

Original Research Article

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Impact of Tillage and Residue Management on Sustainable Food and Nutritional Security

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ABSTRACT

A field experiment was conducted during *kharif* and *rabi* in 2016-17 and 2017-18 at International Crops Research Institute for the Semi-arid Tropics, Patancheru, Hyderabad to study the influence of tillage practices and residue management practices on yield attributes and yield of maize in maize-based cropping systems under semi-arid tropics. The field experiment was laid out on broad-beds and furrows in a split-split design with four replications under rainfed conditions. Main plot consisted of two tillage practices (minimum tillage and conventional tillage), sub-plot of two crop residue management practices (residue addition and no-residue addition) and sub-sub plot of two cropping systems (Maize-chickpea sequential cropping and maize+pigeonpea intercropping system). The results revealed that equivalent yield, system productivity and nutrient content of maize did not vary significantly due to tillage practices, however, minimum tillage led to considerable yield losses. Among the residue management practices, addition of crop residue recorded significantly higher equivalent yield as compared to no residue addition. System productivity was significantly higher under residue addition and maize-chickpea cropping system. Stover nitrogen content was significantly higher under residue addition over no residue addition.

Keywords

Bio-diversity, Food,
Fuel, Fibre, Feed,
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Introduction

India is endowed with a rich and vast diversity of natural resources, particularly soil, water, weather, multipurpose trees and bio-diversity. To realize the potential of production system

on a sustained basis, efficient management of the natural resources is very crucial. With adoption of intensive agriculture to meet the varied growing demands for food, fuel, fibre, feed and fertilizer in the recent years, the natural resources are however, put under

intense strain resulting in fast degradation and lowering of their production efficiency.

Rainfed areas in India are spread across varied climatic and soil conditions where crop production is constrained by several factors. Traditional cultivation practices such as excessive tillage, harvest and removal of entire biomass, burning of the left-over stubbles in the field for preparation of clean seedbed and open grazing aggravate the soil degradation. As a result, the yield of rainfed crops in these soils is very low.

Conservation agriculture (CA) is often advocated as one of the adaptation and mitigation strategies for the climate change and conservation of natural resources. It comprises of three basic components of minimum tillage, biomass addition and crop rotations with legumes (Thierfelder *et al.*, 2013) which are considered to play major role for addressing the challenges of decline in soil health, water-table, size of land holding and factor productivity, rise in cost of cultivation and above all climate change, which are the stumbling blocks in achieving livelihood security, especially of small farm holders in semi-arid tropics.

Most conservation agriculture practices are regarded as improved soil management practices. Minimum soil disturbance increases water productivity, mulching and crop residues improve water infiltration and planting basins maximize soil moisture buffer capacity. Therefore, CA can play an important role in mitigating climate risk especially in arid and semi-arid regions. However, there are divergent views about the long-term impact of conservation agriculture on crop performance and reclamation of soil health. Even a single tillage event in a long-term no-till soil can result in losses of much of the carbon that had been gained under previous years of no tillage (Conant *et al.*, 2007).

The problem of on-farm burning of crop residues is intensifying in recent years due to shortage of human labour, high cost of removing the crop residues by conventional methods and use of combines for harvesting of crops. Burning of crop residues leads to release of soot particles and smoke causing human and animal health problems. Heat generated from the burning of crop residues elevates soil temperature causing death of active beneficial microbial population, though the effect is temporary, as the microbes regenerate after a few days. Addition of these crop residues on the soil surface may positively influence soil chemical and physical properties. Linkages of soil organic matter and soil C with soil health and yield are well established and so investments in terms of organic inputs are likely to benefit in sustainable productivity.

Maize is a major coarse cereal crop cultivated in an area of 18.3 m ha globally, and 7.87 million ha in India. Pigeonpea and chickpea are important legume crops in the drylands covering around 4.8 million ha and 11.0 million ha area globally and around 4.51 million ha and 10.7 million ha in India, respectively. Pigeon pea being deep rooted and slow-growing in its early growth stage, during which the more rapidly growing crop like maize can be conveniently intercropped to utilize the natural resources more efficiently (Willey *et al.*, 1981). Addition of crop residues under this system has enhanced the system productivity and soil health (Saad *et al.*, 2015). Inputs of nitrogen through fallen pigeon pea leaves contribute 75–90 kg N ha⁻¹ which substantially benefits a following maize crop (Sakala *et al.*, 2000). Maize-chickpea cropping sequence is one among the predominant cereal-legume cropping systems being followed in India. Though maize yields are not affected due to photo insensitive nature, the chickpea yields are greatly affected by delayed sowing. Delay in sowing of

chickpea from middle of November to middle of December reduces the yields from 2.0 to 1.5 tonnes ha⁻¹.

There are divergent views on the impacts of CA as such and there is limited reliable long-term data. Hence, there is a need for long-term studies on minimum-till and residue addition with different crops and cropping systems in different soils and under various climate conditions. The present experiment was a continuation of a previous experimental set up which started at ICRISAT in 2009. Therefore, the present study entitled “Impact of tillage and residue management on sustainable food and nutritional security” was undertaken with same tillage, residue management practices and cropping systems.

Materials and Methods

A long-term field experiment was established in *kharif*/rainy (June-Oct) 2009 season at the ICRISAT on-station farm (17.50 °N, 78.26 °E and altitude 545 m) near Hyderabad, Telangana state, India. The soil of the experimental site is a Vertisol. During the growth period, a total rainfall of 998.7 mm was received in 56 rainy days during *kharif* 2016-17 and 1108.4 mm in 61 rainy days during *kharif* 2017-18. The field experiment was laid out on broad-beds and furrows (in 1.05 m wide raised bed followed by 0.45 m wide furrow) in a split-split design with four replications under rainfed conditions. Main plot consisted of two tillage practices (minimum tillage and conventional tillage), sub-plot of two crop residue management practices (residue addition and no-residue addition) and sub-sub plot of two cropping systems (Maize-chickpea sequential cropping and maize+pigeonpea intercrop). Soil disturbance in minimum tillage plots was restricted to minor refreshing of furrows before the start of *kharif*/rainy season, while in conventional tillage plots, ploughing of field

with chisel plough, mould board plough and ridge and harrow as normal farmers’ practice was undertaken. The residues were removed completely from the no-residue addition treatment plots, while entire crop residues were chopped into finer sizes and spread over the beds after end of the crop season in the residue addition plots. Sowing of crop was done with the help of seed-cum-fertilizer drill. Maize hybrid HTM-5401 was intercropped with pigeonpea hybrid ICPH-2671 in the maize+pigeonpea intercropping system. In maize-chickpea sequential cropping system, maize hybrid HTM-5401 was grown in rotation with chickpea variety ICCV-2. The fertilizer schedule adopted for maize crop was 150, 60 and 40 kg ha⁻¹ of N, P and K respectively and for chickpea was 25 and 50 kg ha⁻¹ of N and P respectively.

Entire dose of phosphorus and potassium were applied as basal in the form of DAP and MOP respectively. Nitrogen in the form of urea after calculating the proportion supplied through DAP was applied in three splits as per schedule i.e., 1/3rd N as basal, 1/3rd N at 30 DAS and remaining 1/3rd N at 60 DAS.

Secondary nutrients S in the form of gypsum and micronutrient B in the form of solubor were applied every second year. This study documents the impacts of tillage and residue management during 8th and 9th year of the experiment i.e., during 2016-17 and 2017-18 cropping seasons. For yield estimation, destructive samples were taken in an area of 3 x 3 square metre and yields were extrapolated in kg per ha.

In respective cropping systems viz. maize – chickpea and maize + pigeonpea, yield of chickpea and pigeonpea was converted in to maize grain yield based on their market price prevailing during the season in relation to maize grain yield by using the following formula:

MEY of Chickpea (kg ha⁻¹)

$$= \frac{\text{Chickpea grain yield (kg ha}^{-1}\text{)} \times \text{MSP of chickpea (₹ . ha}^{-1}\text{)}}{\text{MSP of maize (₹ . ha}^{-1}\text{)}}$$

MEY of Pigeonpea (kg ha⁻¹)

$$= \frac{\text{Pigeonpea grain yield (kg ha}^{-1}\text{)} \times \text{MSP of Pigeonpea (₹ . ha}^{-1}\text{)}}{\text{MSP of maize (₹ . ha}^{-1}\text{)}}$$

Where MSP is minimum support price during the cropping year.

The plant samples collected for dry matter production were utilized for chemical analysis which was separated into grain and straw, dried to a constant weight in oven at 65±5 °C. The dried samples were powdered and used for chemical analysis in Charles Renard Analytical Laboratory at ICRISAT, Patancheru. Total N and Pin plant materials were determined by digesting the samples with sulphuric acid-selenium. N and P in the digests were analyzed using auto-analyzer, (Sahrawat *et al.*, 2002a). System productivity of maize-chickpea sequential cropping system was calculated by using the following equation:

$$\text{Maize-chickpea system productivity} = (\text{MEY of chickpea} + \text{Maize grain yield})/365$$

$$\text{Maize+pigeonpea system productivity} = (\text{MEY of pigeonpea} + \text{Maize grain yield})/365$$

Results and Discussion

Maize Equivalent Yield

Maize equivalent yield did not differ significantly in response to tillage practice during both years and pooled means (Table 1). However, maize equivalent yield differed significantly in response to residue management practice during both the years of study and pooled means. Significantly higher maize equivalent yield was recorded with

addition of residue over no residue addition. The percentage increase under residue addition over no residue addition was 18% and 19% in 2016-17 and 2017-18, respectively.

Maize equivalent yield tended to be higher under maize-pigeonpea cropping system and was significantly higher during 2017-18 and pooled means over maize-chickpea cropping system.

Addition of residue increased maize equivalent yield by improving the physico-chemical and biological properties of soil thereby ensuring healthy plant growth. Reduced evaporation losses and moderated soil temperature might have reduced the fluctuations in water availability to crops and increased yield of individual crops and maize equivalent yield in turn (Ramesh *et al.*, 2016).

System productivity

Significantly higher system productivity was recorded under residue addition over no residue addition (Table 2). Among the two cropping systems, significantly higher system productivity was recorded under maize-chickpea sequence over maize+pigeonpea intercropping system during 2016-17. System productivity was non-significant in response to both the cropping systems during 2017-18.

Higher system productivity under residue addition might be due to improved physico-chemical properties of the soil, increased carbon concentration creating favourable conditions for early crop growth in both the cropping systems, consequently leading to efficient photosynthesis and translocation of photosynthates from source to sink resulting in increase in crop biomass. Hence, higher total biomass yield under residue addition could have led to significant increase in system productivity (Kumar and Angadi, 2016).

Nitrogen and phosphorus content of maize stover

No significant difference was observed in the nitrogen content of maize stover in response to tillage and cropping systems during both years of study (Table 3). However, concentration of

nitrogen was found to be significantly higher under residue addition over no residue addition during both years. Concentration of phosphorus remained unaffected due to tillage, residue management and cropping systems during both the years.

Table.1 Effect of tillage and residue management practices on equivalent yield (kg ha⁻¹) of maize in maize-chickpea and maize+pigeonpea cropping systems

Treatment	Maize Equivalent Yield (kg ha ⁻¹)					
	2016-17		2017-18		Pooled	
Main plot: Tillage						
Conventional Tillage	2917		3301		3109	
Minimum Tillage	2685		3331		3008	
S.Em ±	121		95		79	
CD (=0.05)	NS		NS		NS	
Sub plot: Residue management						
No residue addition	2560		3024		2792	
Residue addition	3041		3608		3325	
S.Em ±	48		96		62	
CD (=0.05)	164		331		213	
Sub-sub plot: Cropping system						
Maize-chickpea	2765		2881		2823	
Maize+pigeonpea	2836		3751		3294	
S.Em ±	95		157		87	
CD (P=0.05)	NS		485		370	
Interaction	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)
MxS	131	NS	141	NS	114	NS
MxC	155	NS	189	NS	129	NS
SxC	106	NS	184	NS	107	NS
MxSXC	188	NS	264	NS	168	NS

Table.2 Effect of tillage and residue management practices system productivity of maize-chickpea and maize+pigeonpea cropping systems.

Treatment	System productivity (Kg ha ⁻¹ year ⁻¹)					
	2016-17		2017-18		Pooled	
Main plot: Tillage						
Conventional Tillage	35.5		26.8		31.2	
Minimum Tillage	33.3		24.2		28.8	
S.Em ±	0.81		1.09		0.92	
CD (=0.05)	NS		NS		NS	
Sub plot: Residue management						
Residue addition	31.0		23.1		27.1	
No residue	37.9		27.9		32.9	
S.Em ±	1.05		0.40		0.67	
CD (=0.05)	2.74		1.39		2.32	
Sub-sub plot: Cropping system						
Maize-chickpea	35.1		25.4		30.3	
Maize+pigeonpea	33.8		25.6		29.7	
S.Em ±	0.72		0.64		0.5	
CD (=0.05)	2.21		NS		1.7	
Interaction						
	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)
MxS	1.4	NS	1.2	NS	1.14	NS
MxC	1.1	NS	1.3	NS	1.04	NS
SxC	1.3	NS	0.8	NS	0.83	NS
MxSxC	1.7	NS	1.5	NS	1.34	NS

Table.3 Effect of tillage and residue management practices on nitrogen and phosphorus content of maize stover at harvest in maize-chickpea and maize+pigeonpea cropping systems.

Treatment	Nitrogen (%)						Phosphorus (%)					
	2016-17		2017-18		Pooled		2016-17		2017-18		Pooled	
Main plot: Tillage												
Conventional Tillage	0.52		0.36		0.44		0.05		0.04		0.05	
Minimum Tillage	0.54		0.51		0.53		0.05		0.05		0.05	
S.Em ±	0.01		0.04		0.02		0.004		0.006		0.002	
CD (=0.05)	NS		NS		NS		NS		NS		NS	
Sub plot: Residue management												
No Residue addition	0.50		0.39		0.44		0.04		0.04		0.04	
Residue addition	0.57		0.49		0.53		0.06		0.05		0.06	
S.Em ±	0.01		0.01		0.01		0.004		0.002		0.003	
CD (=0.05)	0.04		0.05		0.04		NS		NS		NS	
Sub-sub plot: Cropping system												
Maize-chickpea	0.52		0.43		0.48		0.05		0.05		0.05	
Maize+pigeonpea	0.54		0.44		0.49		0.05		0.05		0.05	
S.Em ±	0.03		0.03		0.02		0.002		0.003		0.002	
CD (P=0.05)	NS		NS		NS		NS		NS		NS	
Interaction	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)	S.Em ±	CD P(=0.05)
MxS	0.02	NS	0.05	NS	0.03	NS	0.007	NS	0.006	NS	0.003	NS
MxC	0.03	NS	0.05	NS	0.03	NS	0.006	NS	0.007	NS	0.003	NS
SxC	0.03	NS	0.03	NS	0.02	NS	0.005	NS	0.004	NS	0.003	NS
MxSXC	0.04	NS	0.06	NS	0.04	NS	0.007	NS	0.008	NS	0.004	NS

Favourable growth conditions led to improved source and in turn sink capacity of the crop creating higher demands for nutrients. Increased concentration of nutrients with addition of residue can be attributed to better availability. Incorporation of residue improves the fertility and productivity of soil in the long term (Ponnamperuma, 1984). The residue addition provided opportunities for effective recycling of the huge quantities of nutrients in the straw portion of crops. Since nutrient uptake is a function of biomass production, the rapid increase in biomass under residue addition created demand for the available nutrients, thereby leading to higher level of nutrient content (Hiel *et al.*, 2018; Suma *et al.*, 2015; Kumar and Angadi, 2016 and Bahar, 2013).

The study revealed that minimum tillage leads to losses of crop yield in comparison to conventional tillage practices as there is a reduction in plant stand due to compaction of top soil layer. Addition of crop residues proved to be beneficial in improving maize equivalent yield and system productivity by positively influencing soil and plant nutrient content and carbon concentration.

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