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# Impact of conservation agriculture practices on energy use efficiency and global warming potential in rainfed pigeonpea–castor systems

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ABSTRACT

Identification of agricultural practices which maximize crop productivity, energy use efficiency (EUE) and minimize greenhouse gas (GHG) emissions is essential. There is dearth of information in rainfed agriculture in general and conservation agriculture in particular, hence a study was conducted to assess the EUE and GHG emissions of different tillage practices like conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT) and residue levels (harvesting heights resulting in 0, 10 and 30 cm anchored residue) in pigeonpea–castor systems under semi-arid rainfed regions of India. CT recorded 30 and 31% higher energy inputs than ZT in pigeonpea and castor, respectively. The fuel consumption in ZT was 58 and 81% lower than CT in pigeonpea and castor, respectively. This lower fuel consumption in ZT reduced the GHG emissions by 21 and 23% in pigeonpea and castor, respectively, in comparison with CT. EUE and energy productivity were maximum in ZT with 10 cm anchored residue. Further, castor grown on pigeonpea residue recorded 10 and 20% higher energy inputs and GHG emissions over pigeonpea grown on castor residues. Our results indicate that, reduction in one tillage operation with residue have a minimal impact on the crop yields but have a substantial environmental benefits.



## 1. Introduction

One of the biggest challenges in agriculture during the 21st century is to meet the food and fodder demands of the growing population and livestock from decreasing per capita land availability without environmental degradation. To meet these growing demands improved agronomic practices such as intensive tillage, optimized use of fertilizers, improved crop protection practices and burning of crop residues for disposing of the residues from the field are being adopted (Ghasemi Mobtaker et al., 2010). These practices are highly productive but are energy intensive, hence have contributed to a 10-fold increase in the global energy budget since the start of the 20th century (Tandon and Singh, 2010) and increase in anthropogenic emissions of greenhouse gases (GHG) especially non-$CO_2$ emissions grew by 0.9% year$^{-1}$, with a slight increase in growth rates after 2005 (Tubiello et al., 2013). This increase in energy inputs and GHG emissions in agriculture is mostly due to higher fossil fuel combustion during farm operations especially tillage (Koga et al., 2003). Globally, with growing concern on climate change, the focus is to reduce anthropogenic GHG emissions in general and from agriculture in particular. Since the fossil energy inputs and $CO_2$ emissions are directly related (Tzilivakis et al., 2005) studies on increasing the energy use efficiency in crop production is need of the hour. Further, these studies help in development of sustainable practices with higher productivity, energy use efficiency, and preservation of natural resources and also offer opportunities for mitigation of climate change (Dalgaard et al., 2011; Dyer and Desjardins, 2003).

Among the different agro techniques, soil tillage is one of the greatest fossil fuel energy consumers and contributes about 30% of the total energy use in crop production (Singh et al., 2008) and in turn increases greenhouse gas emissions (Soni et al., 2013). Thus, reducing the energy consumption from fossil fuels in agricultural systems will lead to reduction of GHG emissions. Hence, in the current context of growing environmental concerns, reduced or zero tillage is essential, as it can reduce the negative effects of agriculture on the environment by reducing fossil fuel consumption which in turn reduces energy input, $CO_2$ emissions, wind and water erosion of soil along with the reduction in cost of cultivation (Johnson

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et al., 2005; Liebig et al., 2005). But zero tillage has not been adopted widely due to yield variability and also low yields under rainfed conditions (Giller et al., 2009). Hence, in recent times conservation agriculture (CA) which includes minimum soil disturbance, residue retention and crop rotation has emerged as an important management strategy to fight climate change while maintaining crop productivity. The benefits of individual components of CA like reduced tillage, crop rotation are well known, but the components have not been integrated properly. Many studies have been conducted on CA in rice-wheat system in irrigated Indo-Gangetic plains of south Asia (Kumar et al., 2013; Jat et al., 2009), but research in rainfed regions is limited. Further, the success of CA depends on the soil cover or residues. However, the major constraint in adoption of CA is non availability of crop residues due to competing demands of residue for fodder, fuel and also lack of suitable implements to sow the crop (Giller et al., 2009).

In India, 2/3rd of total arable land is rainfed which contributes about 44% of the food production. In the rainfed areas crop production is uncertain due to irregular weather conditions, degraded soil with low inherent soil fertility and low water holding capacity. Pigeonpea {*Cajanus cajan* (L.) Millsp.} and castor {*Ricinus communis* (L.)} are important pulse and oilseed crops of semi arid rainfed regions of India. Pigeonpea is fifth prominent grain legume crop in the world and occupies second position among pulse crop in India. More than 90% of the pigeonpea area is under rainfed conditions, which is typically characterized by recurring droughts, resulting in lower productivity. Also, castor is an important industrial oilseed crop and India accounts for 60% of area and 68% of global production. These crops require less input and are highly suitable for marginal environment. In India, these crops are largely grown by small holders, although the productivity of these crops is low due to erratic monsoon and low soil fertility.

Several studies have evaluated the energy balance (Moreno et al., 2011; Arvidsson, 2010; Tabatabaeefar et al., 2009; Singh et al., 2008) and greenhouse gas emission (Filipovic et al., 2006; Koga et al., 2003; West and Marland, 2002) in different cropping systems but very few studies have combined the energy analysis and GHG emissions from agricultural systems (Mohammadi et al., 2014; Küsterman et al., 2013; Soltani et al., 2013; Soni et al., 2013). Also, there is limited information from rainfed production systems combining different tillage methods and residue management system. Hence this study was conducted with following objectives: (i) to assess the energy input, output and energy use efficiency of CA and CT systems, and (ii) to determine the carbon input, output, $CO_2$ eq. emissions, carbon sustainability index and carbon efficiency of CA systems in pigeonpea and castor cropping systems under rainfed production systems.

## 2. Materials and methods

### 2.1. Cropping systems and treatments

Field experiments were initiated in 2009 at Hayathnagar Research Farm (HRF) of the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, India (17°23′N latitude, 78°29′E longitude, altitude 540 m above mean sea level) in

**Table 1**
Package of practices in different tillage treatments in pigeonpea–castor cropping systems.

| Crop | Month | Operation | CT | RT | ZT |
|---|---|---|---|---|---|
| Pigeonpea | April/May | Land preparation | Disk plowing once | – | – |
| | June | | Cultivator once | Cultivator once | – |
| | June (second fortnight depending on rainfall) | | Disk harrow once | Disk harrow once | – |
| | | Sowing + basal dose of fertilizer + pre emergence herbicide | Sowing + 25:50 N:P Kg ha$^{-1}$ | Sowing +25:50 N:P Kg ha$^{-1}$ | Sowing +25:50 N:P Kg ha$^{-1}$ |
| | | Pre emergence herbicide | – | Pendimethalin | Pendimethalin |
| | July | Inter-cultivation | Bullock pair + hand weeding | – | – |
| | August | Inter-cultivation/post emergence herbicides | Bullock pair + hand weeding | Quizalofop–*p*-ethyl | Quizalofop–*p*-ethyl |
| | September | Inter- cultivation | Bullock pair + hand weeding | Bullock pair + hand weeding | |
| | October and November | Plant protection | Need based plant protection measures | Need based plant protection measures | Need based plant protection measures |
| | January | Harvesting | Combiner | Combiner | Combiner |
| Castor | April/May | Land preparation | Diskplowing once | – | – |
| | June | | Cultivator once | Cultivator once | – |
| | June | | Disk harrow once | Disk harrow once | – |
| | June (second fortnight depending on rainfall | Sowing + basal dose of fertilizer + pre emergence herbicide | Sowing + 25:50 N:P kg ha$^{-1}$ | Sowing + basal fertilizer | Sowing + basal fertilizer |
| | | Pre emergence herbicide | – | Pendimethalin | Pendimethalin |
| | July | Inter-cultivation | Bullock pair + hand weeding | – | – |
| | August | Inter-cultivation/herbicides | Bullock pair + hand weeding | Quizalofop–*p*-ethyl | Quizalofop–*p*-ethyl |
| | September | Inter-cultivation | Bullock pair + hand weeding | Bullock pair + hand weeding | – |
| | September | Top dressing | N fertilizer 25 kg ha$^{-1}$ | N fertilizer 25 kg ha$^{-1}$ | N fertilizer 25 kg ha$^{-1}$ |
| | October and November | Plant protection | Need based plant protection measures | Need based plant protection measures | Need based plant protection measures |
| | December–February | Harvesting – 3 pickings, final harvest in February | Manual | Manual | Manual |

CT – conventional tillage, RT – reduced tillage, ZT – zero tillage.