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Minimum tillage and residue management increase soil water content, soil organic matter and canola seed yield and seed oil content in the semiarid areas of Northern Iraq

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ABSTRACT

Intensive tillage-based agricultural system is a major cause of soil deterioration and reduction in agricultural productivity in the semiarid areas of northern Iraq. A two year (2009–2011) field study was conducted in Mosul, Nineveh, Northern Iraq. The objectives of this study were to investigate the effect of tillage and residue management on soil water content (SWC), soil organic matter (SOM) and canola (*Brassica napus* L.) seed yield and seed oil content. The two tillage systems used were conventional tillage (CT) and minimum tillage (MT). Three levels of wheat residue were incorporated into the soil at 0, 2, and 4 t ha^{-1}. Soil samples were collected from a depth of 0–15 cm at germination, flowering and maturity of canola from a clay loam USDA classified soil. The greatest overall SWC was observed in MT and 4 t ha^{-1} of residue, and the high SWC trend was particularly pronounced in 2010 at the critical period of flowering. In 2011, both 2 and 4 t ha^{-1} of residue increased SOM by 14 and 18%, respectively, compared with no residue treatment. Residue treatments showed no significant effect on SOM in 2010. Seed oil content was generally greater in MT and 4 t ha^{-1} of residue with an average increase of 10 and 20% compared with CT and no residue treatments, in 2010 and 2011, respectively. In 2010, MT with 4 t ha^{-1} of residue resulted in 24% increase in canola seed yield compared with CT without residue. Canola seed yield of the CT with 4 t ha^{-1} of residue was approximately 1617 kg ha^{-1} which was 18% greater than the yield recorded at CT without residue. Thus, appropriate residue management could improve soil quality and agricultural productivity in rainfed semiarid areas using minimum tillage systems.

1. Introduction

The long-term sustainability of dryland farming in northern Iraq depends on the ability to develop appropriate farming practices that arrest or even reverse the detrimental effects of tillage on soil physical and chemical properties. Whilst several countries around the world have developed highly productive, profitable and sustainable farming approaches based on minimizing tillage practices, the Iraqi agricultural systems have remained heavily dependent on tillage. Farmers are accustomed to till their lands twice a year, to control weeds and to prepare fine seedbeds. However, extensive and unnecessary cultivations disrupt soil physical properties and reduce its organic matter (Ahmad et al., 1996; Das et al., 2014; Kuotsu et al., 2014; Roper et al., 2013). As a result, drylands productivity in northern Iraq have dropped by more than 40% in the last two decades (Hussein et al., 2007; Jaradat, 2003). This addresses an urgent need for developing farming practices that are able to improve soil quality and crop productivity.

The interest in reducing tillage operations has grown dramatically, particularly in the rainfed cereals agrosystems where this technique has proven to increase soil water recharge and the amount of the available water for sufficient crop yields (Kahlon et al., 2013; Nielsen, 1997). Agriculture in semiarid areas of northern Iraq often experiences considerable annual variation in crop yield and profitability due to two direct reasons. Rainfall volume and distribution during the season. Therefore, this variable rainfall conditions should be accounted for when evaluating the production potential for any alternative cropping systems.

Minimum tillage (MT) is not a new approach. However, the concept of minimizing soil disturbance clashes with most Iraqi farmers who used to plow the soil to obtain softer seedbeds. For the farmers, minimally tilled soils seems harder and resist root penetration than plowed soils. Indeed, hard soils have proven to reduce or even prevent plant root development (Atwell, 1993; Hill, 1990). Reduced tillage with stubble retention increase soil water

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recharge by reducing surface runoff and evaporation losses and increasing soil water infiltration (Ji and Unger, 2001; Van Eerd et al., 2014). Canola seed yield and seed oil content are positively correlated with soil moisture availability, while unfavorable soil moisture condition particularly during flowering and bud development results in intensive assimilates, pod abortion and loss in seed weight (Johnson et al., 1995; Nielsen, 1997).

MT is known to have positive influences on several soil chemical and physical properties including soil organic matter (Bescansa et al., 2006; Cambardella and Elliott, 1992; Conant et al., 2011; Kahlon et al., 2013). However, there is a conflicting evidence about the predicted period for MT to alter soil organic matter. For example, Hejazi et al. (2010) estimated 10–12 years for the change in soil organic matter to be observed bellow 20 cm soil depth, after switching from moldboard plow to MT. This has occurred when MT retained more than 80% of the previous crop residue. In contrast, only three years of MT were required for the soil to develop favorable organic matter above the 15 cm soil depth, when MT was implemented with the most recent modification by incorporating previous crop residue into the soil (Kahlon et al., 2013; Van Eerd et al., 2014). Generally, changes in soil organic matter due to utilizing MT depend on several factors including initial soil and climate conditions and differences in carbon input/output balances induced by soil management along with these factors interactions (Conant et al., 2011; Deligios et al., 2013; Kuotsu et al., 2014). In fact, it has been concluded that, for the soil, the interaction between the management and the environment is more important that the management alone (Aziz et al., 2013; Roper et al., 2013).

Successful strategies to integrate MT into the Iraqi farming systems require information on how this shift would influence soil chemical and physical properties. Information is also required to determine whether this shift increases soil water availability and whether this increase occurs at periods correspond to greater seed yield and seed quality. Therefore, this study aimed to determine the effects of tillage and residue management on canola seed yield and seed oil content as affected by changes in soil water content and soil organic matter during germination, flowering and maturity of canola in the semiarid climates of northern Iraq.

2. Materials and methods

2.1. Site characteristics and crop management

A two year (2009–2011) field experiment was carried out at The University of Mosul, Nineveh, Northern Iraq (36.340°N, 43.130°E, 260 m above sea level). The average seasonal temperature (February–July) was 11 and 6 °C and precipitation was 187 and 221 mm, for 2010 and 2011, respectively (Al-Dabbas et al., 2012). The growing season precipitation was below average in 2010 and above average in 2011. The study area was characterized by a considerable temperature variation from an average of -3 °C in February and March to 46 °C in July and August.

Monoculture canola (*Brassica napus* L.) was managed under conventional tillage (CT) and minimum tillage systems (MT). The CT operation consisted of two plowings; moldboard plowing (20–25 cm depth) when preparing the field, followed by disk plowing (10–15 cm depth) to prepare fine seedbed. Minimum soil disturbance occurred under MT using filed cultivator (5–7 cm depth). Wheat residue was mechanically incorporated into the soil simultaneously during tillage at three levels 0, 2, and 4 t ha^{-1}. Soil tillage was performed late in February from each season while weeds were controlled manually when required.

The trail was conducted on a clay loam soil USDA classification (USDA, 1992). The surface soil (0–15 cm) has a pH of 6.2 (1:5 soil: 0.01 M $CaCl_2$ extract), electrical conductivity of 0.01 dS m^{-1} (1:5 soil/water extract), cation exchange capacity of 3.22 cmol (+) kg^{-1} and N concentration of 400 mg kg^{-1}. The surface soil contains an average of 209 g sand kg^{-1}, 411 g silt kg^{-1}, 318 g clay kg^{-1}, and approximately 64 g $CaCO_3$ kg^{-1}. Most of the soil morphological properties at the study site have previously been described by Khattab and Al-Taie (2006). In January, prior to the initiation of the experiment, organic matter content for the 0–15 cm soil depth was 13 g C kg^{-1} and volumetric soil water content at field capacity was approximately 11% and at permanent wilting point was 4%. The trial was implemented on a soil has recently been subjected to agriculture which represent an ideal situation to investigate changes in soil properties from initial stages.

2.2. The experimental design and treatments

The experiment was a split-plot design with three replicates. Each replicate (60 m × 3 m) consisted of two main-plots and three sub-plots. The tillage treatments were the main plots and the residue treatments were the sub-plots. The treatments were as follows: treatment 1, conventional tillage without residue; treatment 2, minimum tillage without residue; treatment 3, conventional tillage with residue; treatment 4, minimum tillage with residue. Nitrogen fertilizer, 30 kg ha^{-1} (urea 46-0-0) was applied at two stages, half at planting and the other half a month after sowing. The split application was required to enhance residue decomposition (Sainju et al., 2011).

2.3. Soil core sampling

Soil samples were collected from 0–15 cm depth from a minimally disturbed soil at approximately 20 cm away from the cropping rows. Soil water content (SWC) was determined using the core method, which was done at three development stages of canola. The first stage, when 90% of the plants appeared on the soil surface. The second stage, when at least 50% of the plants had one fully open flower. The third stage, when approximately 50% of the vegetation turned out brown pods. The cores were collected from two sites per plot and then wrapped up in cloth cover sheets to be placed in the oven at 65 °C for 48 h. Volumetric SWC was measured using the gravimetric method as described by Lampurlanes et al. (2001). In the event of rainfall, soil sampling was postponed one day to reduce soil disturbance.

2.4. Laboratory measurements

To determine the percentage of accumulated soil organic matter (SOM) following the addition of wheat residues; air dried soil samples representing the top 15 cm of the soil were ground to pass a 2 mm sieve. The organic materials on the surface (e.g., visible plant materials) were discarded. SOM was estimated in a form of organic carbon based on Walkley-Black acid digestion method as described by Anderson and Domsch (1989). A conversion factor of two was used to calculate SOM (i.e., soil organic matter = 2 × soil organic carbon).

2.5. Seed yield and oil content measurements

Canola plants were harvested when more than 50% of the pods turned mature color. Seed yield was determined by hand harvesting the four mid rows of each plot. After harvesting, several hundred seeds were randomly selected from each plot. Seeds were oven dried at 70 °C for 48 h. The percentage of seed oil content was determined using a Soxhlet extraction method (A.O.A.C, 1984) at the Agriculture Research Institution Laboratory in Mosul, Nineveh.