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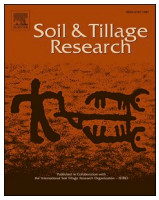

Review

Bio-tillage: A new perspective for sustainable agriculture

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ABSTRACT

For sustainable agricultural production, we propose bio-tillage, which is defined as improving soil structure with plant roots to boost the growth of crops, in this paper. Cover crops with thick and deep roots can be used for bio-tillage since they can effectively improve soil structure and water and air conductivity by forming biopores (root channels), which provide space with the least resistance and a high level of oxygen and nutrients to promote root growth. The effect of bio-tillage on crop yields varies with climate conditions and management practices. An effective bio-tillage cover crop should have thick and deep roots with rapid root growth rates, rapid decomposition of remnant roots, and good adaption to climate and soil constraints. Planting cover crops in a timely manner and eliminating them at a suitable stage with a roller-crimper can benefit bio-tillage. The limited understanding of ideal biopore architecture for root growth, more effective bio-tillage cover crop species, and field management of bio-tillage, needs to be addressed before a wide application of bio-tillage.

1. Introduction

Achieving the Zero Hunger target for the Sustainable Development Goals of the United Nations by 2030 is an immense challenge, as approximately 820 million people (slightly below 11 percent of the world population) were still considered hungry in 2019 (FAO et al., 2019). Though, in recent decades, the world has seen a remarkable increase in food production, 280 % in Asia, 200 % in Latin America and the USA, and 68 % in Western Europe, mostly due to the extensive use of new crop varieties and livestock breeds, chemical fertilizers, pesticides and machinery in agriculture (Pretty and Bharucha, 2014). Agricultural intensification for food production has resulted in severe biodiversity losses, environmental pollution and soil degradation, threatening the welfare of humanity (Gomiero, 2016; Lanz et al., 2018; Evans et al., 2019). Sustainable agriculture, which involves maintaining crop production with less inputs while protecting natural resources and environments, is receiving increasing attention as a mechanism to achieve global sustainable development (Brooker et al., 2016; Flora, 2018). Soils are basic to agricultural production and supply fundamental ecological services for human beings, such as carbon sequestration, regulation of water and nutrient cycling, disposal of wastes, and maintenance of biodiversity (Adhikari and Hartemink, 2016; Greiner et al., 2017). Thus, sustainable soil management must be considered when moving towards sustainable agriculture.

Tillage has a history as long as that of the human shift from gathering and hunting to sedentary and settled agriculture (Hobbs et al., 2008). Tillage has played a vital role in agricultural production for thousands of years and has become a synonym of agriculture. There are many benefits that tillage can provide to farmers, such as preparing favorable soil structure for seeds and seedlings, inhibiting weeds, insects and plant diseases, incorporating crop residues and amendments to the soil, promoting soil aeration and releasing of nutrients through mineralization of soil organic matter (Gebhardt et al., 1985; Triplett and Dick, 2008). However, tillage also has detrimental effects on soil resources and the environment. Conventional tillage with heavy machinery usually results in severe subsoil compaction, which limits air aeration and water infiltration of subsoil and consequently restricts crop root growth and yield (Horn, 2004; Horn and Smucker, 2005; Dang et al., 2006). Conventional tillage usually degrades soil fertility because soil organic matter is oxidized quickly in loosened soil, and consequently, soil erosion easily occurs due to heavy rain and wind (Gao et al., 2016b; Peng et al., 2016). One of the best-known examples of this scenario was the tragic dust storm that devastated a wide area of the mid-western United States in the 1930s, which woke up farmers and scientists to reflect on how to manage the soil sustainably (Lal et al., 2007). After that, a move to protect soil by reducing tillage and maintaining soil covered, termed

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