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Impacts of compaction relief treatments on soil physical properties and performance of sugarcane (*Saccharum* spp.) under zonal tillage system

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ABSTRACT

An on-farm experiment was conducted at Ramu sugarcane plantation of Papua New Guinea to assess implications of alleviating soil compaction in wheel tracks under the zonal tillage production system. Under zonal tillage system only the row area is cultivated in preparation for planting the sugarcane sett and the inter-row area remains undisturbed and much compacted. Three soil tillage treatments were imposed to wheel tracks formed after planting sugarcane genotype Q198 in 2004. Treatments involved, ripping the soils in the compacted wheel track zones (with a pair of rippers), ripping and hilling the compacted soil to cane rows (with the hilling boards attached to the rippers) and a control. Millable cane and sugar yields were monitored for the plant-cane (2005) and subsequent 3 ratoons' (2006, 2007 and 2008). Millable cane yield and sugar yields were found to be consistently (in four crop cycles) and significantly ($P<0.05$) higher in ripping and hilling treatment than the ripping and control. Millable cane yield production of plant-cane and three ratoons' (cumulative) in ripping and hilling treatment was 21% greater than the control plots and sugar yields were greater by almost 6.75 t ha^{-1}, which was 24.5% higher than the control. Soil physical investigations revealed that cane rows in ripping and hilling treatment had significantly ($P<0.05$) lower soil bulk density of 1.21 g cm^{-3} in the first 30 cm soil depth compared to the 1.37 g cm^{-3} in ripped and 1.39 g cm^{-3} in control plots. Ripping and hilling the wheel tracks significantly ($P<0.05$) decreased the penetration resistance in cane rows by 29%. Beneficial effects of ripping and hilling of compacted wheel tracks was attributed to the appreciable improvement in the water infiltration rates in cane rows and consequent enhanced sub-surface (10–30 cm) moisture storage.

1. Introduction

Use of machinery with heavy axle loads and their wheel traffic are found to affect soil physical, chemical and biological properties of cane fields depending on the prevailing climatic conditions in various field crops. In the mechanized sugarcane (*Saccharum* spp.) production, effects of soil compaction and subsequent yield decline have been well documented elsewhere (Braunack and Peaty, 1999; Garside et al., 2004; Kuht and Reintam, 2004) and in Ramu sugarcane plantation of Papua New Guinea (Hartemink, 1998). Compacted soils show lower rates of water infiltration and drainage from the compacted layer; availability of nutrient and exchange of gases slows down causing aeration-related problems (Kulli et al., 2003) ultimately affecting plant growth and the crop yields. Problems of compaction can be minimized by the practice of zonal tillage system which involves planting cane double rows in beds separated by permanent wheel tracks at a spacing of 1.8 m. Such controlled traffic systems is followed widely in Australia and Ramu sugarcane plantation of Papua New Guinea (Bangita, 2010; Garside et al., 2004). There is considerable scope for the wheel tracks to be highly compacted over years of cane production cycles. Harvesters used for cane generally weigh up to 20 t and fully loaded haul-outs up to 30 t. To compound the effects of axle load on soil compaction, harvesting is done under wet conditions, which leads to wheel slip with greater potential for soil compaction (Naseri et al., 2007).

In the controlled traffic systems, preparatory tillage or zonal tillage is performed only to the cane growth zones, to remove stubbles of previous crop and to prepare seed bed for the next billet (sugarcane setts) planting; compacted wheel traffic zone is mostly untouched (Park et al., 2010). Compacted condition of the inter-row spaces is assumed to be not significant enough to affect the cane growth and yield. There are significant evidences of increased water runoff after an intense rainy event and top soil erosion due to increased compaction in wheel tracks (Cheong et al., 2009). We hypothesize that compaction left unattended in inter-row zone does affect the soil physical properties which may have detrimental effects on cane productivity and sugar yield. For testing this hypothesis two tillage treatments were imposed on to the compacted inter-row spaces between

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the cane rows and the effects of this, one-time tillage, was monitored on millable cane and sugar yields and soil physical properties as well. The study was undertaken with the objectives of assessing changes in important soil physical properties such as bulk density, soil strength, storage and infiltration rates of water, as affected by compaction relief tillage operations performed to compacted wheel traffic zone and to evaluate the effect of such tillage on millable cane stalk yield and sugar yields of sugarcane.

2. Materials and methods

2.1. Site and crop management description

A long term experiment was conducted in Ramu sugarcane plantation in Madang Province of Papua New Guinea, to assess the effect of compaction relief practices on sugarcane yield and soil properties. Ramu sugarcane plantation is owned by Ramu Agri-Industries Limited (RAIL), and is situated about 120 km from Lae City in Papua New Guinea. Experimental site was 400 m above mean sea level, at latitude 5° 50′ South and longitude 145° 40′ East. In the experimental site after preparatory tillage, cane billets (genotype, Q198) were planted in February, 2004. Crop was solely maintained under rainfed conditions. Annual rainfall of the site varies from 200 to 250 cm with mean annual temperature around 30 °C. Observed weather pattern during experimentation are presented in Fig. 1. Although there were wide diurnal fluctuations in the weather pattern, little variation was observed from year to year.

Most of the arable land under cane in Ramu is from natural grassland origin with the top soils derived from alluvial deposits from Ramu River and built up of sedimentation from its tributaries. The main taxonomic orders of the soils are Vertisols and Fluvisols characterized by cracks and swells or shrinks in changing moisture content (Hartemink, 1998). Soil physico-chemical properties of the experimental site were analyzed by standard procedures and presented in Table 1. Soils used for experiment had slightly acidic soil reaction (Anderson and Ingram, 1989). The hydrometer method was used for soil texture analysis as described by Gee and Bauder (1986) and the soil at the experimental site was of sandy clay loam texture. Cation exchange capacity and base saturation % were analyzed by 1 M ammonium acetate percolation method (Rhoades, 1982). Total organic carbon and nitrogen contents were estimated with a LECO-CN analyzer (Yeomans and Bremner, 1991).

2.2. Treatment details

According to the general cropping practice under controlled traffic system, cane is planted at 1.8 m apart with planting zone separated from the wheel traffic zones. Planting was done with a billet planter in the February, 2004. Three treatments were imposed after germination and establishment of cane in May, 2004. The treatments imposed were ripping the wheel tracks (RA), ripping and hilling (RH), and a control (Fig. 2). Treatments were imposed to plots of 0.7 ha size, laid out in completely randomized design with seven replicates.

Ripping alone (RA) treatment involved ripping the compacted soil in the wheel traffic zone and implement used for the tillage had a pair of rippers clamped onto a standard drawbar. Both rippers had shanks welded to 50 cm non-rotating shafts. The shafts were made of non-wearing steel attached to mounting brackets. The brackets were

Table 1
Physico-chemical properties of the top soil (0–15 cm) at the experiment site (February, 2004).

pH (1:2 w/v soil:water)	6.33
Total organic carbon content	26.0 g kg^{-1}
Total nitrogen	1.93 g kg^{-1}
Cation exchange capacity (CEC)	40.0 c mol (+) kg^{-1}
Base saturation	84.5%
Soil textural analysis (hydrometer method)	
Clay	365 g kg^{-1}
Silt	123 g kg^{-1}
Sand	512 g kg^{-1}
Bulk density	1.42 g cm^{-3}

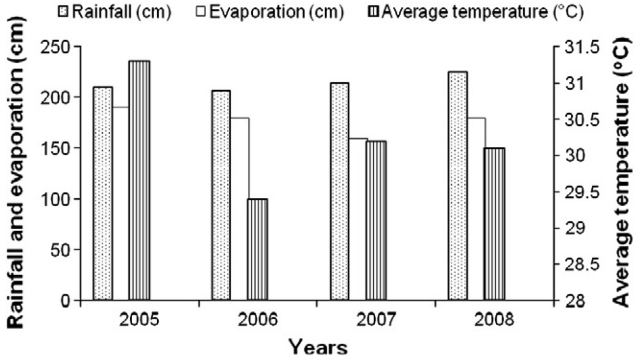

Fig. 1. Weather pattern during experimental period at Ramu sugarcane plantation, Papua New Guinea.

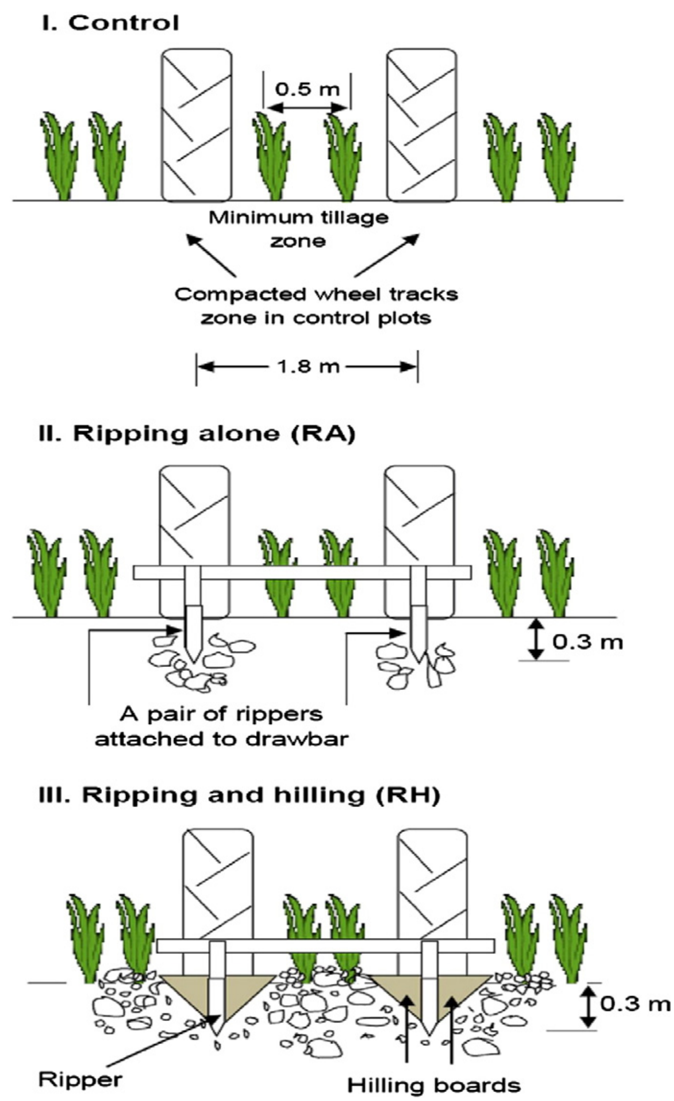

Fig. 2. Schematic diagram of the compaction alleviation treatments tested in Ramu sugarcane plantation, Papua New Guinea.