Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences
ISSN：1674-2974 | CN 43-1061 / N

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

MORPHO-PHENOLOGICAL AND YIELD RESPONSE OF WHEAT TO TILLAGE PRACTICES AND STRAW INCORPORATION IN SALINE SODIC SOIL

B.A. NINDWANI*
Department of Farm Power and Machinery, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, Pakistan. *Corresponding Author E-mail: barkatali_04@yahoo.com
A.A. TAGAR
Department of Farm Power and Machinery, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, Pakistan.
N. LEGHARI
Department of Farm Power and Machinery, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, Pakistan.
I. RAJPER
Department of Soil Science, Faculty of Crop Production, Sindh Agriculture University, Tandojam, Pakistan.

Abstract

In order to examine its morpho-phenological and yield response of wheat to tillage practices and straw incorporation, the study was carried out in saline sodic soils, using tillage practices, wheat straw amendments and gypsum amendments as treatment factors in a randomized complete block design (RCBD) with four replications. Tillage practices comprised of shallow tillage (ST) to 0.10 m with two passes of a disk harrow and deep tillage (DT) using moldboard ploughing to a depth of 0.25 m followed by two passes of disk harrow as under ST. Wheat straw amendments consisted of 3 mg ha^{-1}(WS3), 7 mg ha^{-1} (WS7) and 10 mg ha^{-1}(WS10); while gypsum amendments consisted of 25% of gypsum requirement (GR25), 50% of gypsum requirement (GR50) and 75% of gypsum requirement (GR75). These treatment factors were tested under conventional practice (CK) with no straw, only NPK and gypsum; and control (CTRL) without straw and gypsum amendments. It was concluded that seed emergence, number of tillers, plant height, spike length, grains spike^{-1}, number of grains spike^{-1}, seed index and grain yield in wheat increased significantly ($P<0.05$) when straw was incorporated into the soil, and this increase in the values of these parameters was proportional to the rate of straw application. Under shallow tillage, ST_{WS3} - ST_{WS10} (wheat straw 10 Mg ha^{-1} + 50 or 75% gypsum) resulted in higher wheat yields; while in deep tillage, DT_{WS3} - DT_{WS10} (wheat straw 7-10 Mg ha^{-1}+75% gypsum) resulted in higher wheat yields than rest of the treatments. Replacement of NPK with wheat straw remained highly beneficial for soil health and crop yield. Moreover, the crop yield was higher under deep tillage as compared to shallow tillage practice. Regardless of rate of straw incorporation to the soil, the grains spike^{-1}, seed index and grain yields were higher in the second year of experiment over the first year of study. This indicated that longer the time between straw application and wheat sowing, more will be the grains spike^{-1}, greater seed index and higher grain yields. The crop performance was significantly improved with the rate of straw incorporated into the soil in the order for plant height and spike length ($DT_{WS10}>ST_{WS10}>DT_{WS7}>ST_{WS7}>DT_{WS3}>ST_{WS3}$); while the order for seed emergence, number of tillers, grains spike^{-1}, seed index and grain yield stood as $ST_{WS10}>DT_{WS10}>ST_{WS7}>DT_{WS7}>ST_{WS3}>DT_{WS3}$.

Keywords: *Wheat, morpho-phenological, yield response, tillage practices, straw incorporation, gypsum amendment*

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

INTRODUCTION

Worldwide, the soil stores about 1550 Pg of carbon; the most of which is organic carbon. The carbon pool found in terrestrial plants and in the atmosphere are both much less than the soil organic carbon pool, which is approximately 2.5 times as high as the other two carbon pools (Jarecki and Lal, 2003). Because of this, even slight changes in the amount of organic carbon found in the soil can have a significant impact on the amount of carbon dioxide found in the atmosphere (Benbi and Senapati, 2010). Prior to the discovery of this problem, the primary purpose of soil tillage was to enhance crop yields by improving growth conditions in the soil, to conserve water, and to prevent soil erosion (Gao et al., 2003). In spite of this increased awareness of the greenhouse effect, research has shown that soil organic carbon is easily influenced by tillage and fertilization, and that different tillage practices exert a considerable influence on soil disturbances, aggregate stability, and organic carbon flux rates; in result the crop growth and yield are influenced (Benbi and Senapati, 2010; Erenstein and Laxmi, 2008; Miura et al., 2010). The objective of soil cultivation has evolved from merely increasing agricultural yields to also decreasing the amount of greenhouse gas emissions that are produced as a result (Koga and Tsuji, 2009).

Increasing agricultural productivity and sustainable food production will be crucial in the future as the world's population increases; thus, increase in production of cereal grains should be the focus (Li et al., 2022). Among cereals, wheat (Triticum aestivum L.) is a source of food for nearly half of the world population (Belderok et al., 2000; Shewry, 2009); and more than 60% population of Pakistan dependent of wheat for their daily diet, where the average per capita utilization of wheat is 125 kg (Khan and Habib, 2003). In Pakistan, wheat is cultivated on an area of 9,168 thousand ha with a production of 26.394 million tons (GoP, 2022).

Wheat can be successfully produced even in temperatures that are greater if the crop is maintained in a different manner from an agronomic aspect (Ortiz et al., 2008). The vulnerability of wheat to heat stress can be reduced by implementing a number of different agronomic practices, such as; adoption of water conservation methods, (ii) judicious fertilization, (iii) consistent sowing at the appropriate time of year; and (iv) the application of exogenous protectants (Singh et al., 2011b). The pace of grain filling in wheat, the length of time it takes for the grain to fill, and the size of the grain are all dependent on a consistent supply of water. When it comes to sustaining appropriate moisture and thermal regimes in the soil system, which are not attainable in regions that are rain-fed and produce wheat, mulching can be the finest solution. The application of a protective layer made of straw mulch on top of the soil might be done in order to stop the soil from drying out (Chen et al., 2007). Wheat yields, on the other hand, are susceptible to falling when less tilling is done; as a potential option, mulching is proposed (Glab and Kulig 2008). In other contexts, it has been documented that increasing the amount of mulch applied to heat-stressed and water-deficient wheat fields can result in enhanced wheat yields (Chakraborty et al., 2008). Organic mulches have the ability to increase the efficiency with which water and nitrogen are used, and as a result, they have the potential to minimize expenses associated with water and nitrogen. This is because organic mulches assist preserve soil moisture and boost plant growth and development (Singh et al., 2011b). It has been demonstrated that the production of wheat in regions that experience extreme heat stress, such as temperate and tropical countries, can considerably benefit from the utilization of this technology.

Extensive research has demonstrated that conservation tillage, which includes zero tillage, minimum tillage, and the incorporation of straw, is an effective alternative to conventional tillage in terms of reducing soil disturbance and the destruction of the soil aggregate structure. Additionally, conservation tillage has the potential to slow the rate at which macro aggregates decompose, protect organic carbon from being degraded by microbes, and extend the amount of time aggregates are able to retain organic carbon (Muramoto and Werner, 2002; Peterson, 2003). On the other hand, there are a number of studies that refute this. When compared to conventional tillage, conservation tillage as believed by Carter (2002) and Blanco-Canqui et al., (2011), is thought to result in a lower level of carbon storage in the soil profile. Even though many studies have investigated the effects of various tillage practices and field management methods on the amount of organic carbon contained in soil as well as its capacity for storage, the question of whether or not conservation tillage can increase the amount of organic carbon stored in soil remains an important one (Fonte et al., 2009; Six et al., 2000; Li et al., 2007; Holland, 2004). In addition, the vast majority of previous research has been on a single crop variety grown in either dryland or paddy fields (Choudhury et al., 2010; West and Post, 2002; Rudrappa et al., 2006). Tillage practices have an impact, albeit of varied degrees, on the physicochemical characteristics of the soil as well as the yields of crops. In addition, the use of a single type of ploughing for an extended length of time results in soil conditions that are unfavorable for the growth of plants (Campbell et al., 2001). As a result, it is contested as to whether conventional tillage or zero tillage and straw integration with conservation tillage can meet the demand for both ecological and production benefits, that is, increasing the capacity of soil carbon preservation and improving crop yields.

The soil microbial biomass and activity are affected by management practices like tillage and straw incorporation because of the way these practices change the soil environment such as temperature, moisture, root development stage, and amount and quality of crop residues; which in turn affects the content and stability of soil aggregates and, by extension, land productivity (Curaqueo, 2011; Ramachandran et al., 2009; Zhang, 2012). When applied to agriculture, zero-tillage and straw integration allow the topsoil to build a complex breakdown sub-system that mimics the natural environment. This component of the system can operate as a shock absorber for the soil mass and a source of energy and nutrients for the crop roots in the topsoil when no-tillage techniques are used. Identical distributions are a natural phenomenon that can boost recycling rates and energy efficiency (Lorenz et al., 2005; Husnjak et al., 2002; Aoyama et al., 1999; Bandyopadhyay et al., 2010). However, protecting the topsoil from repeated wet-dry freeze-thaw processes by adding plant residues in conjunction with minimal tillage can increase the concentration of stable macro aggregates. The turnover of macro aggregates in farmland can be reduced by zero tillage, and organic carbon can be more easily enclosed in micro aggregates, allowing for greater quantities of physically protected organic carbon and an increase in macro aggregate formation (Causarano et al., 2008). This is mostly due to the release of organic components like polysaccharides and organic acids from fresh straw and other organic materials. Both the microbial and fungal development they foster and the cementation of straw and soil particles into macro aggregates are aided by the presence of these organic compounds (Decaens, 2000). According to Fonte et al. (2012), the increased content and stability of macro aggregates in the topsoil layer can be attributed to the enormous intake of plant wastes and the avoidance of disturbance under zero tillage.

Quantitative changes in the soil organic carbon in deep soil are brought about by various tillage practices, in addition to the alternating wet and dry soil environment, particularly in cropland under rice-wheat rotation. Conventional tillage, such as ploughing, on the other hand, absorbs organic elements, such as straw mulch at the soil surface and residual roots in shallow soil, into deeper soil, as opposed to zero tillage, which does neither of these things. When organic matter is linked to soil particles, mineralization is more stable and organic carbon accumulates in the subsoil (Pinheiro et al., 2004). This finding also suggests that using only shallow soil for organic carbon analysis will produce inaccurate results. To accurately quantify the carbon preservation capability of bulk soil, particularly in deep soil. Numerous studies have demonstrated that zero-tillage farming practices can increase wheat yields (Changquan et al., 2001; Lithourgidis et al., 2006). The impact of zero tillage on rice yields, however, has been found to have both positive and negative results. Zhuang et al. (1999) proposed that the increased bulk density of the soil between 7 and 14 cm deep is the principal reason of rice premature ageing and decreased yield under zero-till conditions. Increased soil permeability under zero tillage, as documented by Feng et al. (2006), has been linked to decreased water percolation and fertilizer leakage, which in turn leads to less rice tillering and an insufficient population, both of which reduce rice yields. Results reported by Ke Song et al. (2016) showed that zero-till significantly increased wheat yields by 13.32%. However, rice yields were reduced by 10.55 percent due to zero-till practices. The zero tillage can increase the effective panicle number and wheat yield by enriching the topsoil with nutrients (Gangwar et al., 2004; Li et al., 2001; Shumin et al., 2010).

Adding straw to soil is a tried and true method of boosting soil health in a number of ways, including increased fertility, decreased bulk density, increased permeability, and elevated organic carbon levels (Shreyasi et al., 2013). Research by Ke Song et al. (2016) found that increasing the rate of straw integration improved soil carbon preservation capacity and raised the concentration of SOC in aggregates. Wheat yields may be impacted by straw integration; though, the inclusion of rice straw into wheat resulted in lower wheat yields because the added straw took too long to breakdown and mineralize. Conventional tillage introduces straw to the topsoil, where its high spacing between pieces has a negative impact on soil water losses, seedling germination, and root development. Both the rate at which wheat germinates and the quality of its early growth are affected by factors such as a lack of water and the presence of straw. Thus, under straw integration and normal tillage, wheat yields dropped significantly. Toxins released during the straw decomposition and mineralization process can stunt the development of crop seedlings, which in turn reduces crop yields. In this study, wheat crop was subjected to examine its morpho-phenological and yield response to tillage practices and straw incorporation in saline sodic soil.

MATERIALS AND METHODS

Experimental site

The study was carried out at farmer’s field taluka Khipro, district, Sanghar (Sindh), Pakistan (Lat. 25°45'0" N, Long. 69°23'15" E, Elev. 13 m AMSL). The experimental site had been barren for more than 20 years due to salinity/sodicity problems and unavailability of water. Across all treatment plots and based on USDA soil particle size analysis (Bouyoucos, 1927), the soil at the study site was classified as silt loam, and a Haplic Yermosol (FAO, 2006). Table 1 shows the physical properties of experimental soil. Respectively, the monthly average minimum and maximum temperatures were 18.21^{o}C and 41.55^{o}C during 2018 and 16.90^{o}C and 40.57^{o}C during 2019. The average monthly minimum and maximum rainfall was 2.2 mm and 4.2 mm in 2018 and 2.1 mm and 5.2 mm in 2019, respectively.

Experimental design

The treatments were arranged in a randomized complete block design (RCBD) with four replications as follows:

A) Tillage practices

1) Shallow tillage (ST) to 0.10 m with two passes of a disk harrow
2) Deep tillage (DT), moldboard ploughing to a depth of 0.25 m followed by two passes of disk harrow as under ST

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

B) Wheat straw amendments

1) 3 Mg ha^{-1} (WS3)
2) 7 Mg ha^{-1} (WS7)
3) 10 Mg ha^{-1} (WS10)

C) Gypsum amendments

1) 25% of gypsum requirement (GR25)
2) 50% of gypsum requirement (GR50)
3) 75% of gypsum requirement. (GR75)

- Conventional practice (CK) with no straw, only NPK and gypsum,
- Control (CTRL) with no straw and no gypsum,

The experimental field (66 m × 520 m) was accordingly divided into 104 plots (26 × 4) (15 m × 20 m each). Wheat straw was chopped into 50 mm pieces (Zhang et al., 2014b) and three rates of straw were mixed with the soil using the specified tillage practices during 2018–2019.

The gypsum requirement was calculated as Nan et al. (2016):

$$\mathrm{GR} = 0.344 \cdot \rho \cdot \mathrm{d} \cdot \left([\mathrm{Ca}^{2+}]_{\mathrm{g}} - [\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}]_{\mathrm{f}}\right)$$
(1)

Where,

GR	is the soil gypsum requirement (Mg ha^{-1})
$\left[\mathrm{Ca}^{2+}\right]_{\mathrm{g}}$	is the Ca^{2+} content of a saturated gypsum solution (me L^{-1})
$\left[\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}\right]_{\mathrm{f}}$	is the Ca^{2+} + Mg^{2+} content of the filtrate (me L^{-1})
d	is the soil depth (m)
ρ	is the soil bulk density (Mg m^{-3})

Statistical analysis: The data were processed using Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA) and then subjected to an analysis of variance (ANOVA) using the SPSS 17.0 Statistical Package (SPSS Inc., Chicago, IL, USA). Multiple comparisons of various treatments were conducted using Tukey's method. The graphics were produced using Origin 8.0 (OriginLab Corp., Northampton, MA, USA).

RESULTS AND DISCUSSION

Seed emergence

The seed emergence was significantly influenced by the tillage treatments as well as wheat straw and gypsum amendments ($P<0.05$). The seed emergence was higher in shallow tillage (ST) and deep tillage (DT) treatments comprised of soil amendment with wheat straw and gypsum $\mathrm{ST_{WS7}GR_{75}} \times \mathrm{DT_{WS7}GR_{75}}$ (82.5 and 83.5%), $\mathrm{ST_{WS10}GR_{75}} \times \mathrm{DT_{WS10}GR_{7}}$ (82.0 and 84.5%), respectively. The seed emergence followed a marginal decrease in ST×DT treatment combinations of $\mathrm{ST_{WS10}GR_{50}} \times \mathrm{DT_{WS10}GR_{5}}$ (80.5 and 77.5%),

$ST_{WS3}GR_{75} \times DT_{WS3}GR_{75}$ (79.5 and 82.5%) and $ST_{WS3}GR_{50} \times DT_{WS3}GR_{50}$ (79.0 and 80.5%), respectively. Subsequently, a decline in seed emergence ($P<0.05$) was noted in ST×DT treatment combinations of $ST_{WS7}GR_{50} \times DT_{WS7}GR_{50}$ (73.0 and 75.5%), $ST_{WS10}GR_{25} \times DT_{WS10}GR_{2}$ (69.0 and 63.0%), $ST_{WS7}GR_{25} \times DT_{WS7}GR_{25}$ (63.5 and 60.5%) and $ST_{WS3}GR_{25} \times DT_{WS3}GR_{25}$ (61.0 and 48.5%), respectively. However, the least seed emergence was seen in ST×DT treatment combination of $ST_{NPK}GR_{25} \times DT_{NPK}GR_{25}$ (47.0 and 41.5%) and control treatment $ST_{CK} \times DT_{CK}$ (44.0 and 44.5%), respectively. Apparently the response of deep tillage to wheat straw and gypsum amendments was greater than the shallow tillage treatment.

The data indicated that the seed emergence was 28-33 and 27-31% higher under straw incorporated treatments (shallow tillage: ST_{WS3}-ST_{WS10} and DT_{WS3}-DT_{WS10}) than deep tillage as compared to those of without straw incorporated treatments (ST_{NPK} and DT_{NPK} and ST_{CK} and DT_{CK}) after two years (Fig. 1 a, b). Seed emergence was 3.22, 0.9, 2.62, 2.59 and 2.32% higher under shallow tillage treatments ($ST_{WS3,}$ $ST_{WS7,}$ $ST_{WS10,}$ ST_{NPK} and ST_{CK}) than under deep tillage treatments ($DT_{WS3,}$ $DT_{WS7,}$ $DT_{WS10,}$ DT_{NPK} and DT_{CK}). Seed emergence significantly increased with the rate of straw incorporated into the soil in the order $ST_{WS10} > DT_{WS10} > ST_{WS7} > DT_{WS7} > ST_{WS3} > DT_{WS3}$. Seed emergence increased significantly ($P<0.05$) with the passage of time; and it was higher (2.56-2.7%) and (1.33-1.4%) in 2019 as compared to 2020 under both shallow and deep tillage treatments, respectively.

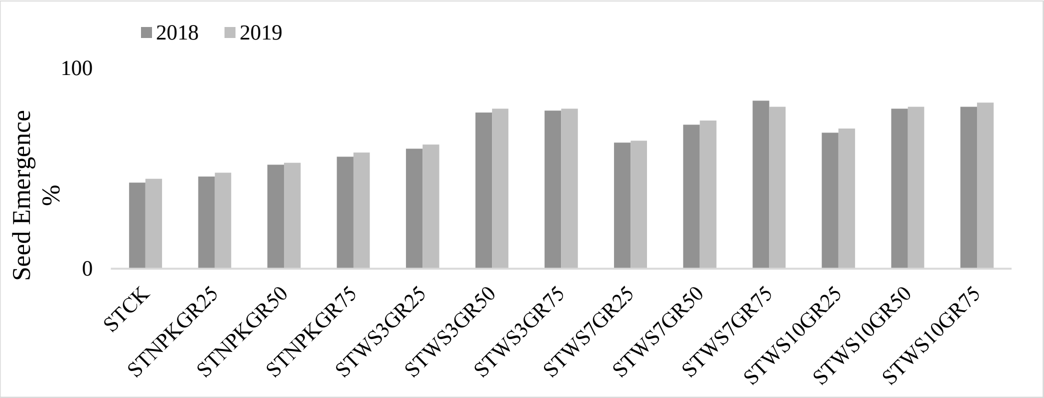

Fig. 1a. Seedling emergence % under shallow tillage treatment at different rates of wheat straw in saline sodic soil

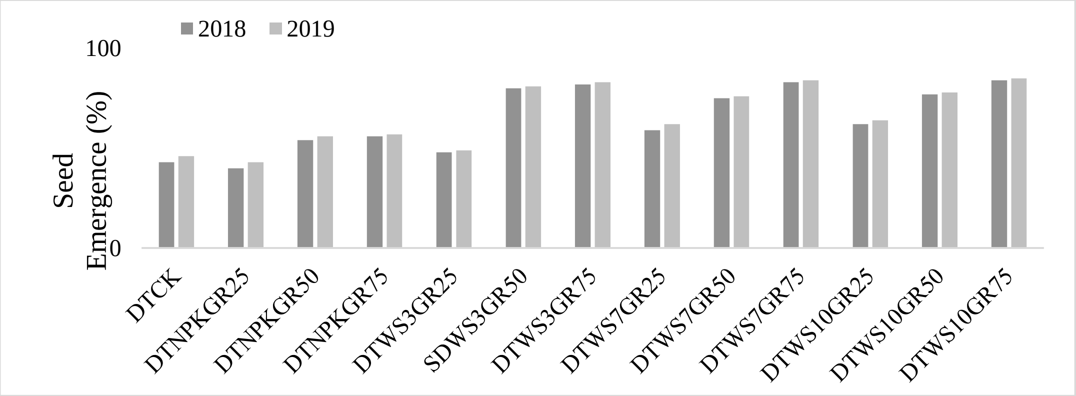

Fig. 1b. Seedling emergence under deep tillage treatment at different rates of what straw in saline sodic soil

Number of tillers

The effect of tillage treatments and soil amendment based on wheat straw (WS) and gypsum requirement (Gr) was significant ($P<0.05$). The number of tillers plant^{-1} was equally maximum in ST and DT treatments $ST_{WS7}GR_{75} \times DT_{WS7}GR_{75}$ (3.5 and 3.5) and $ST_{WS10}GR_{75} \times DT_{WS10}GR_{75}$ (3.5 and 3.5), respectively; followed by $ST_{WS10}GR_{50} \times DT_{WS10}GR_{50}$ (3.5 and 3.0%), $ST_{WS10}GR_{25} \times DT_{WS10}GR_{25}$ (3.5 and 2.5), respectively. The tillers plant^{-1} followed a marginal decrease under ST×DT treatments of $ST_{WS3}GR_{50} \times DT_{WS3}GR_{50}$ (3.0 and 3.0), $ST_{WS3}GR_{75} \times DT_{WS3}GR_{75}$ (3.0 and 3.0) and $ST_{WS3}GR_{75} \times DT_{WS7}GR_{50}$ (3.0 and 3.0) tillers plant^{-1}, respectively. Considerable decrease in tillers plant^{-1} ($P<0.05$) was observed in ST×DT treatments of $ST_{NPK}GR_{50} \times DT_{NPK}GR_{50}$ (3.0 and 2.5) and $ST_{NPK}GR_{5} \times DT_{NPK}GR_{5}$ (3.0 and 2.5) tillers plant^{-1}, respectively. The minimum number of tillers plant^{-1} was recorded under ST×DT treatment of $ST_{WS3}GR_{25} \times DT_{WS3}GR_{25}$ (2.5 and 2.0) against control treatment $ST_{CK} \times DT_{CK}$ (2.5 and 2.5), respectively. The crop response regarding the number of tillers plant^{-1} was relatively better in shallow tillage compared to deep tillage treatment; while discontinuation of wheat straw application caused more reduction in tillers plant^{-1} as compared to termination of gypsum application.

The results showed that the number of tillers was 33 and 24% higher under straw incorporated treatments (shallow tillage: ST_{WS3} - ST_{WS10} and deep tillage: DT_{WS3} - DT_{WS10}) as compared to those of without straw incorporated treatments (ST_{NPK} and DT_{NPK} and ST_{CK} and DT_{CK}) after two years as illustrated in Fig. 2 a, b. Tillers number normally increased with rate of straw incorporated into soil in the order $ST_{WS10} > DT_{WS10} > ST_{WS7} > DT_{WS7} > ST_{WS3} > DT_{WS3}$. Number of tillers was 11.33, 11.33, 11.33, 25.64 and 0% higher under shallow tillage treatments (ST_{WS3}, ST_{WS7}, ST_{WS10}, ST_{NPK} and ST_{CK}) than deep tillage treatments (DT_{WS3}, DT_{WS7}, DT_{WS10}, DT_{NPK} and DT_{CK}). Tillers increased significantly ($P<0.05$) with the time; and were higher (11.33-25% and 12.4-20.12%) in 2019 as compared to 2018 under both shallow and deep tillage practices.

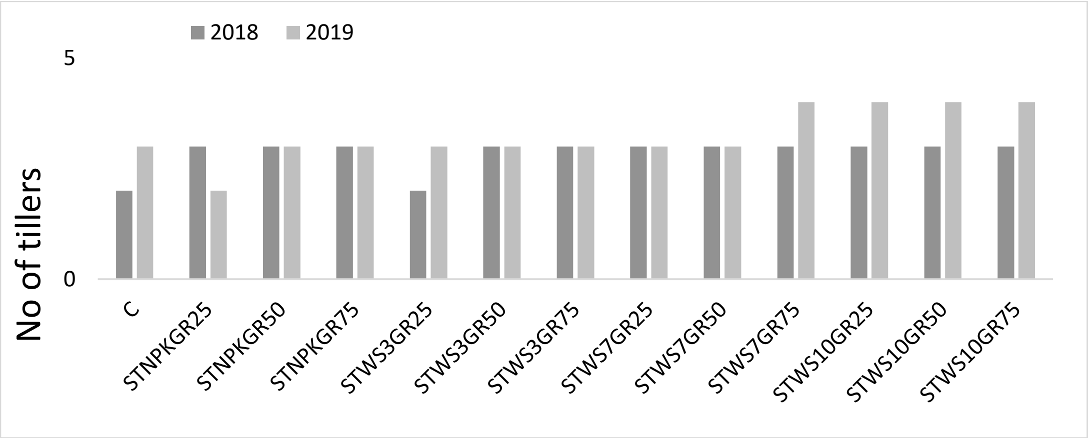

Fig. 2a. No. of tillers under shallow tillage treatment at different rates of wheat straw in saline sodic soil

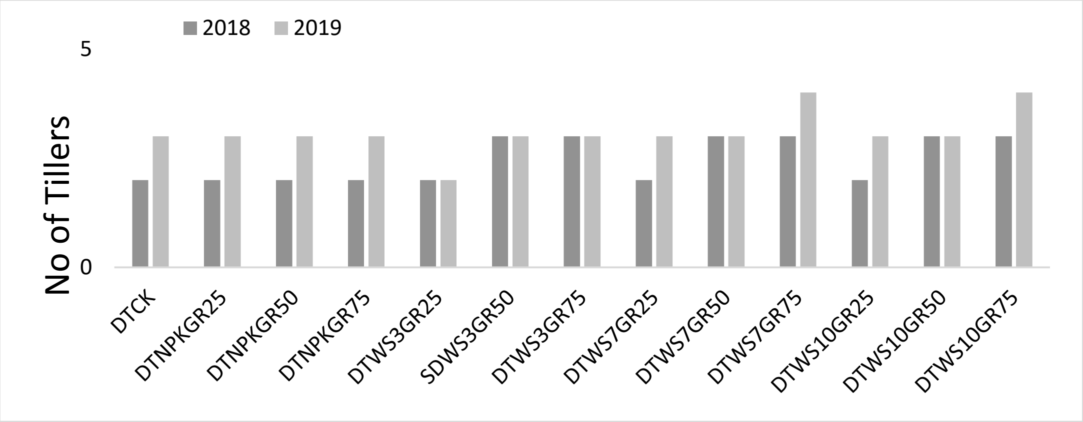

Fig. 2b. No. of tillers deep tillage treatment at different rates of wheat straw in saline sodic soil

Plant height

The plant height of wheat was significantly ($P<0.05$) affected by tillage treatments as well as by the wheat straw (WS) and gypsum (Gr) based soil amendment. The plant height was maximum in ST and DT treatments $ST_{WS10}GR_{75}$ × $DT_{WS10}GR_{75}$ (84.0 and 84.5 cm), followed by treatments $ST_{WS10}GR_{50}$ × $DT_{WS10}GR_{50}$ (82.0 and 83.5 cm), $ST_{WS10}GR_{25}$ × $DT_{WS10}GR_{25}$ (80.5 and 82.0 cm), and $ST_{WS7}GR_{75}$ × $DT_{WS7}GR_{75}$ (79.5 and 81.5 cm), respectively. The plant height decreased considerably ($P<0.05$) under ST×DT treatments of $ST_{WS7}GR_{50}$ × $DT_{WS7}GR_{50}$ (76.0 and 79.0 cm), $ST_{WS3}GR_{75}$ × $DT_{WS3}GR_{75}$ (74.5 and 80.5 cm) and $ST_{WS7}GR_{25}$ × $DT_{WS7}GR_{25}$ (73.0 and 77.0 cm) plant height, respectively. The plant height diminished when wheat straw application was discontinued in treatments of $ST_{NPK}GR_{75}$ × $DT_{NPK}GR_{75}$ (66.5 and 73.5 cm), $ST_{NPK}GR_{50}$ × $DT_{NPK}GR_{50}$ (68.5 and 71.5 cm) plant height, respectively; while in control treatment ST_{CK} × DT_{CK} the plant height was (63.0 and 64.0 cm), respectively. In absence of wheat straw, the plant height of wheat was significantly influenced in negative direction even in presence of NPK application. However, the effect of gypsum on plant height of wheat was dose dependent.

It is evident from the results that the height of plants was 16.4-26.5% and 19-24% higher under straw incorporated treatments (shallow tillage: ST_{WS3} - ST_{WS10} and deep tillage DT_{WS3} - DT_{WS10}) as compared to those of without straw incorporated treatments (ST_{NPK} and DT_{NPK} and ST_{CK} and ST_{CK}) after two years (Fig. 3 a, b). Plant height significantly increased with rate of straw incorporated into soil in the order $DT_{WS10} > ST_{WS10} > DT_{WS7} > ST_{WS7} > DT_{WS3} > ST_{WS3}$. The plant height was 0, 3.7, 6.41, 5.71 and 3.17% higher under deep tillage (DT_{WS3}, DT_{WS7}, DT_{WS10}, DT_{NPK} and DT_{CK}) than under shallow tillage treatments (i.e., ST_{WS3}, ST_{WS7}, ST_{WS10}, ST_{NPK} and ST_{CK}). Plant height (cm) increased significantly ($P<0.05$) with the passage of time. Plant height was higher (0.1% to 1.3% and 0.4% to 0.78%) in 2020 as compared to 2019 under both shallow and deep tillage practices.

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

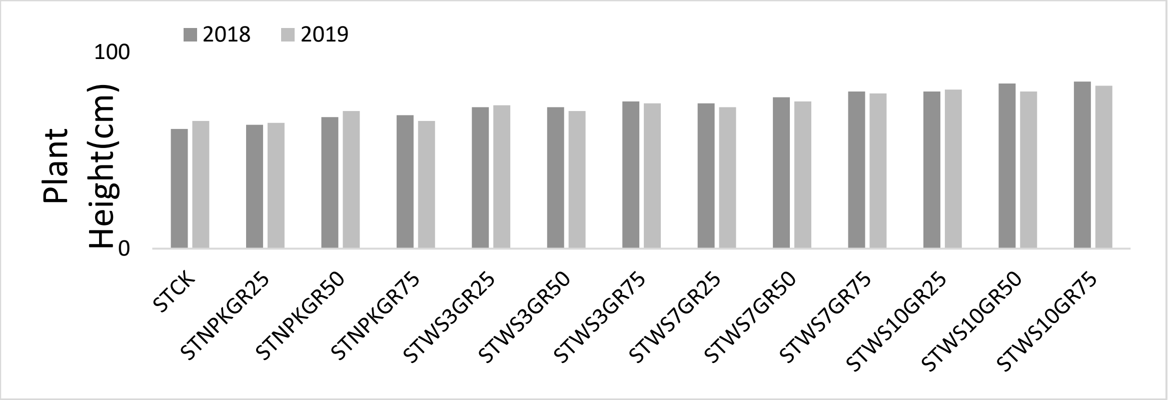

Fig. 3a. Plant height under shallow tillage treatment at different rates of wheat straw in saline sodic soil

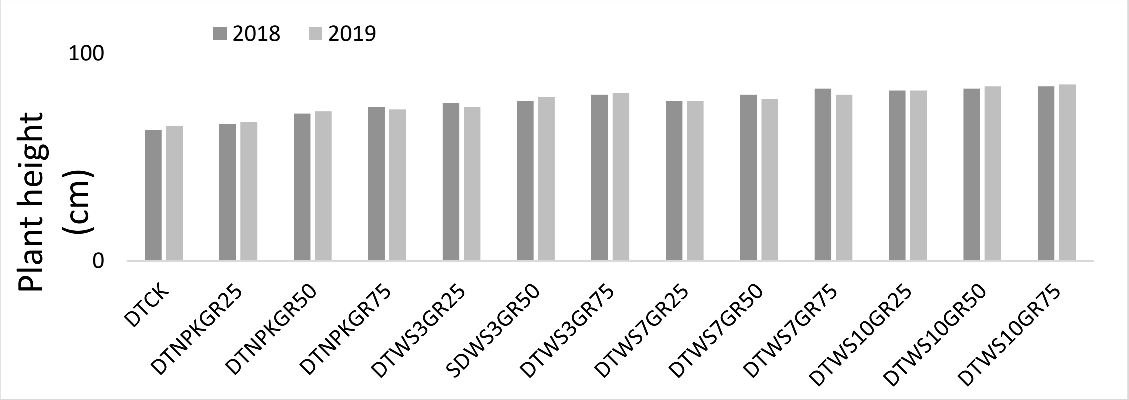

Fig. 3b. Plant height under deep tillage treatment at different rates of wheat straw in saline sodic soil

Spike length

The spike length in wheat was measured to examine the effect of soil amendment with wheat straw and gypsum at different concentrations under shallow tillage and deep tillage systems. The data showed that the effect of tillage treatments and soil amendment treatments on spike length was significant ($P<0.05$). Relatively longer spikes were obtained in ST and DT treatments comprised of $ST_{WS10}GR_{75}$ × $DT_{WS10}GR_{75}$ (10.1 and 9.8 cm), followed by $ST_{WS10}GR_{50}$ × $DT_{WS10}GR_{50}$ (9.4 and 10.0 cm), $ST_{WS7}GR_{75}$ × $DT_{WS7}GR_{75}$ (9.6 and 9.4 cm), $ST_{WS7}GR_{50}$ × $DT_{WS7}GR_{50}$ (9.4 and 9.8 cm), $ST_{WS3}GR_{75}$ × $DT_{WS3}GR_{75}$ (9.5 and 9.1 cm), and $ST_{WS3}GR_{50}$ × $DT_{WS3}GR_{50}$ (9.1 and 9.1 cm) spike length, respectively. The spike length declined ($P<0.05$) under ST×DT treatments of $ST_{NPK}GR_{75}$ × $DT_{NPK}GR_{75}$ (7.6 and 7.3 cm), $ST_{NPK}GR_{50}$ × $DT_{NPK}GR_{50}$ (7.6 and 7.8 cm) spike length, respectively; while in control treatment ST_{CK} × DT_{CK} the spike length was least (6.7 and 6.7 cm), respectively. This indicates that absence of wheat straw as soil amendment caused adverse effect on spike length even when the recommended rate of NPK was applied. The effect of gypsum on spike length of wheat was associated with its rate of application.

It can be seen from the data that the spike length of wheat was 32.5-38.1% and 25-31% higher under straw incorporated treatments (deep tillage: DT_{WS3}-DT_{WS10} and shallow tillage ST_{WS3}-ST_{WS10}) as compared to those of without straw incorporated treatments (DT_{NPK} and ST_{NPK} and DT_{CK} and ST_{CK}) after two years (Fig. 4 a, b). This trait was significantly improved with the rate of straw incorporated into the soil in the order ST_{WS10} > ST_{WS10} >DT_{WS7} > ST_{WS7} > DT_{WS3} > ST_{WS3}. Spike length was 7.56, 1.74, 0.67, 4.2 and 6.25% higher under shallow tillage treatments (DT_{WS3}, DT_{WS7}, DT_{WS10}, DT_{NPK} and DT_{CK}) than those in deep tillage treatments (ST_{WS3}, ST_{WS7}, ST_{WS10}, ST_{NPK} and ST_{CK}). Length of spike increased significantly ($P<0.05$) with the time; and it was higher (5.13-5.08% and 1.94-0.31%) in 2020 as compared to 2019 under both deep and shallow tillage practices, respectively.

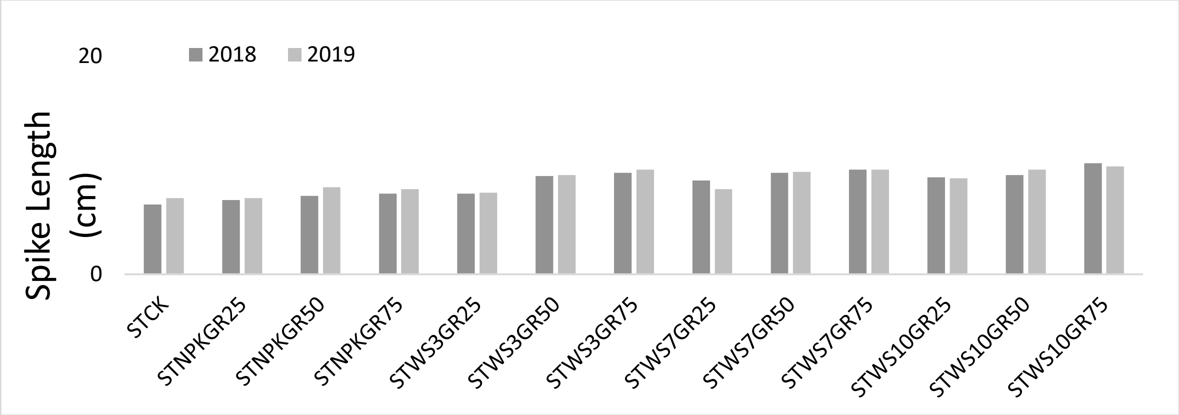

Fig. 4a. Spike length under shallow tillage treatment at different rates of wheat straw in saline sodic soil

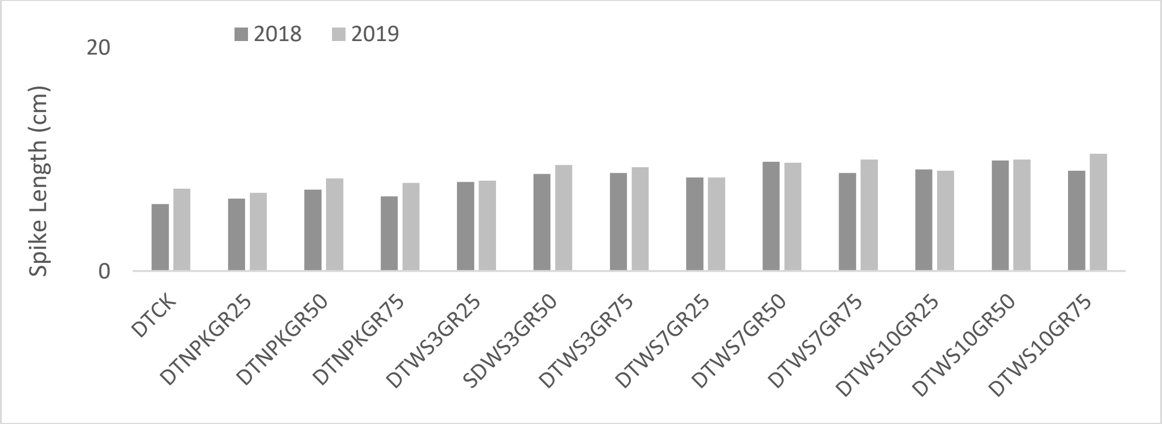

Fig. 4b. Spike length under deep tillage treatment at different rates of wheat straw in saline sodic soil

Grains spike^{-1}

The number of grains spike^{-1} in wheat was counted to investigate the effect of soil amendment with wheat straw and gypsum at different concentrations under shallow tillage and deep tillage treatments. The results indicated that tillage treatments and soil amendment treatments had significant ($P<0.05$) influence on the number of grains spike^{-1}. Comparatively more grains spike^{-1} were counted in ST and DT treatments comprised of $ST_{WS10}GR_{75} \times DT_{WS10}GR_{75}$ (48.5 and 49.0), followed by treatments $ST_{WS7}GR_{75} \times DT_{WS7}GR_{75}$ (47.0 and 47.5), $ST_{WS7}GR_{50} \times DT_{WS7}GR_{50}$ (46.5 and 42.5), $ST_{WS10}GR_{50} \times DT_{WS10}GR_{50}$ (48.0 and 42.0), $ST_{WS3}GR_{75} \times DT_{WS3}GR_{75}$ (39.0 and 44.0), and $ST_{WS3}GR_{50} \times DT_{WS3}GR_{50}$ (43.5 and 39.5) grains spike^{-1}, respectively. The grains spike^{-1} declined ($P<0.05$) under ST×DT treatments of $ST_{NPK}GR_{75} \times DT_{NPK}GR_{75}$ (39.5 and 41.0), $ST_{NPK}GR_{50} \times DT_{NPK}GR_{50}$ (37.5 and 37.5) grains spike^{-1}, respectively against control treatment $ST_{CK} \times DT_{CK}$ where the grains spike^{-1} was least (33.0 and 33.5), respectively. The grains spike^{-1} were greater in most cases when deep tillage was adopted as compared to shallow tillage; however, in treatments with wheat straw soil amendment, the grains spike^{-1} were more under shallow tillage

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

treatments as compared to deep tillage practice. Moreover, corresponding to the rate of wheat straw and gypsum, the grains spike^{-1} were affected.

The data for two years indicated that the grains spike^{-1} was 20.5-32.6% and 15.38-23.25% higher in straw incorporated treatments (shallow tillage: ST_{WS3} - ST_{WS10} and deep tillage: DT_{WS3} - DT_{WS10}) as compared to those of without straw incorporated treatments [ST_{NPK} and DT_{NPK} and ST_{CK} and DT_{CK}] (Fig. 5 a, b). Grains spike^{-1} proportionately increased with rate of straw incorporated into the soil in the order $ST_{WS10} > DT_{WS10} > ST_{WS7} > DT_{WS7} > ST_{WS3} > DT_{WS3}$. Grains spike^{-1} were 0.88, 6.66, 6.52, 0.8 and 3.12% higher under shallow tillage treatments ($ST_{WS3,}$ $ST_{WS7,}$ $ST_{WS10,}$ ST_{NPK}) than deep tillage treatments (ST_{CK} $DT_{WS3,}$ $DT_{WS7,}$ $DT_{WS10,}$ DT_{NPK} and DT_{CK}). Grains spike^{-1} increased with the time (P<0.05) and was higher (6.12-9.3% and 4.87-2.27%) in 2020 as compared to 2019 under both shallow and deep tillage practices.

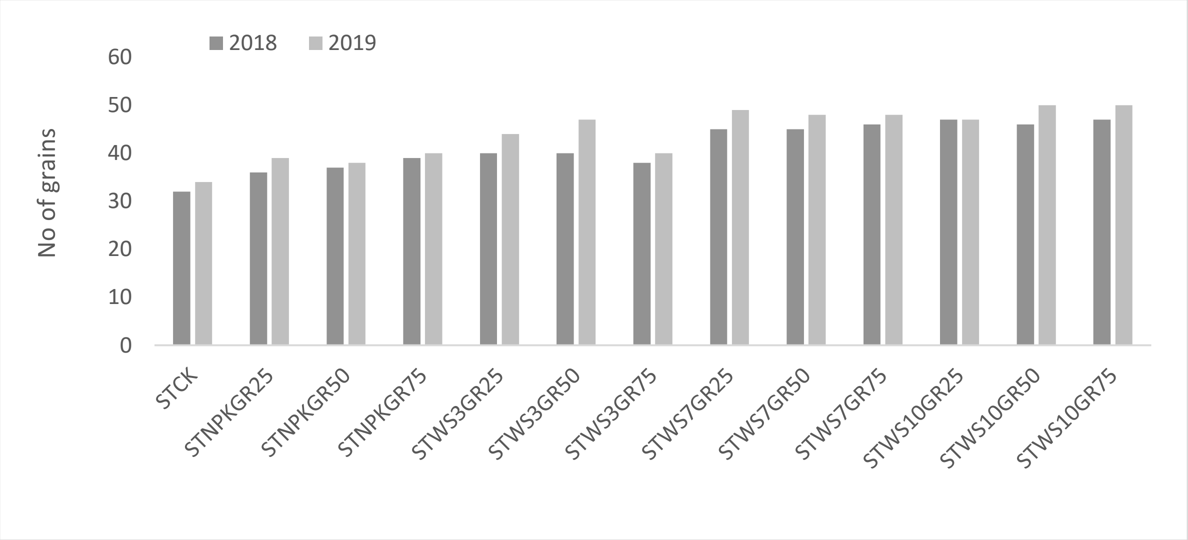

Fig. 5a. Grains per spike under shallow tillage treatment at different rates of wheat straw in saline sodic soil

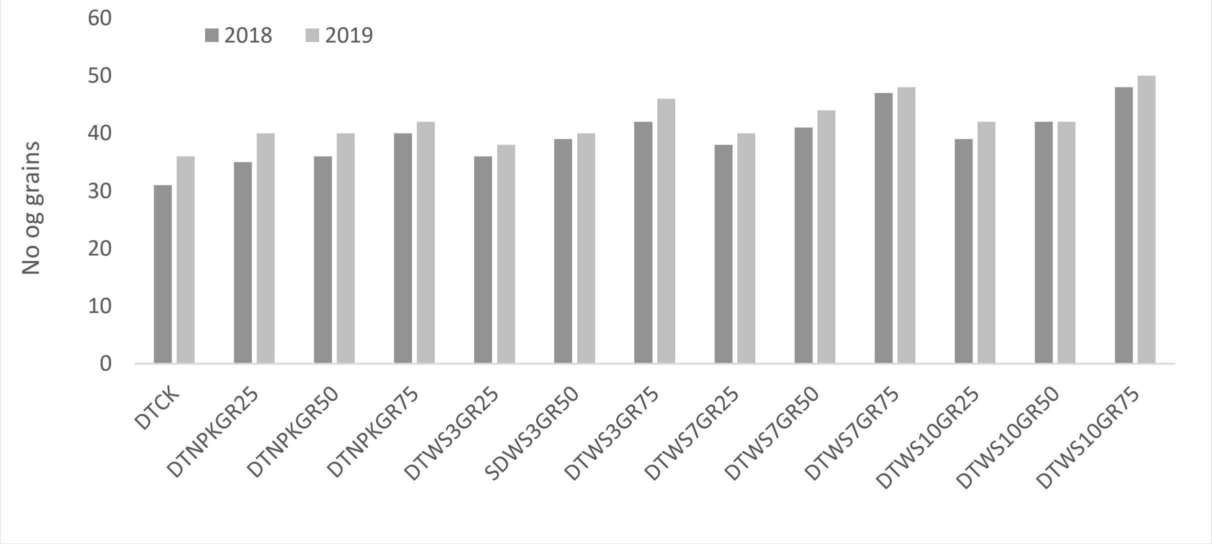

Fig. 5b. Grains per spike under deep tillage treatment at different rates of wheat straw in saline sodic soil

Seed index (1000 grain weight)

The seed index was calculated on the basis of 1000 wheat grains and the data revealed that tillage treatments and soil amendment treatments had significant ($P<0.05$) effect on seed index value. It can be seen from the data that seed index was greater in ST and DT treatments comprised of $ST_{WS10}GR_{75}$ × $DT_{WS10}GR_{75}$ (47.5 and 45.9 g), followed by treatments $ST_{WS10}GR_{50}$ × $DT_{WS10}GR_{50}$ (47.5 and 45.4 g), $ST_{WS10}GR_{25}$ × $DT_{WS10}GR_{25}$ (45.0 and 46.5 g), $ST_{WS7}GR_{75}$ × $DT_{WS7}GR_{75}$ (46.0 and 43.0 g), $ST_{WS7}GR_{50}$ × $DT_{WS7}GR_{50}$ (46.0 and 44.5 g), $ST_{WS7}GR_{25}$ × $DT_{WS7}GR_{25}$ (43.5 and 45.5 g), $ST_{WS3}GR_{75}$ × $DT_{WS3}GR_{75}$ (46.3 and 42.5 g), $ST_{WS3}GR_{50}$ × $DT_{WS3}GR_{50}$ (45.0 and 43.9 g) and $ST_{WS3}GR_{25}$ × $DT_{WS3}GR_{25}$ (43.0 and 44.5 g) seed index, respectively. The seed index declined ($P<0.05$) under ST×DT treatments of $ST_{NPK}GR_{75}$ × $DT_{NPK}GR_{75}$ (43.5 and 40.9 g), $ST_{NPK}GR_{50}$ × $DT_{NPK}GR_{50}$ (43.0 and 40.8 g) and $ST_{NPK}GR_{25}$ × $DT_{NPK}GR_{25}$ (39.5 and 38.9 g) seed index, respectively against control treatment ST_{CK} × DT_{CK} where the seed index was least (37.0 and 34.0), respectively. It was observed that soil amendment with wheat straw and gypsum showed significant and positive influence on seed index value, which indicates that the improvement in the grain quality.

The results further suggested that the seed index was 25.5-26% and 20.4-23.9% higher under straw incorporated treatments (deep tillage: DT_{WS3} - DT_{WS10} and shallow tillage: ST_{WS3} - ST_{WS10}) as compared to those of without straw incorporation (ST_{NPK} and DT_{NPK} and ST_{CK} and DT_{CK}) after 2 years (Fig. 6 a, b). Seed index markedly improved with increasing rate of straw incorporation into soil in the order $ST_{WS10} > DT_{WS10} > ST_{WS7} > DT_{WS7} > ST_{WS3} > DT_{WS3}$. Seed index was 2.2, 2.2, 2.17, 7.3 and 8.57% higher under shallow tillage treatments (ST_{WS3}, ST_{WS7}, ST_{WS10}, ST_{NPK} and ST_{CK}) than deep tillage treatments (i.e., DT_{WS3}, DT_{WS7}, DT_{WS10}, DT_{NPK} and DT_{CK}); and it increased significantly ($P<0.05$) with time advancement; and was higher (2.2-2.08% and 2.27-2.17%) in 2020 as compared to 2019 under both shallow and deep tillage practices.

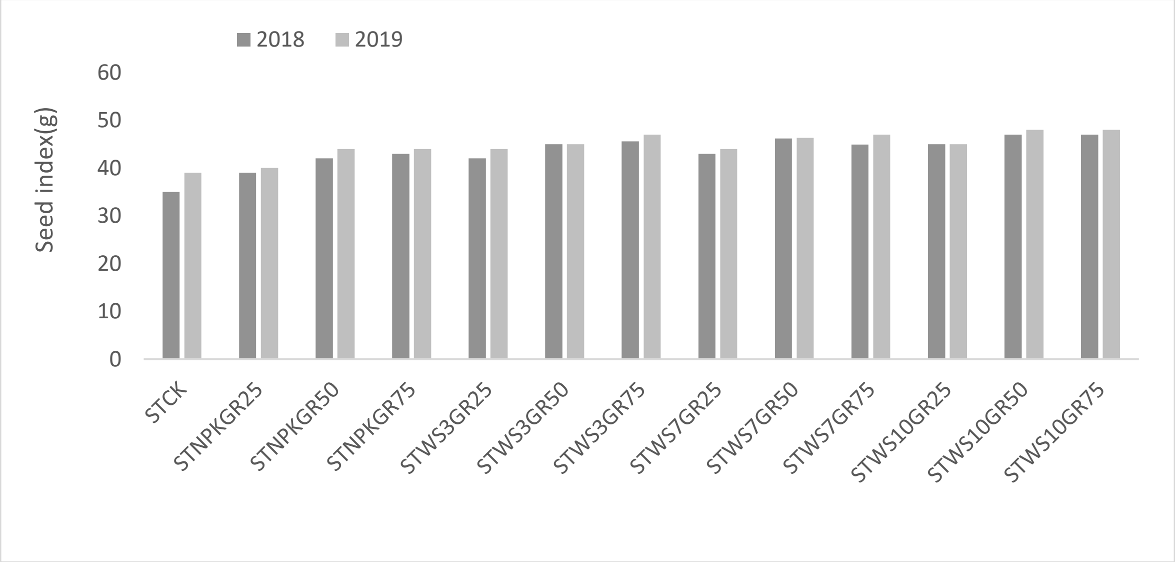

Fig. 6a. 1000 grain weight under shallow tillage treatment at different rates of wheat straw in saline sodic soil

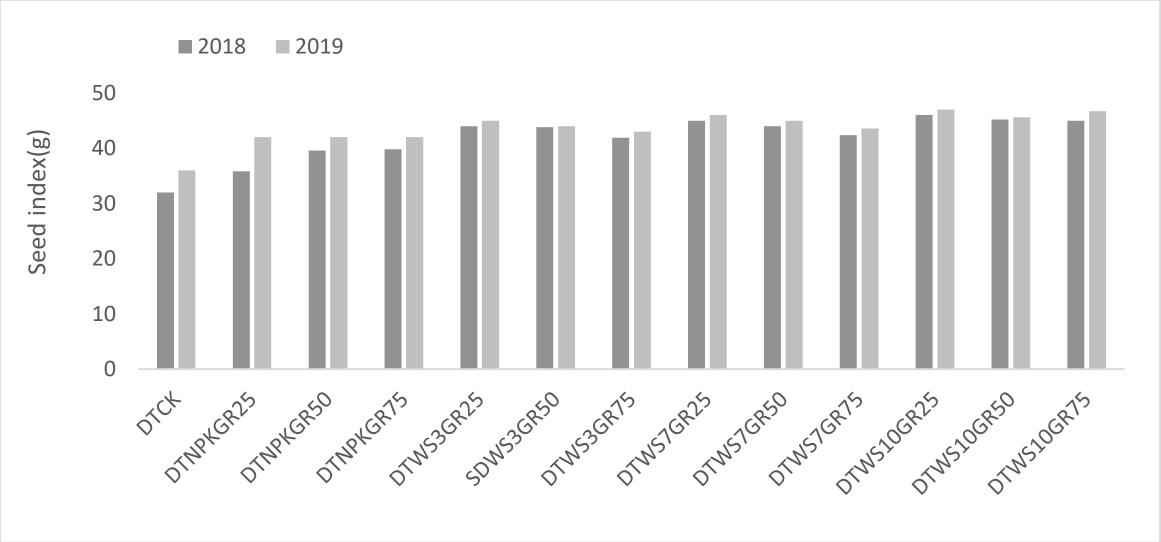

Fig. 6b. 1000 grain weight under deep tillage treatment at different rates of wheat straw in saline sodic soil

Grain yield

The effect of shallow and deep tillage practices on grain yield of wheat sown in wheat straw and gypsum amended soil at different concentrations was investigated. The results revealed that the grain yield was significantly affected by tillage treatments as well as by the soil amendment ($P<0.05$). Significantly highest grain yield was achieved under ST and DT treatments comprised of $ST_{WS10}GR_{75} \times DT_{WS10}GR_{75}$ (3.7 and 3.7 t ha^{-1}), followed by $ST_{WS10}GR_{50} \times DT_{WS10}GR_{50}$ (7.3 and 7.6 t ha^{-1}), $ST_{WS7}GR_{75} \times DT_{WS7}GR_{75}$ (3.6 and 3.6 t ha^{-1}), $ST_{WS7}GR_{50} \times DT_{WS7}GR_{50}$ (3.6 and 3.4 t ha^{-1}), $ST_{WS3}GR_{75} \times DT_{WS3}GR_{75}$ (3.3 and 3.4 t ha^{-1}) and $ST_{WS3}GR_{50} \times DT_{WS3}GR_{50}$ (3.3 and 3.1 t ha^{-1}) grain yield, respectively. The grain yield declined ($P<0.05$) under ST×DT treatments of $ST_{NPK}GR_{75} \times DT_{NPK}GR_{75}$ (2.1 and 2.1 t ha^{-1}), $ST_{NPK}GR_{50} \times DT_{NPK}GR_{50}$ (1.9 and 1.9 t ha^{-1}) grain yield, respectively; while in control treatment $ST_{CK} \times DT_{CK}$ the grain yield was minimum (1.1 and 1.2 t ha^{-1}), respectively. This indicates that absence of wheat straw as soil amendment caused adverse effect on grain yield even when the recommended rate of NPK was applied. The effect of gypsum on grain yield of wheat was associated with its rate of application.

It is evident from the results that the grain yield of wheat was 64-69% and 55-62% higher under straw incorporated treatments (shallow tillage: ST_{WS3} - ST_{WS10} and deep tillage: DT_{WS3} - DT_{WS10}) as compared to those of without straw incorporated treatments (ST_{NPK} and DT_{NPK} and ST_{CK} and DT_{CK}) after two years (Fig. 7 a, b). The increase in grain yield was distinctly associated with rate of straw incorporated into the soil in the order $ST_{WS10} > DT_{WS10} > ST_{WS7} > DT_{WS7} > ST_{WS3} > DT_{WS3}$. The change in yield was 0.33, 6.08, 4.76, 0.54 and -9.09% under shallow tillage treatments (ST_{WS3}, ST_{WS7}, ST_{WS10}, ST_{NPK} and ST_{CK}) over deep tillage treatments (DT_{WS3}, DT_{WS7}, DT_{WS10}, DT_{NPK} and DT_{CK}); and increased ($P<0.05$) with progress in time. Regardless of tillage system, yield was higher (3.23-8.3% and 2.85-7.7%) in 2020 over 2019.

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

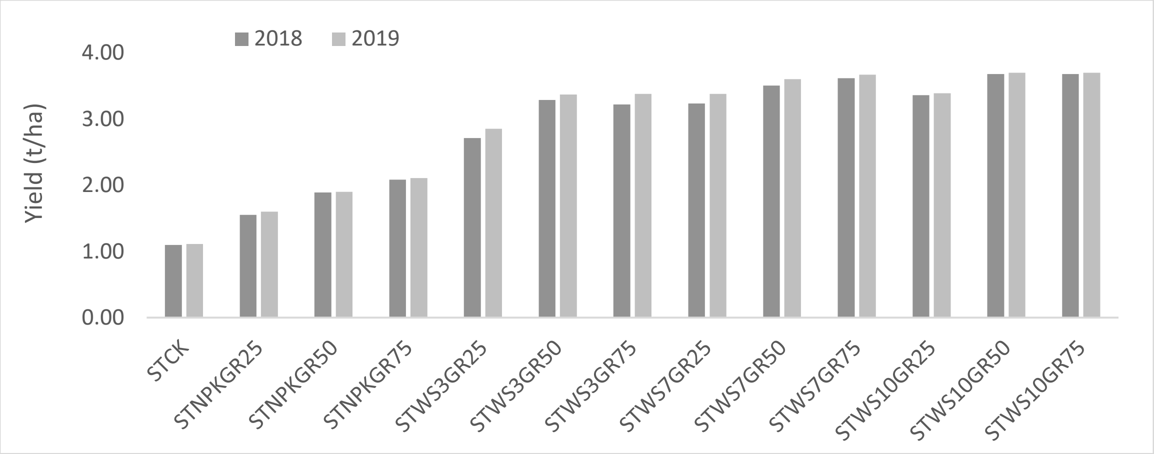

Fig. 7a. Yield under shallow tillage treatment at different rates of wheat straw in saline sodic soil

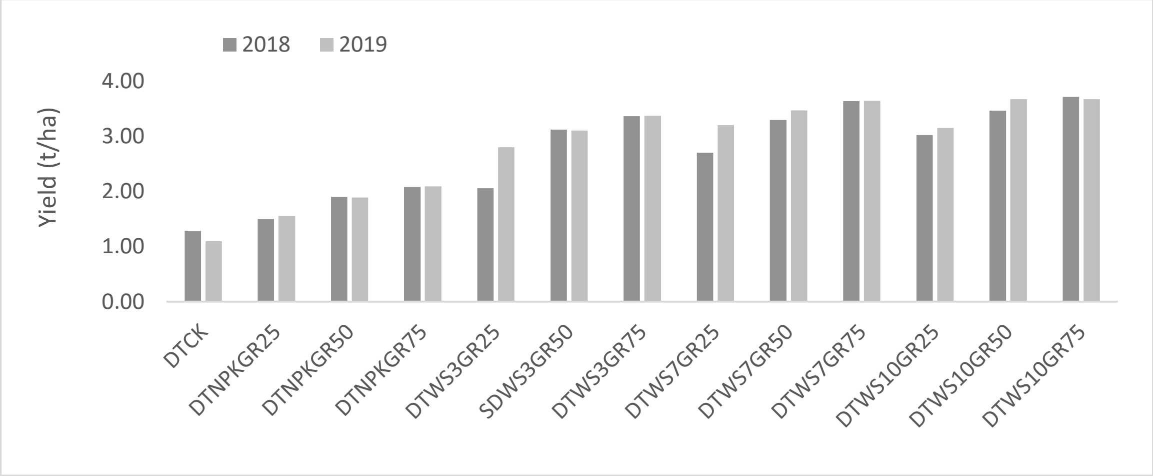

Fig. 7b. Yield under deep tillage treatment at different rates of wheat straw in saline sodic soil

DISCUSSION

In decreasing soil disturbance and soil aggregate structure destruction, organic mulching and incorporation of wheat straw to the soil are considered as effective tillage practices. (Peterson, 2003). The study showed that the seed emergence, number of tillers, plant height, spike length and grains spike^{-1} in wheat increased significantly ($P<0.05$) when straw was incorporated into the soil, and this increase in the values of these parameters was proportional to the rate of straw application. Moreover, all these traits improved in the second year of study as compared to first year of experiment. This indicates that with the passage of time after straw incorporation to the soil, the soil fertility was improved due to increased soil nutrients and soil organic matter in result of straw incorporation into the soil. The greater values were observed under shallow and deep tillage practices for seed emergence (2.56-2.7%), number of tillers (11.33-25%), plant height (0.1-1.3%), spike length (5.13-5.08%), and grains spike^{-1} (6.12-9.3%) during 2019 as compared to 2018 for seed emergence (1.33-1.4%), number of tillers (12.4-20.12%), plant height (0.4-0.78) and spike length (1.94-0.31) and grains spike^{-1} (4.87-2.27%), respectively. There are numerous studies worldwide showing the similar results (Fonte et al., 2009; Six et al., 2000; Li et al., 2007; Holland, 2004; Choudhury et al., 2010). According to these studies, the tillage practices have an impact, albeit of varied degrees, on the physicochemical characteristics of the soil as well as the yields of crops. Ramachandran et al. (2009)

found substantial improvement in soil organic matter and other soil nutrients when chopped wheat straw was incorporated into the soil. Zhang (2012) reported that tillering capacity in wheat improved apart from a minor increase in plant height; while grains per spike also improved in after straw treatment or straw retention. Deep tillage was more effective to improve wheat yields over the shallow tillage or zero-tillage. This suggested that straw integration allow the topsoil to build a complex breakdown sub-system that mimics the natural environment and in result improved soil organic matter and subsequent increase in crop yields. Fonte et al. (2012) reported stability of macro aggregates in the topsoil layer that attributed to the enormous intake of plant wastes. Under integration of wheat straw and deep plowing, the crop yields were increased because organic matter is linked to soil particles, mineralization is more stable and organic carbon accumulates in the subsoil (Pinheiro et al., 2004). Ke Song et al. (2016) reported 13.32% increase in growth traits and yield of wheat due to the effect of improved tillage practices.

The study further showed that the number of grains spike^{-1}, seed index (1000 grains weight) and grain yield showed a remarkable improvement ($P<0.05$) in result of straw incorporation into the soil, and with increased quantity or rate of straw application to the soil, these yield traits showed a simultaneous positive and highly significant response to straw incorporation to soil. Regardless of rate of straw incorporation to the soil, the grains spike^{-1}, seed index and grain yields were higher in the second year of experiment over the first year of study. This indicated that longer the time between straw application and wheat sowing, more will be the grains spike^{-1}, greater seed index and higher grain yields. Moreover, under deep tillage, the crop performance was markedly better than the crop under shallow tillage practice. The greater values were observed under shallow and deep tillage practices for number of grains spike^{-1} (6.12-9.3%), seed index (2.2-2.08%) and grain yield (3.23-8.3%) during 2019 as compared to preceding year of study 2018 for number of grains spike^{-1} (4.87-2.27%), seed index (2.27-2.17%) and grain yield (2.85-7.7%), respectively. Shreyasi et al. (2013) reported that adding straw to soil is a tried and true method of boosting soil health including increased fertility, decreased bulk density, increased permeability, and elevated organic carbon levels; which ultimately affect the crop yields positively. Ke Song et al. (2016) found that increasing the rate of straw integration improved soil carbon preservation capacity, in result increased wheat yields. Arif et al. (2011) reported increased crop yields due to integrated use of wheat straw as mulch. Imdad et al. (2015) reported that crop residue incorporation into the soil resulted in increased crop yields and soil health as well. Pandiaraj et al. (2015) reported higher grain and straw yields in wheat under crop residues management treatments. Sohail et al. (2017) suggested that 60% crop straw incorporation under reduce tillage practice is the best option decrease soil dry bulk density, increase porosity, SOC and SCS as well as achieve optimum yield under the wheat-rice cropping system. Reported that greater grain yields as well as higher nutrient contents were achieved with different tillage practices and increased the crop yields by upto 26.75% over control. Yu et al. (2016) reported that the based on strategy of incorporating 9000 kg ha^{-1} wheat straw to replace inorganic potassium (150 kg K_2O ha^{-1}) was effective for achieving higher crop yields.

CONCLUSIONS

The seed emergence, number of tillers, plant height, spike length, grains spike-1, number of grains spike-1, seed index and grain yield in wheat increased significantly ($P<0.05$) when straw was incorporated into the soil, and this increase in the values of these parameters was proportional to the rate of straw application. Under shallow tillage, ST_{WS3} - ST_{WS10} (wheat straw 10 Mg ha^{-1} + 50 or 75% gypsum) resulted in higher wheat yields; while in deep tillage, DT_{WS3} - DT_{WS10} (wheat straw 7-10 Mg ha^{-1} + 75% gypsum) resulted in higher wheat yields than rest of the treatments. Replacement of NPK

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

with wheat straw remained highly beneficial for soil health and crop yield. Moreover, the crop yield was higher under deep tillage as compared to shallow tillage practice.

REFERENCES

- Aoyama, M., Angers, D. A., & N'dayegamiye, A. (1999). Particulate and mineral-associated organic matter in water-stable aggregates as affected by mineral fertilizer and manure applications. Canadian Journal of Soil Science, 79(2), 295-302.
- Bajracharya, R. M., Lal, R., & Kimble, J. M. (2018). Soil organic carbon distribution in aggregates and primary particle fractions as influenced by erosion phases and landscape position. In Soil processes and the carbon cycle (pp. 353-367). CRC Press.
- Bandyopadhyay, P. K., Saha, S., Mani, P. K., & Mandal, B. (2010). Effect of organic inputs on aggregate associated organic carbon concentration under long-term rice–wheat cropping system. Geoderma, 154(3-4), 379-386.
- Belderok, B., Mesdag, J., & Donner, D. A. (2000). The Netherlands and Belgium. In Bread-making quality of wheat (pp. 179-203). Springer, Dordrecht.
- Benbi, D. K., & Senapati, N. (2010). Soil aggregation and carbon and nitrogen stabilization in relation to residue and manure application in rice–wheat systems in northwest India. Nutrient Cycling in Agroecosystems, 87(2), 233-247.
- Blanco-Canqui, H., Schlegel, A. J., & Heer, W. F. (2011). Soil-profile distribution of carbon and associated properties in no-till along a precipitation gradient in the central Great Plains. Agriculture, ecosystems & environment, 144(1), 107-116.
- Campbell, C. A., Selles, F., Lafond, G. P., Biederbeck, V. O., & Zentner, R. P. (2001). Tillage-fertilizer changes: effect on some soil quality attributes under long-term crop rotations in a thin Black Chernozem. Canadian Journal of Soil Science, 81(2), 157-165.
- Carter, M. R. (2002). Soil quality for sustainable land management: organic matter and aggregation interactions that maintain soil functions. Agronomy journal, 94(1), 38-47.
- Causarano, H. J., Franzluebbers, A. J., Shaw, J. N., Reeves, D. W., Raper, R. L., & Wood, C. W. (2008). Soil organic carbon fractions and aggregation in the Southern Piedmont and Coastal Plain. Soil Science Society of America Journal, 72(1), 221-230.
- Chakraborty, D., Nagarajan, S., Aggarwal, P., Gupta, V. K., Tomar, R. K., Garg, R. N., ... & Kalra, N. (2008). Effect of mulching on soil and plant water status, and the growth and yield of wheat (Triticum aestivum L.) in a semi-arid environment. Agricultural water management, 95(12), 1323-1334.
- Changquan, W., Chengming, W., & Tingaiang, L. (2001). Effect of different zero tillage on the crop yield and soil property. Sichuan Nongye Daxue Xuebao (China).
- Chen, S. Y., Zhang, X. Y., Pei, D., Sun, H. Y., & Chen, S. L. (2007). Effects of straw mulching on soil temperature, evaporation and yield of winter wheat: field experiments on the North China Plain. Annals of Applied Biology, 150(3), 261-268.
- Choudhury, S. G., Bandyopadhyay, P. K., Mallick, S., & Sarkar, S. (2010). Soil aggregation as affected by cultivation under low and upland situations. Journal of the Indian Society of Soil Science, 58(4), 371-375.
- Curaqueo, G., Barea, J. M., Acevedo, E., Rubio, R., Cornejo, P., & Borie, F. (2011). Effects of different tillage system on arbuscular mycorrhizal fungal propagules and physical properties in a Mediterranean agroecosystem in central Chile. Soil and Tillage Research, 113(1), 11-18.
- Curaqueo, G., Barea, J. M., Acevedo, E., Rubio, R., Cornejo, P., & Borie, F. (2011). Effects of different tillage system on arbuscular mycorrhizal fungal propagules and physical properties in a Mediterranean agroecosystem in central Chile. Soil and Tillage Research, 113(1), 11-18.

DOI 10.17605/OSF.IO/T3DJA
Vol: 59 | Issue: 12 | 2022
Nindwani et al,. (2022)

- Decaëns, T. (2000). Degradation dynamics of surface earthworm casts in grasslands of the eastern plains of Colombia. Biology and Fertility of Soils, 32(2), 149-156.
- Erenstein, O., & Laxmi, V. (2008). Zero tillage impacts in India's rice–wheat systems: a review. Soil and Tillage Research, 100(1-2), 1-14.
- Yuehua, F., Yingbin, Z., Buresh, R. J., Guiling, X., Hejun, A., & Shuhong, W. (2006). Effects of no--tillage and direct broadcasting on soil physical and chemical properties and growth and yield fFormation in hybrid rice. Zuo wu xue bao, 32(11), 1728-1736.
- Fonte, S. J., Quintero, D., Velásquez, E., & Lavelle, P. (2012). Interactive effects of plants and earthworms on the physical stabilization of soil organic matter in aggregates. Plant and Soil, 359(1), 205-214.
- Fonte, S. J., Winsome, T., & Six, J. (2009). Earthworm populations in relation to soil organic matter dynamics and management in California tomato cropping systems. Applied soil ecology, 41(2), 206-214.
- Gangwar, K. S., Singh, K. K., & Sharma, S. K. (2004). Effect of tillage on growth, yield and nutrient uptake in wheat after rice in the Indo-Gangetic Plains of India. The Journal of Agricultural Science, 142(4), 453-459.
- Gao, H. W., Li, W. Y., & Li, H. W. (2003). Conservation tillage technology with Chinese characteristics. Transactions of the CSAE, 19(3), 1-4.
- Głąb, T., & Kulig, B. (2008). Effect of mulch and tillage system on soil porosity under wheat (Triticum aestivum). Soil and Tillage Research, 99(2), 169-178.
- Holland, J. M. (2004). The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, ecosystems & environment, 103(1), 1-25.
- Husnjak, S., Filipovic, D., & Kosutic, S. (2002). Influence of different tillage systems on soil physical properties and crop yield. Rostlinna Vyroba-UZPI (Czech Republic).
- Jarecki, M. K., & Lal, R. (2003). Crop management for soil carbon sequestration. Critical Reviews in Plant Sciences, 22(6), 471-502.
- Song, K., Yang, J., Xue, Y., Lv, W., Zheng, X., & Pan, J. (2016). Influence of tillage practices and straw incorporation on soil aggregates, organic carbon, and crop yields in a rice-wheat rotation system. Scientific Reports, 6(1), 1-12.
- Habib, I., & Khan, A. S. (2003). Genetic model of some economic traits in bread wheat (Triticum aestivum L.). Asian Journal of Plant Sciences, 2(17-24), 1153-1155.
- Koga, N., & Tsuji, H. (2009). Effects of reduced tillage, crop residue management and manure application practices on crop yields and soil carbon sequestration on an Andisol in northern Japan. Soil Science and Plant Nutrition, 55(4), 546-557.
- Li, H., Lu, W., Liu, Y., & Zhang, X. (2001). Effect of different tillage methods on rice growth and soil ecology. Ying Yong Sheng tai xue bao= The Journal of Applied Ecology, 12(4), 553-556.
- Li, X. G., Wang, Z. F., Ma, Q. F., & Li, F. M. (2007). Crop cultivation and intensive grazing affect organic C pools and aggregate stability in arid grassland soil. Soil and Tillage Research, 95(1-2), 172-181.
- Lithourgidis, A. S., Dhima, K. V., Damalas, C. A., Vasilakoglou, I. B., & Eleftherohorinos, I. G. (2006). Tillage effects on wheat emergence and yield at varying seeding rates, and on labor and fuel consumption. Crop Science, 46(3), 1187-1192.
- Lorenz, K., & Lal, R. (2005). The depth distribution of soil organic carbon in relation to land use and management and the potential of carbon sequestration in subsoil horizons. Advances in agronomy, 88, 35-66.
- Miura, T., Kaneko, N., & Komatsuzaki, M. (2010). Earthworm contributes to supply available phosphorus in agricultural soil with no-tillage, weed-cover and low-input management. A case study of nature farming in Ibaraki Prefecture. Org. Agric. Sci, 2, 30-39.

- Muramoto, J., & Werner, M. R. (2002). Mustard powder vermifuge: an alternative to formalin expulsion method for earthworm sampling. Edaphologia, 70, 7-11.
- Ortiz, R., Sayre, K. D., Govaerts, B., Gupta, R., Subbarao, G. V., Ban, T., & Reynolds, M. (2008). Climate change: can wheat beat the heat?. Agriculture, Ecosystems & Environment, 126(1-2), 46-58.
- Paterson, E. (2003). Importance of rhizodeposition in the coupling of plant and microbial productivity. European journal of soil science, 54(4), 741-750.
- Pinheiro, E. F. M., Pereira, M. G., & Anjos, L. H. C. (2004). Aggregate distribution and soil organic matter under different tillage systems for vegetable crops in a Red Latosol from Brazil. Soil and Tillage research, 77(1), 79-84.
- Ramachandran Nair, P. K., Mohan Kumar, B., & Nair, V. D. (2009). Agroforestry as a strategy for carbon sequestration. Journal of plant nutrition and soil science, 172(1), 10-23.
- Rudrappa, L., Purakayastha, T. J., Singh, D., & Bhadraray, S. (2006). Long-term manuring and fertilization effects on soil organic carbon pools in a Typic Haplustept of semi-arid sub-tropical India. Soil and Tillage Research, 88(1-2), 180-192.
- Shewry, P. R., Saulnier, L., Guillon, F., Gebruers, K., Courtin, C., Delcour, J., & Charmet, G. (2010). Improving the benefits of wheat as a source of dietary fibre. Dietary fibre: new frontiers for food and health, 65-78.
- Choudhury, S. G., Srivastava, S., Singh, R., Chaudhari, S. K., Sharma, D. K., Singh, S. K., & Sarkar, D. (2014). Tillage and residue management effects on soil aggregation, organic carbon dynamics and yield attribute in rice–wheat cropping system under reclaimed sodic soil. Soil and Tillage Research, 136, 76-83.
- Liang, S., Xie, R., Tang, Y., Yang, J., Li, C., Wang, L., ... & Li, S. (2010). Effects of tillage systems on fields in Chengdu plain. I. The effects of tillage systems on soil properties and crop yields. Scientia Agricultura Sinica, 43(19), 3988-3996.
- Singh, A., Singh, D., & Gill, B. S. (2011, February). Planting time, methods, and practices to reduce the deleterious effects of high temperature on wheat. In International conference on preparing agriculture for climate change, Punjab Agric. Univ. Ludhiana (pp. 338-339).
- Singh, A., Singh, D., Kang, J. S., & Aggarwal, N. (2011). Management practices to mitigate the impact of high temperature on wheat: a review. IIOABJ, 2(7), 11-22.
- Six, J. A. E. T., Elliott, E. T., & Paustian, K. (2000). Soil macro aggregate turnover and micro aggregate formation: a mechanism for C sequestration under no-tillage agriculture. Soil Biology and Biochemistry, 32(14), 2099-2103.
- West, T. O., & Post, W. M. (2002). Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Science Society of America Journal, 66(6), 1930-1946.
- Zhuang, H. Y., Liu, S. P., Shen, X. P., Chen, H. Q., & Lu, J. F. (1999). Effect of long-term minimal and zero tillage on rice and wheat yields, soil organic matter and bulk density. Sci Agric Sin, 32(4), 39-44.
- Zhang, S., Li, Q., Zhang, X., Wei, K., Chen, L., & Liang, W. (2012). Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. Soil and Tillage Research, 124, 196-202.

- Zhang, S., Li, Q., Zhang, X., Wei, K., Chen, L., & Liang, W. (2012). Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. Soil and Tillage Research, 124, 196-202.