Design Approaches of One-Pass Strip-Till Machines

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Abstract. All over the world and in our country, the increasing awareness on the conservation of soil and water resources, together with the demands of reducing production costs, made it necessary for researchers to turn to alternative production ways in agriculture. As a result of these searches, it has been revealed that conservation tillage methods should become widespread as an alternative to traditional tillage method, where field traffic and fuel consumption are high, and environmental effects such as carbon emissions, soil degradation and air pollution. Despite years of research and government support, no-tillage, which is one of the sustainable agricultural practices and applied on an area of approximately 200 million hectares in the world, has unfortunately not been sufficiently adopted in Türkiye. Strip-tillage, which creates a soil environment that enhances seed germination, is a new alternative to no-tillage in areas where poorly drained soils are dominant. In this context, the strip tillage and sowing method is a combination of traditional and no-tillage methods and provides both environmental and economic benefits by saving time, labour and fuel as an alternative to the traditional method. Where soil moisture conditions are suitable, strip-tillage creates narrow-width tilled strips, traditionally in the fall, to increase early spring soil evaporation and soil temperature in the top 5 cm of the soil. When the previous studies on sowing with strip tillage are examined, it is seen that it is frequently applied in countries where agriculture is developed in the world, but there is not enough research and application area in Türkiye. In countries where agriculture is developed, it is seen that the strip tillage and sowing method is applied as a combination of two separate machines in a one-pass (tillage and sowing). In the studies carried out in Türkiye (strip tillage and sowing), it is applied separately in two stages. Both sowing application and strip-tillage can be performed in one-pass. The basic requirements for strip-tillage to be effective are accuracy in matching tillage equipment on the tool bar with the planter and placement of seeds in the tilled zones. In this study, an in-row of pneumatic spacing drill, mounted on a single chassis that can reduce the field traffic to a one-pass, is designed and simulated.

Keywords: Strip tillage · Conservation tillage · Sustainable agriculture

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E. Cavallo et al. (Eds.): ANKAgEng 2023, LNCE 458, pp. 60–67, 2024.
https://doi.org/10.1007/978-3-031-51579-8_7

1 Introduction

Global warming, which means the continuous increase in the Earth's temperature due to the greenhouse effect, has disrupted the agricultural ecosystem and caused unexpected changes in agricultural climate elements such as drought, temperature, precipitation, weather events and sunlight. In terms of agricultural production, these negative changes lead to a decrease in product yield and quality, a decrease in soil fertility, an increase in soil erosion due to heavy rainfall, and an increase in diseases and pests. It is an important known problem of today that climate change increases the fluctuation in agricultural production and harms agricultural production in general. Therefore, considering the food security of the ever-increasing world population, it is extremely important to create sustainable agricultural production systems that will reduce greenhouse gas emissions, resistant and sensitive to climate change, and develop technological and innovative agricultural mechanization tools and machines. Moreover, the search for new sustainable production systems that protect natural resources such as soil, water and air in agricultural production has accelerated. As a result of these searches, alternative conservation tillage to traditional tillage and the development of new tools and machines to be used in this process come to the fore. Conservation tillage is a practice in which the soil surface is covered with at least 30% of the pre-plant residues after planting, in order to reduce water and wind erosion along with soil moisture loss [1, 2]. The main purpose of conservation tillage is to keep pre-crop residues on the field surface and reduce tillage intensity. The main problems of today's world are drought and limited water resources, so it is important to ensure the preservation of in-soil water and moisture. Since plant residues cover the soil surface and block sunlight, humidity rates are higher than in parcels without plant residues [3, 4]. In areas where the soil is intensively and continuously cultivated, soil degradation caused by soil preparation is clearly visible.

Strip tillage method is a conservation tillage method in which 30%-40% of the field surface is allowed to be cultivated before planting for seed bed preparation. In this practice, soil tillage is mostly done together with planting, but it is also known to be done before planting. A 10 to 40 cm wide band that overlaps the sowing row line is processed (Fig. 1). Apart from this, the remaining rows are left unprocessed, covered with stubble. Therefore, the method can be perceived as a mixture of reduced tillage and no tillage method [5].

In multi-year field experiment, the soil properties after application of one-pass strip tillage technology for 8 years were compared to those of soil under conventional tillage with the use of a moldboard plough to a depth of 20 cm, and equally deep loosened and reduced tillage. A field experiment of these three treatments was performed. A total of 44 features were examined that described the physical, chemical, biological, and biochemical soil properties in the 0–20 cm layer, and penetration resistance, bulk density and soil moisture in the 25–30 cm layer. The influence of the one-pass strip tillage technology on the yield of crops was also determined. Multivariate analysis shows that the one-pass strip tillage technology method, in terms of affecting the soil properties, differs considerably from reduce tillage and conventional tillage treatments. The soil after the one-pass strip tillage technology method contained two- to four-fold more earthworms, with a mass 2- to fivefold higher, than those in the soil following reduce tillage and conventional tillage respectively [6].



Fig. 1 Strip tillage system

In the study, Mzuri Pro-Til, a combined strip tillage planting machine, was tested. They made an evaluation of the effect of the strip tillage method on soil properties and the effects of crop cultivation. Scientific observations and field trials were carried out in Poland, Ukraine, Lithuania, the Czech Republic, Slovakia, the eastern states of Germany, Belarus, Serbia and Romania. Compared to traditional tillage, soil moisture, organic carbon content, infiltration, number of microorganisms and worms, and organic activity were found to be higher, especially during periods of lack of rainfall. It has been shown that the strip tillage method provides fuel savings of 20–30 L/ha compared to reduced and conventional tillage methods, respectively, and is successful in terms of plant emergence and product yield. Increasing tillage intensity increased soil CO_2-C fluxes and bacterial populations, but decreased fungal populations. In the research, they stated that strip tillage will be the key element in conservation agriculture [7].

It compared one-pass strip tillage (combined strip tillage plus seeder), conventional tillage and reduced tillage methods in an 8-year field trial. In this research, a total of 44 properties describing the physical, chemical, biological and biochemical properties of the soil in the 0–20 cm layer and the penetration resistance, bulk density and soil moisture in the 25–30 cm layer were examined. Statistically, significant differences were detected in the strip tillage method compared to the reduced and conventional method. In the strip tillage method, the phosphorus and available potassium content, the total number of bacteria, cellulolytic microorganisms and fungi, and the activity of phosphatases were significantly higher. It reduced and found two to four times more earthworms than conventional tillage. The yield of winter rapeseed and wheat grown with strip tillage was found to be higher than the conventional and reduced method [8].

Strip tillage applied in sugar beet (*Beta vulgaris* L.) production compares conventional tillage and dirno tillage methods. It was determined that strip tillage caused less soil erosion and retained more moisture than conventional tillage. Compared to the no tillage method, it has been shown that there is better seedbed preparation, optimum fertilizer placement, more carbon sequestration and less fuel consumption. It has been

stated that the strip tillage method is a more profitable alternative method compared to no tillage and the conventional method, considering efficiency and input costs [9].

In the research, three different strip widths were created by changing the connection of three different milling (rotor) blades on the flanges and were tested comparatively with the conventional tillage method. They compared three strip tillage methods and one conventional method with strip widths of 22.5, 30.0 and 37.5 cm on CO_2-C flux, bacterial and fungal populations during sunflower growth. They identified significant differences in CO_2-C fluxes, microbial populations, soil bulk weight and total porosity between different tillage systems. The highest CO_2-C fluxes during the flowering and harvest periods were in the conventional method, and the lowest values were observed in the 22.5 cm strip spacing [10].

When the studies on strip tillage are examined, the main reasons why strip tillage method is gaining more and more importance in agricultural production are as follows: It can be listed as providing a good seed bed preparation on stubble soil, providing in-soil water and moisture conservation, soil protection against erosion, reducing carbon dioxide emissions into nature, saving fuel consumption by limiting the number of tractor passes in the field, low cost and high yield potential [11–13]. It is seen that it is frequently applied in developed countries, but in our country, this method is not applied sufficiently on a producer basis and sufficient research has not been done. With this research, it is aimed to design and develop a lightweight one-pass strip tillage planting machine unit that can be applied under Türkiyeconditions.

2 Methods

The study was articulated in two parts. The first step consisted of reviewing the literature about strip tillage method, comparing one-pass and two-pass. Literature about one-pass strip tillage technology has been revised through a targeted search on scientific journals databases, such as Science Direct, Applied Engineering in Agriculture, Soil and Tillage Research, and Asabe. A keyword-based search was used to identify articles, using the following keywords: Strip tillage* OR one-pass technology* OR conservation tillage* OR reduce tillage*. In the second step of the research, the designs and simulation studies of the one-pass strip tillage planting machine unit planned to be developed were carried out at Çukurova University Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering.

3 Results

Nowadays, strip tillage and planting practices are carried out in two different ways: one-pass and two-pass. In two-pass; first, strip tillage cultivation (Fig. 2) is carried out, and then the processed strips are planted with a normal planting machine (Fig. 3).



Fig. 2 Strip tillage machine



Fig. 3 Spacing drill

There are two types of strip tillage machines commonly used in two-pass strip tillage. These consist of different unit combinations that process the band on the planting line before planting. The strip tillage machine with chisel tines, which works by tearing the soil and forming a narrow band, is one of the most commonly used combinations of this combination (Fig. 4). Soil processor elements consist of stubble cutting disc, scratch cleaners, chisel tines and roller units.



Fig. 4 Strip tillage machine with Chisel tines unit

Another commonly used type of strip tillage is the machine that processes the soil by creating a wider band with the rototiller unit, the active parts of which consist of the soil milling machine (Fig. 5).

It is seen that in countries where agriculture is developed, strip-tillage and planting method is applied as a combination of two separate machines in a one-pass (tillage and planting) (Fig. 6 and Fig. 7). Compared to the two-pass method, field traffic is minimized, providing less fuel consumption and less soil compaction [6].

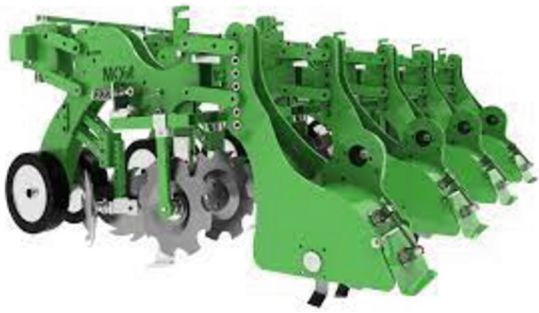

Fig. 5 Strip tillage machine with rototiller unit



Fig. 6 One-pass strip tillage machine combination



Fig. 7 Another one-pass strip tillage machine combination

Combined strip tillage machines used in a one-pass are very heavy types, have high production costs and require high traction power. A one-pass strip tillage planting machine unit suitable for use by farmers and producers in our country's conditions was designed in this research (Fig. 8). The designed unit consists of planter arrangement and soil processing organs (stubble cutting disc, chisel tines and roller) mounted on a single chassis.

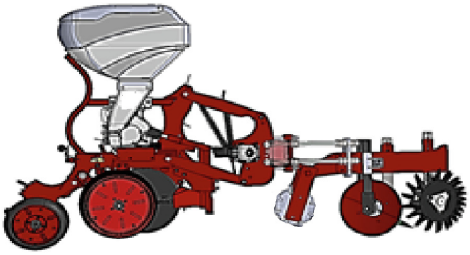

Fig. 8 Preliminary work of the designed one-pass strip tillage planting machine unit

Designed one-pass strip tillage planting machine unit may have toothed discs at the front that loosen the soil strip and break up the stubble on the surface. These discs can also be equipped with scratch removers. Chisel type tines, capable of deep processing, placed behind the stalk shredder and soil loosening discs, cut long plant residues after harvest and push them between the rows. Chisel tines with replaceable wings at the bottom prevent moist soil from drying out quickly, clumping and crusting by deeply loosening a narrow strip of soil without raising it to the field surface. Mineral fertilizer applicator can be mounted behind the chisel tines.

4 Conclusion

Research on conservation tillage methods shows that strip tillage methods are becoming increasingly important in agricultural production. In this research, one-pass and two-pass methods applied in strip tillage methods were examined. Although two-pass methods are common, tillage and planting in a one-pass will minimize field traffic. With this study, a strip tillage planting machine unit was designed to be applied in a one-pass, which will provide environmental, economic and social benefits to farmers, who are the end users within the scope of sustainable agricultural practices. As a result, the one-pass strip tillage unit will directly contribute to agriculture and the environment, and will benefit the country's economy with reduced fuel consumption, reduced input costs and reduced time consumption. It is estimated that this study will reduce the carbon footprint and prevent stubble burning, which is one of the important problems of the country. In the continuation of the research, it is recommended to evaluate, design and develop the strip tillage planting machine as a whole.

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