, enhances the grain yield as compared to three split application (Singh, 2010). But, at the same time split application entails more labour cost as compared to one time application and there is already a labour shortage in Indian agriculture. Moreover, the residue retention on the soil surface under CA becomes hurdle of split-urea application and lowers the NUE as part of it either volatilized or immobilized due to fraction of applied fertilizer rest on the residue and consumed by the microbes. For enhancing profitability in maize system through CA there is need to enhance fertilize N-use efficiency through use of slow release fertilizer which will also act as problem solving for labour shortage in agriculture. Hence, proper management practices requires for enhancing NUE and reducing environmental foot print in CA system. So, the review suggests that there is need of proper N management practices for accelerating adoption of CA. Keeping above-mentioned points in view, one time application of sulphur- and neem-coated urea has been compared with split application of prilled urea under CA in maize in our study.

Materials and methods

The experiment was conducted during *kharif* season 2015 in ‘9B’ block of the experimental farm of the ICAR–Indian Agricultural Research Institute, New Delhi. The field had an even topography and good drainage system. The study was a part of the long-term trial started in *Kharif* 2012. Before this, field was under maize-wheat rotation since 2007. 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 N management practices consisting absolute control, prilled urea (PU), sulphur-coated urea (SCU) and neem-coated urea (NCU) arranged in split-split plot design and replicated thrice. The soil of the experimental site was sandy loam in texture with neutral pH having low N, medium P and high K availability. The growth parameters including plant height (at harvest), leaf area index and dry matter accumulation (at 90 DAS) were recorded in maize 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 data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for split-split-plot design using SAS 9.1 software (SAS Institute, Cary, NC). The least significant difference test was used to decipher the effect of treatments at 5 per cent level of significance (P=0.05). Critical difference (CD) values for different pair-wise comparison among the treatment effect were computed.

Results and discussion

Growth parameters

There was no significant effect of cropping system on plant height of maize at harvest. However, residue application significantly increased plant height at harvest in zero-till maize compared to WoR (Table 1). The significantly taller maize plant was observed with neem-coated urea (NCU) application, which was on par with sulphur-coated urea (SCU) and prilled urea (PU). Significantly higher dry matter accumulation (218 g/plant) was recorded under MWMb compared to MMuMb (184 g/plant) cropping system. However, there was no significant effect of residue retention on DMA at 90 DAS. Among N management practices, the highest DMA was recorded with the application of NCU. Significant interaction effect of nitrogen with residue and system was also found for DMA at 90 DAS (Table 1).

The leaf area and leaf area index (LAI) of the maize were significantly enhanced by MWMb over MMuMb cropping system. Similarly, residue retention affected the leaf area and LAI significantly compared to residue removal. The highest leaf area and LAI were recorded under NCU application and SCU and PU remained at par with each other (Table 1).

The lower mineral N availability reported in our study in 0–30 cm soil depth could be the important reasons for

Table 1. Effect of cropping system, residue and nitrogen management on growth parameters in zero-till *Kharif* maize.

Treatment	Plant height (cm)	DMA (g/plant)	Leaf area (cm^2/plant)	LAI
Cropping system				
Maize-mustard-mungbean (MMuMb)	206.4	184b	4094b	3.06b
Maize-wheat-mungbean (MWMb)	210.5	218a	4911a	3.66a
LSD (p=0.05)	NS	21.1	79.5	0.0637
Residue management				
Permanent beds - residue (WoR)	205.4b	202	4125b	3.08b
Permanent beds + residue (WR)	211.5a	201	4880a	3.64a
LSD (p=0.05)	4.30	NS	72.8	0.053
Nitrogen management				
Absolute control	169.9b	122c	2874c	2.14c
N by prilled urea (PU)	222.0a	222b	4749b	3.54b
N by sulphur-coated urea (SCU)	219.9a	219b	4944b	3.69b
N by neem-coated urea (NCU)	221.9a	240a	5443a	4.06a
LSD (p=0.05)	7.85	8.4	273.6	0.2037
p values				
System	0.1338	<.0001	<.0001	<.0001
Residue	0.0337	0.7965	<.0001	<.0001
System × Residue	0.2228	0.2048	<.0671	<.0001
System × Nitrogen	0.7800	<.0001	0.0038	0.0037
Residue × Nitrogen	0.2798	<.0001	<.0001	<.0001
Nitrogen	<.0001	<.0001	<.0001	<.0001

Note: Means followed by different letters in each column are statistically different at $LSD_{0.05}$.

lower growth parameters under MMuMb system. Moreover, the enhancement in organic carbon and soil microbial activities recorded in this system might also have contributed for higher growth of maize in MWMb system. Some of the earlier studies also found cropping system effects on the crop growth parameters in maize (Thierfelder *et al.*, 2015; Parihar *et al.*, 2016). The residue retention helps in lowering down the drought stress effect in maize as evident from the very high (-3.39°C) canopy temperature depletion recorded in our study which might be the important reason behind the enhancement of growth parameters of maize in WR compared to WoR. In addition to this, the residue retention over a period of time resulted in positive changes in soil properties and hence improvement in crop growth was occurred. The residue retention led to enhancement in crop growth might be attributed to enhanced soil moisture (Erenstein and Laxmi, 2008; Choudhary *et al.*, 2019), lower weed population and improvement in soil health. The similar effects of residue retention's enhancement in crop growth were also reported by many workers in varied ecologies (Tolk *et al.*, 1999; Campbell *et al.*, 2000). 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). However, such effects were less pronounced instead reversed in tropical and sub-tropical agro-ecologies. The application of N enhanced the growth parameters in maize significantly over control and these were significantly higher in neem or sulphur-coated urea over prilled urea application. The slow and continuous supply of N with coated fertilizer (Cong *et al.*, 2010; Shivay and Prasad, 2014) to the crop lead to better photosynthesis which increased the root and shoot growth in the crop (Zhao *et al.*, 2013). The similar effects of coated fertilizer on the crop growth of maize also reported by many workers (Sharma and Prasad, 1996; Tanwar, 2014).

Table 2. Effect of cropping system, residue and nitrogen management on physiological indices in zero-till *kharif* maize

Treatment	Crop growth rate (g/plant/day)			Relative growth rate (mg/g/day)			Net assimilation rate (g/cm^2 leaf area/day)	
	0–30 DAS	30–60 DAS	60–90 DAS	0–30 DAS	30–60 DAS	60–90 DAS	30–60 DAS	60–90 DAS
Cropping system								
Maize-mustard-mungbean (MMuMb)	0.85b	1.31	3.97b	46.3b	13.7	15.1	1.401	0.088
Maize-wheat-mungbean (MWMb)	0.92a	1.53	4.82a	47.6a	14	15.7	1.801	0.033
LSD (p=0.05)	0.0346	NS	0.605	0.51	NS	NS	NS	NS
Residue management								
Permanent beds - residue (WoR)	0.84b	1.4	4.45	46.2b	14.2	15.7	1.310b	0.032b
Permanent beds + residue (WR)	0.93a	1.44	4.35	47.7a	13.5	15	1.893a	0.089a
LSD (p=0.05)	0.0351	NS	NS	0.62	NS	NS	0.484	0.043
Nitrogen management								
Absolute control	0.57d	0.93c	2.58c	41.0c	14.1	14.5b	1.802a	0.073a
N by prilled urea (PU)	0.88c	1.46b	5.09a	47.3b	14.1	16.7a	2.006a	0.104a
N by sulphur coated urea (SCU)	1.01b	1.61ba	4.67b	49.4a	13.8	14.8b	1.267b	0.031b
N by neem coated urea (NCU)	1.08a	1.68a	5.25a	50.2a	13.5	15.5ba	1.329b	0.034b
LSD (p=0.05)	0.0609	0.21	0.324	1.2	NS	1.4	0.404	0.0384
p values								
System	0.003	0.0053	<.0001	0.0011	0.5494	0.2546	0.008	0.0004
Residue	0.0004	0.6109	0.3846	0.0002	0.2497	0.1726	0.0003	0.0002
System × Residue	0.2826	0.5488	0.2039	0.0922	0.2443	0.518	0.0111	<.0001
System × Nitrogen	0.3681	0.0309	0.003	0.1421	0.0884	0.3558	0.2298	0.0005
Residue × Nitrogen	0.0069	0.2576	<.0001	0.0125	0.0972	0.0033	0.0254	0.0254
Nitrogen	<.0001	<.0001	<.0001	<.0001	0.9048	0.0182	0.0018	0.0014

Note: Means followed by different letters in each column are statistically different at $LSD_{0.05}$.

Physiological indices

The data showed that MWMb had significant effect on CGR during 0–30 and 60–90 DAS compared to MMuMb cropping system (Table 2). Residue retention also had significant effect on CGR only in first 30 days (Table 2). Among nitrogen management practices, the highest CGR was recorded with the application of NCU which was on par with the PU and SCU during 60–90 DAS and 30–60 DAS, respectively. The data showed that RGR recorded highest at younger stage (0–30 DAS) then decline gradually in all the treatments. Significantly higher RGR was recorded with MWMb cropping system and residue retention at 0–30 DAS only while NCU application at two growth stages where it was on par with SCU at 0–30 DAS and PU at 60–90 DAS (Table 2). The data on NAR of maize at various growth stages showed that there was no significant effect of cropping systems on NAR while residue retention significantly enhanced the NAR at both the stages but the increase was more at 60 DAS. Among the nitrogen treatments, significantly highest NAR was recorded with the application of PU, which was at par with control treatment (Table 2).

The MWMb system recorded higher CGR and RGR at initial crop growth stages (0–30 DAS) which could be attributed to enhanced leaf area and dry matter accumulation due to better soil nutrient supply observed in this system compared to MMuMb. Similar effects on CGR and RGR along with NAR of maize was recorded by WR compared to WoR, which thereby boost crop health under residue retention over period of time and better crop nutrition compared to WOR.

The application of N by NCU or SCU lead to enhancement in CGR, and RGR at most of the crop growth stages but the NAR of maize at various crop growth stages was higher in control. The higher NAR in the control could be attributed to lower dry weight and leaf area of the plant at initial growth stages observed in our study, which caused more net assimilation of photosynthates with per unit of leaf area in maize.

Table 3. Effect of cropping system, residue and nitrogen management on physiological stages in zero-till *kharif* maize

Treatment	Days to tasseling	Days to silking	Days to maturity	Reproductive period (days)
Cropping system				
Maize-mustard-mungbean (MMuMb)	55.3	62.8	101.1	45.9
Maize-wheat-mungbean (MWMb)	54.0	62.1	102.7	48.7
LSD (*p*=0.05)	NS	NS	NS	NS
Residue management				
Permanent beds - residue (WoR)	54.3	62.2	101.7	47.4
Permanent beds + residue (WR)	54.9	62.8	102.1	47.2
LSD (*p*=0.05)	NS	NS	NS	NS
Nitrogen management				
Absolute control	61.5a	70.0a	102.3	40.8b
N by prilled urea (PU)	51.9b	59.6b	101.3	49.4a
N by sulphur coated urea (SCU)	52.4b	60.7b	101.8	49.3a
N by neem coated urea (NCU)	52.6b	59.6b	102.2	49.6a
LSD (*p*=0.05)	2.01	2.82	NS	2.40
***p* values**				
System	0.0728	0.4448	0.0632	0.0021
Residue	0.4391	0.5513	0.3451	0.8413
System × Residue	0.5910	0.7978	0.5976	0.4856
System × Nitrogen	0.8204	0.6408	0.2379	0.5288
Residue × Nitrogen	0.8551	0.3701	0.3642	0.6779
Nitrogen	<.0001	<.0001	0.2896	<.0001
System × Residue × Nitrogen	0.5299	0.7752	0.4016	0.5774

Note: Means followed by different letters in each column are statistically different at $LSD_{0.05}$

Moreover, the application of N fertilization resulted in timely tasseling and silking in maize compared to control where it got delayed by 9 to 10 days. However, the maturity was arrived on same time, which resulted in decreasing of reproductive period of crop by almost 9 days. This could be attributed to better growth parameters of leaf area of the crop with N fertilization compared to control, which helped in achieving crop developmental stages on time.

Physiological stages

The data showed that cropping system and residue retention had no significant effect on days to 50 per cent tasseling, 50 per cent silking, maturity and reproductive period. However, days to 50 per cent tasseling and silking was recorded significantly higher in control plots (61.5 and 70 days) compared to lowest PU (51.9 days and 59.9 days) which were statistically at par with SCU and NCU (Table 3). Days to maturity were found to be non-significant with nitrogen management practices. Reproductive period recorded significantly higher with the application of NCU, which was on par with the application of PU and SCU. No interaction effect was recorded among the cropping system, residue retention and nitrogen management practices for physiological stages in maize (Table 3).

NDVI values

Normalized differential vegetation index (NDVI) value shows direct correlation with plant growth and development and is one of the indicators for plant health. Cropping system and residue retention had no significant effect on NDVI value at any crop growth stage but significantly higher NDVI was recorded in NCU at 30 DAS, which was statistically at par with PU and SCU (Table 4). At 60 and 90 DAS, PU recorded significantly higher NDVI which was on par with the SCU and NCU but significantly superior over control.

Table 4. Effect of cropping system, residue and nitrogen management on NDVI, SPAD and canopy temperature depression (CTD) in fourth zero-till *kharif* maize

Treatment	NDVI			SPAD values			CTD (^{o}C)
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	60 DAS
Cropping system (System)							
Maize-mustard-mungbean (MMuMb)	0.509	0.608	0.485	45.4	36.3	43.9	-2.45
Maize-wheat-mungbean (MWMb)	0.525	0.612	0.479	45.7	38.3	44.0	-2.78
LSD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS
Residue management (Residue)							
Permanent beds - residue (WoR)	0.524	0.603	0.473	45.5	36.9	43.6	-1.84a
Permanent beds + residue (WR)	0.510	0.617	0.491	45.6	37.7	44.3	-3.39b
LSD (*p*=0.05)	NS	NS	NS	NS	NS	NS	1.041
Nitrogen management (Nitrogen)							
Absolute control	0.404b	0.505b	0.422b	30.2c	30.9c	34.4b	-2.59
N by prilled urea (PU)	0.552a	0.658a	0.512a	48.3b	41.8a	46.9a	-2.83
N by sulphur coated urea (SCU)	0.546a	0.639a	0.486a	50.9ab	37.5b	46.1a	-2.43
N by neem coated urea (NCU)	0.566a	0.637a	0.509a	52.9a	38.9ab	48.4a	-2.61
LSD (*p*=0.05)	0.051	0.0497	0.0365	3.2026	3.2811	4.0628	NS
***p* values**							
System	0.9607	0.8088	0.5989	0.7610	0.1018	0.9528	0.3114
Residue	0.6178	0.4136	0.1745	0.9550	0.4461	0.6363	<.0001
System × Residue	0.7945	0.3143	0.1952	0.0632	0.5087	0.9057	0.7661
System × Nitrogen	0.7940	0.9918	0.1651	0.2316	0.2185	0.1298	0.1346
Residue × Nitrogen	0.4035	0.3960	0.0940	0.5619	0.5001	0.1419	0.4247
Nitrogen	0.7516	<.0001	<.0001	<.0001	<.0001	<.0001	0.8493

Note: Means followed by different letters in each column are statistically different at $LSD_{0.05}$.

SPAD values

SPAD (Soil Plant Analysis Development)/chlorophyll meter value also show direct correlation with plant growth and development and indicate plant health. The highest SPAD values were observed with the NCU at 30 and 90 DAS, which were at par with SCU at 30 DAS and PU and SCU at 90 DAS (Table 4). However, PU recorded significantly higher value at 60 DAS and was at par with NCU but the least SPAD values were in the control. The enhanced availability of N in soil lead to increased N uptake and hence the application of residue and NCU and other fertilization lead to increased values of NDVI and SPAD values as these values directly correlate with the N in leaves. The similar finding of better nutrition lead enhanced NDVI and SPAD values were also reported by Mohanty *et al*. (2015).

Canopy temperature depression (CTD)

Data on CTD were recorded at 60 DAS in maize after a dry spell of 12 days (Table 4). There was no significant effect of cropping system and nitrogen management practice on CTD, but residue retention had the significant effect on CTD compared to residue removal. More reduction in canopy temperature was recorded WR (-3.39°C) compared to WoR (-1.84°C).

Conclusion

It was concluded that the basal application of NCU and residue retention in MWMb system was found significantly superior for enhancing the growth parameters and physiological indices in maize under conservation agriculture.

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