TARMAKDER
TARIM MAKİNALARI DERNEĞİ

Tarım Makinaları Bilimi Dergisi
Journal of Agricultural Machinery Science
http://dergipark.org.tr/tr/pub/tarmak
Research Article / Araştırma Makalesi

e-ISSN: 2651-4230

20(2), 2024: 84-95

Impact Assessment of Alternative Tillage Practices on the Stubble Cover

Alternatif Toprak İşleme Uygulamalarının Anız Örtüsü Üzerindeki Etkisinin Değerlendirmesi

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Article Info

Received date : 05.06.2024
Revised date : 12.07.2024
Accepted date : 17.07.2024

Keywords:

Amount of stubble
Tillage
Soil moisture

Atıf için:

Çıtıl, E., Çarman, K. (2024). Impact Assessment of Alternative Tillage Practices on the Stubble Cover, Tarım Makinaları Bilimi Dergisi, 20(2): 84-95

ABSTRACT

Stubble associated with conservation tillage minimizes soil water evaporation, erosion and temperature fluctuations. The aim of this study is to determine the effects of traditional tillage and alternative reduced tillage methods on stubble surface cover, stubble burial rate and soil water conservation after tillage. The amount of stubble remaining on the soil surface in post-tillage applications varies between 96-130.66 gm^{-2}, and the stubble burial rate varies between 48.21-61.95%. The lowest amount of stubble on the cultivated area with the highest burial rate (61.95%) in the vertical shaftrotary tillers. Stubble coverage after tillage varied from 2.85-26.57%. The effect of treatments on stubble cover was statistically significant (P<0.01). The winged chisel treatment was found to maintain about 25% more soil moisture than the other alternative treatments about 4 days after tillage.

Makale Bilgisi

Alınış tarihi : 05.06.2024
Düzeltilme tarihi : 12.07.2024
Kabul tarihi : 17.07.2024

Anahtar Kelimeler:

Anız miktarı
Toprak işleme
Toprak nemi

Çıtıl, E., Çarman, K. (2024). Impact Assessment of Alternative Tillage Practices on the Stubble Cover, Tarım Makinaları Bilimi Dergisi, 20(2): 84-95

ÖZET

Koruyucu toprak işleme ile ilişkili anız kalıntısı, toprak suyunun buharlaşmasını, erozyonu ve sıcaklık dalgalanmalarını en aza indirir. Bu çalışmada, geleneksel toprak işleme yöntemi ile alternatif azaltılmış toprak işleme yöntemlerinin, toprak işleme sonrası anızın yüzey kaplama ve gömülme oranına etkilerinin belirlenmesi amaçlanmıştır. Uygulamalara bağlı olarak toprağın işleme sonrası yüzeydeki anız miktarı 96-130.66 gm^{-2} ve anızın gömülme oranları ise %48.21-61.95 arasında değişmiştir. İşleme sonrası tarla üzerindeki en düşük anız miktarı, en yüksek gömme oranıyla (%61.95) düşey milli rotatillerde elde edilmiştir. Toprak işleme sonrası kalan anızın yüzeyi kaplama oranları ise %2.85-26.57 arasında değişmiştir. Uygulamaların anızın yüzeyi kaplama oranları üzerindeki etkisi istatistiki açıdan önemli bulunmuştur (P<0.01). Kanatlı çizel uygulamasında, toprak işlemeden yaklaşık 4 gün sonra toprak neminin diğer alternatif uygulamalara göre yaklaşık %25 daha fazla korunduğu saptanmıştır.

1. INTRODUCTION

Stubble control applications aim to change the amounts of stubble remaining on the soil surface to reduce clogging of the seeding foot during operation with planters. Stubble control starts with adjusting the mowing height during harvesting and the amount of stubble that will allow the seeding foot to pass through the stubble without clogging. Nowadays, farmers do not consider stubble management during harvest due to the cost of deep mowing and the decrease in harvest success. In these conditions, post-harvest stubble management systems are important to reduce the amount of stubble (Midwood and Birbeck, 2010). Crop residues on or near the surface protect the soil by slowing down the flow of water and creating channels for water to enter the soil, reducing the presence of impermeable material in the soil, under the influence of the erosive force of wind and raindrops.

The sustainability of agricultural production is closely related to the state of soil quality. Various agricultural practices such as deep and intensive tillage, removal or burning of harvest residues, use of chemical fertilizers without taking into account plant needs and soil analysis, and excessive water use cause the deterioration in soil, water and air quality to worsen. Effects such as decrease in soil organic carbon content, weakening of soil biodiversity, compaction, increased runoff and accelerated nutrient erosion loss negatively affect the fulfillment of ecosystem services related to soil quality.

The geometry and position of the seeding coulter on a planting machine can reduce blockages during planting. The tiller foot retains stubble in the field, protects the soil from erosion, and helps the soil retain moisture by reducing surface runoff and reducing evaporation rates. The stubble cover remaining on the field surface can help preserve the soil structure by increasing the microbial activities of the soil. Despite many benefits of stubble, the height of the stubble may prevent the machines from working during planting. Choosing the appropriate seeding foot for this purpose can eliminate this negative situation.

In Türkiye, as in the rest of the world, soils have begun to lose their quality as a result of intensive and unconscious use, and significant decreases in productivity have been observed. For this reason, optimum efficiency is aimed instead of obtaining maximum product per unit area. Optimum efficiency is possible with the use of stubble management and agricultural production systems that will ensure sustainability in agricultural production with minimum energy input.

Goals of a conservation tillage system are to bury excessive amounts of residue, reduce the size of residue and redistribute it evenly over the field. To determine the value of ground cover for wind erosion control, assess the percentage of covered ground viewed directly from above. In conservation tillage, there should be at least 30% of vertical stubble in the soil, which is a height between approximately 30 cm to 60 cm and 50% to 60% of horizontal stubble (Anonymous, 2011). When the coverage rate of crop surface residue left on the soil surface is 20%, the percentage of erosion reduction that may occur in soil loss is approximately 50%, while this rate increases to 64 % when the coverage rate is increased to 30 % (Dickey et al., 1986). Retained stubble improves water infiltration. Stubble increases soil moisture retention, particularly in the soil surface pre-seeding and during early crop development. In addition to the benefits of mixing the crop residues left on the field surface after the harvest with the soil, if it is not mixed with the soil properly, it makes the work of the soil cultivation and sowing machines difficult due to the blockages in the seed bed preparation and seeding processes for the next crop. Göknur and Özarslan (1995) investigated the effect of forward speed on the burial rate of crop residues on the soil surface while working with plows and reported that the highest stubble burial rate was determined at forward speeds between 3.69 and 5.92 km h^{-1}. The effects of low cutting and high cutting applications and different stubble control systems on fuel consumption, work success and the amount of stubble remaining in the field were revealed. Additionally, direct seeding of lentils on stubble and plant emergence were examined for each stubble management system. The difference between low cutting height and high cutting height was found to be statistically insignificant in terms of fuel consumption and the amount of stubble remaining in the field. It has been observed that fuel consumption varies more with the waste management system rather than the cutting height (Kolay et al., 2018)

Unger (1984) found stubble burial rates as 90% in mouldboard and disc plows, 50% in tandem and offset disk harrows, 25% in chisels, and 10% in large tines cultivators. Çarman and Konak (1996) investigated the effect of different direction angle and forward velocity on the burial rate of surface stubble in their study with a heavy-duty disc harrow. They found that the burial rate values varied between 54% and 88%.

Raper (2001) investigated the effect of working depths of disc and chisel type equipment on the burial of crop residues. It has been determined that at large working depths, disc type tillage equipment has a greater effect on the burial of crop residues than chisel type equipment. It has been revealed that when the working depths of chisel type equipment are reduced from 0.33m to 0.18m, the drawbar force and energy requirement are reduced by 50%.

In stubble tillage, it is reported that small fragmentation of crop residues is necessary in order to be mixed with the soil at a higher rate and to decompose in a shorter time (Wieneke, 1990; Tebrügge, 1993). On the other hand, stubble stalks remaining in rough form and not fully fragmented in the soil may prevent the seed from contacting the soil and this may negatively affect germination (Önal and Aykas, 1993).

In a study of the effect of different tillage tools on the amount of stubble on the soil surface, the effect of two different working depths and forward speeds on the amount of stubble remaining on the soil surface was determined for each tillage tool by using the straight line method. In the study, the effect of working depth on the amount of stubble was found to be insignificant for first class tillage tools. According to the data obtained with the straight line method, the effect of the forward speeds on the amount of stubble was found to be significant for first class tillage practices and second class tillage implements treated with plough, while the effect of forward speeds was found to be insignificant in the second class tillage implements in the area treated with chisel (Korucu and Yurdagül, 2013a). Korucu and Yurdagül (2013b) determined the effect of surface residue coverage rate remaining on the soil surface after tillage and tested the reliability of image processing method. They reported that the surface residue coverage ratio values determined as a result of image processing method and intersecting line method are related to each other. Observation-based method, photo comparison method, calculation method and intersecting line method are the most commonly used methods for determining the coverage rate of surface residue on the soil surface (Brown et al., 1992; Al-Kaisi and Hanna, 2013; Korucu, 2003).

Considering that the plow is used extensively by farmers in Central Anatolia today, studies conducted as an alternative to the traditional tillage method have not determined how much of the soil surface is covered with pre-plant residues after planting and whether the application is really effective in preserving soil moisture. Çelik and Altikat (2022) In their study to determine the effect of power harrow on the wheat residue cover and residue incorporation into the tilled soil layer, they determined that 47% of the residue remaining on the soil surface and in the depths of the tilled soil layer after harvest remained on the soil surface, the rest was incorporated into the tilled soil layer, and the amount of residue incorporated into the tilled soil depth decreased as the soil depth increased. They also reported that the average amount of residue mixed into the soil decreased with all factors as the tilled soil depth increased. Numerous studies have been conducted on the effects of tillage and residue on soil temperature and plant growth, but only a few have involved the effects of alternative tillage practices or crop residue amount on moisture change. Çarman et al. (2021) in their study comparing strip tillage systems, periodically measured soil moisture and temperature measurements until the seed germinated and the sprouts were completed and found that the soil moisture content in conventional tillage was lower compared to strip tillage applications. As a result of the study, they reported that there was a significant difference in soil moisture status between different soil tillage systems and that as the strip width increased, the loss of soil moisture through evaporation also increased and as a result, they reported that the soil moisture content was maintained in relatively narrow strips and despite this, there was no significant difference between strip tillage applications.

In this study, it was aimed to determine the effects of the machines used in conventional tillage and alternative reduced tillage methods on the amount of stubble on the soil surface, surface coverage, burial rate and soil water preservation.

MATERIALS AND METHODS

The experiments were carried out in the Soil, Water and Desertification Control Research Station in Konya, Türkiye. In the US Soil Taxonomy, the soils of the research station are classified as Typical Xerfluent. Soil properties of the trial area are given in Table 1.

Table 1. Physical and mechanical properties of the soil

	Sand	36.88	
Texture (%)	Clay	42.94	Clay
	Silt	20.18	
PH	8.20		
EC.10^{-3} (mmhos/cm)	0.67		
Organic matter (%)	1.21		
Bulk density (gcm^{-3})	0-15 cm		1.18
	15-30 cm		1.41
Penetration resistance (MPa)	2.66		
Surface roughness (%)	10.5		
Shear resistance (Ncm^{-2})	1.96		

In the experiments, the conventional soil tillage method, vertical spindle soil tillage machine + roller, horizontal spindle (L blade) soil milling machine + roller and chisel + roller combinations used in the reduced soil tillage method were used and the experiments were carried out with 3 replications.

Tillage methods and machines used are as follows.

• CT: Conventional method: plough + Cultivator - rotary harrow (2 times)
• AT1: Vertical spindle soil milling machine - with roller
• AT2: Horizontal spindle soil mill (L type) - with roller
• AT3: Chisel (winged) - roller

New Holland trademark TD90 model tractor was used. The characteristics of the tools and machines used in the trials are given in Table 2.

Table 2. The specifications of the tools used in experiment

Tool	Body number	Construction work (Implement) width (cm)	Type
Plough	4	122	Mounted
Cultivator-rotary harrow combination	11	263	Mounted
Rotary cultivators with vertical axes	8	227	Mounted
Rotary cultivators with horizontal axes (L type) – roller combination	11	260	Mounted
Chisel (winged type) – roller combination	7	210	Mounted

Soil moisture was measured by gravimetric method with a calibrated TDR device (Black et all. 1965). Measurements were made in 10 replicates at 0-20 cm depths in each plot before (control (BT)) and after tillage. In order to observe the moisture changes in the soil due to different tillage treatments, measurements were made at the 2nd, 12th, 24th, 48th and 96th hours after tillage. Penetrometer resistance values obtained up to a depth of 30 cm for every 1 cm depth interval in the soil were recorded on the device (Çarman, 1997). John Deere brand radar device was used to determine operating speeds. Surface profile irregularity was measured using a profilmeter constructed from a series of vertical rods spaced 2.5 cm apart on a 100 cm long profile. Surface profile irregularity was calculated using the Kuipers equation (Çarman, 1997).

$$R = 100 \,.\, \log_{10} \,.\, S \qquad (1)$$

Here;
R: Surface irregularity of the field (%)
S: It is the standard deviation of the measured value.

Before tillage (control (BT)), to determine the amount of stubble on the surface of the trial area, a frame with an area of 1 m^2 was placed on each trial plot, the stubble in the frame was cut at the soil level and the collected stubble was weighed. This process was carried out in 3 replications for each application parcel and was found to be g m^{-2}. Images were taken from each application with a digital camera. A frame of 50 x 50 cm (0.25 m^2) was used to take the images. The images taken with the camera were saved as image format on the computer. MATLAB programme was used to digitise the stubble density. In MATLAB programme, the images were opened in JPG format and stubble density was determined by image processing on the opened images (Korucu and Yurdagül, 2013b; Çarman, et al., 2018).

RESULTS

The working characteristics of the equipment of different treatments are given in Table 3. Similar working depths were obtained in the conventional and reduced tillage treatments in the winged chisel. The lowest working depth was obtained in rotary cultivators with horizontal axes.

Table 3. Working characteristics of equipment

Tool	Working depth (cm)	Working width (cm)	Average speed (km h^{-1})
Plough	22	120	5.5
Cultivator-rotary harrow combination	15	220	7
Rotary cultivators with vertical axes- roller kombination	18	215	3.0
Rotary cultivators with horizontal axes (L type) – roller combination	12	250	4.2
Chisel (winged type) – roller combination	22	215	2.8

Some physico-mechanical properties of the soil and stubble burial rates after tillage are given in Figures 1 to 6. The effects of different tillage machines on the penetration resistance of the soil are given in Figure 1. Soil penetration resistance values vary between 0.789-1.085 MPa depending on different tillage practices. The largest change in soil penetration resistance was achieved with a 126% decrease in the vertical shaft machine. The effect of different tillage machines on the penetration resistance of the soil was found to be significant (P<0.01).

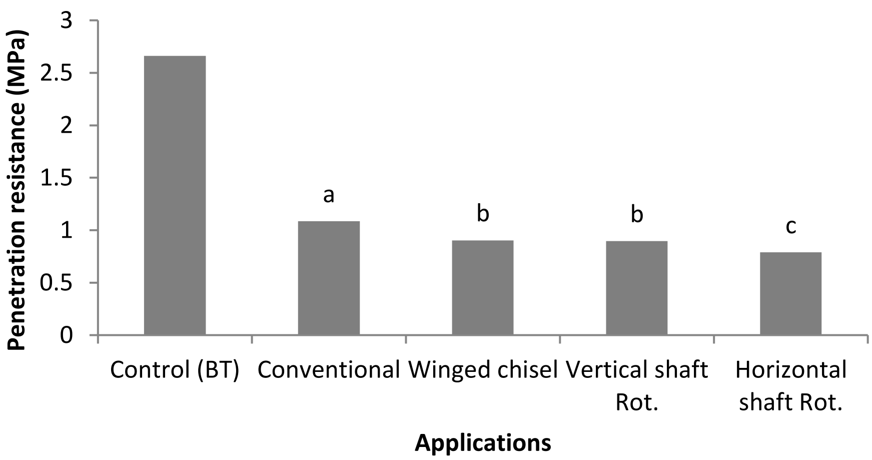

Figure 1. Variation in penetration resistance of soil depending on the treatments
(Means indicated by the same letter are not significantly different)

Figure 2 shows the effect of machines on the shear stress of the soil. Depending on the engaging part, the shear stress values of the soil vary between 0.34-0.54 Ncm^{-2}. The biggest change in the shear stress of the soil, 82.6%, was obtained in the combination of vertical shaft soil milling machine and roller. The effect of engaging parts on the shear stress of the soil was found to be significant (P<0.01).

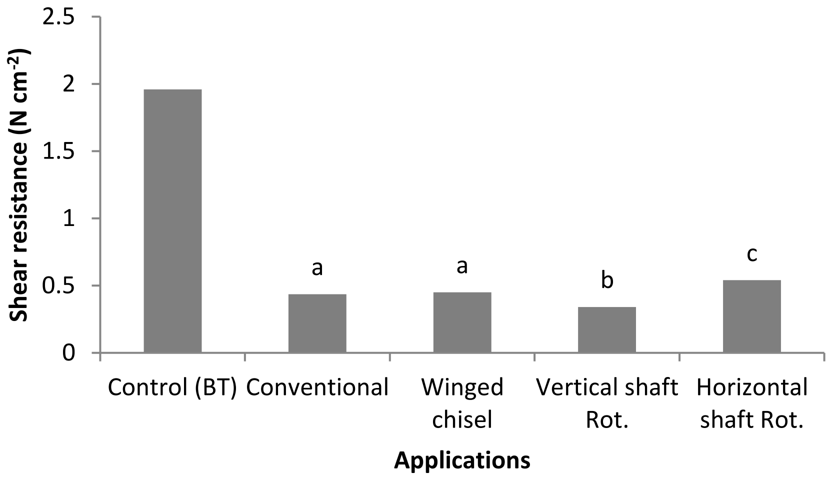

Figure 2. Change in shear resistance of soil depending on the treatments
(Means indicated by the same letter are not significantly different)

The effects of different tillage organs on the surface roughness of the soil are given in Figure 3. Depending on the tillage organ, soil surface irregularity values varied between 10.5-29%. The highest value of soil surface irregularity was obtained from the winged chisel application with 29%, while the lowest value was obtained from the before tillge (control (BT)) with 10.5%. The effect of cultivating organs on soil surface irregularity was found to be significant (P<0.01).

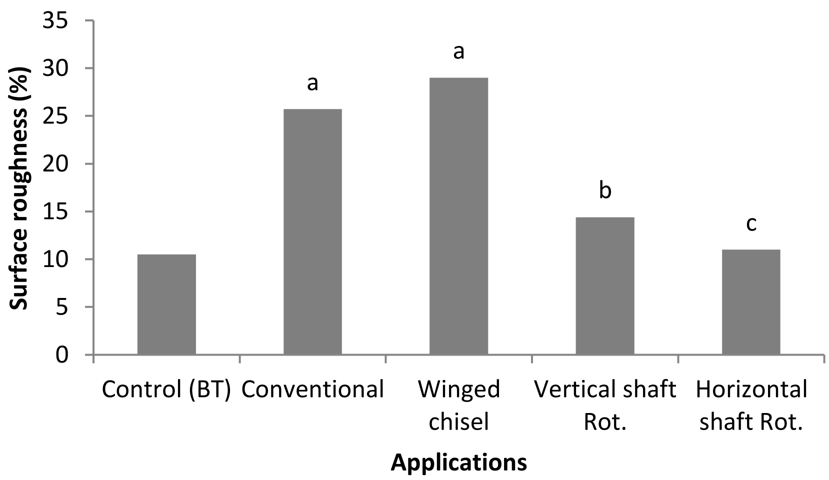

Figure 3. Change in surface roughness of the soil depending on the treatments
(Means indicated by the same letter are not significantly different)

The effect of the applications after tillage on the amount of stubble remaining on the soil surface and the stubble burial rate in the soil is given in Figure 4. It was observed that the amount of stubble remaining on the soil surface after tillage varied between 96-130.66 grm^{-2} depending on the applications. The stubble burial rates of the applications vary between 48.21-61.95%. A 61.95% burial rate was achieved in the rotary cultivators with vertical axes. The effect of engaging parts on stubble burial rate was significant (P<0.01). Çıtıl (2023), conducted a study with disc harrows and found that the stubble burial rate was 87% with increasing disc diameter, direction angle and number of revolutions.

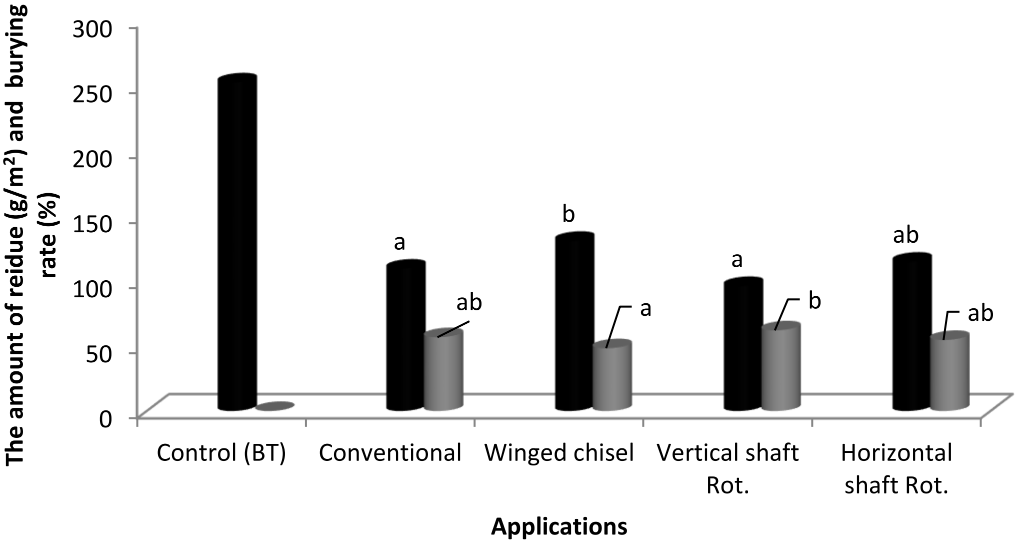

Figure 4. Change in stubble burial rate depending on the treatments
(Means indicated by the same letter are not significantly different)

The surface coverage rate of the stubble remaining after tillage varied between 2.85-26.57% (Figure 5). The highest surface coverage rate (26.57%) was obtained with a change of 48.3% in the machine with winged chisel type. The effect of the post-tillage cultivator organs on the stubble coverage rate was found to be significant (P<0.01). It was determined that the effects of winged chisel and rotary cultivators with horizontal axes on stubble coverage rates were similar. When evaluated in terms of protective tillage technique, it was found that the results obtained were below the desired minimum limit values (30% in standing stubble and 50-60% for prostrate stubble). Olaoye (2002) reported that after tillage, disc harrow ploughing, ploughing, then disc harrow, disc ploughing, then disc harrow and disc ploughing and then two passes of disc harrow, the crop residue remaining on the soil surface was not significantly different between the disc harrow and plough tillage treatments followed by disc harrow tillage treatments, while the residue on the soil surface in no-till application was not significantly different compared to tillage application, while the application of disc harrow and disc ploughing followed by two passes of disc harrow left 32.1% and 44.3% more residue, respectively. Dursun and Dursun (2018) conducted a research using various tillage methods to estimate the percentage of crop residue cover remaining in the soil in wheat, barley, oat and rye fields, and reported that there was a crop residue between 14.64% and 90.1% on the soilsurface after tillage.

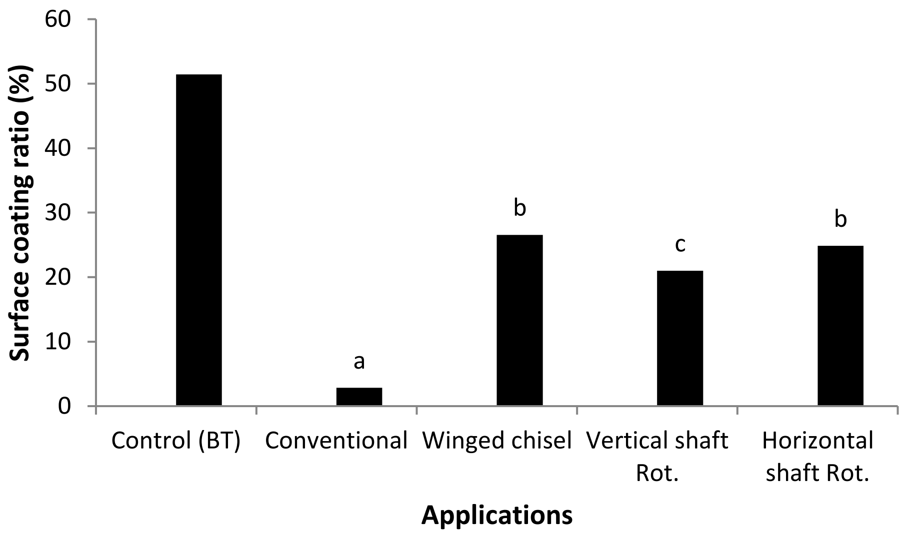

Figure 5. Variation in stubble surface coverage ratios depending on the treatments (Means indicated by the same letter are not significantly different)

The effect of the machines on the soil moisture change depending on the time after tillage is given in Figure 6. Depending on the treatments, the average soil moisture values at 96th hour after tillage varied between 7.46 and 9.42%. There was a significant parabolic relationship between time after tillage and soil moisture (R=0.993). The greatest change in soil moisture values after tillage was obtained with a decrease of 61.5% in the machine with vertical shaft working organ and the smallest change was obtained with 48% in the machine with winged chisel. At 96th hour after tillage, moisture preservation was found to be about 25% higher in the winged chisel treatment compared to the other treatments. The fact that this treatment had the highest stubble coverage rate with 26.57% after tillage showed that it preserved soil moisture better. The effect of tillage organs on the change of soil moisture values was found to be significant ($P<0.01$). At the end of the multiple comparison test, the effects of the applications on soil moisture after the 96th hour were CT:a, AT1:b, AT2:a, AT3:a. The source of the difference was the AT1 application. Abdullah (2014) studied minimum tillage and residue management in semiarid areas. He said that the important reason for soil degradation and decrease in agricultural productivity in semi-arid areas is the agricultural system based on intensive tillage. Minimal tillage and residue management in canola production have been shown to increase soil water content. Ghuman and Sur (2001) studied the effects on soil properties tillage and residue management. They found that 10-13% more water was retained in the soil layers in plots with minimum tillage than in plots with conventional tillage. Çıtıl (2023), conducted with disc harrows, determined the soil moisture loss as 45% approximately 48 hours after tillage depending on the diameter of the concave disk and the direction angle of the disc.

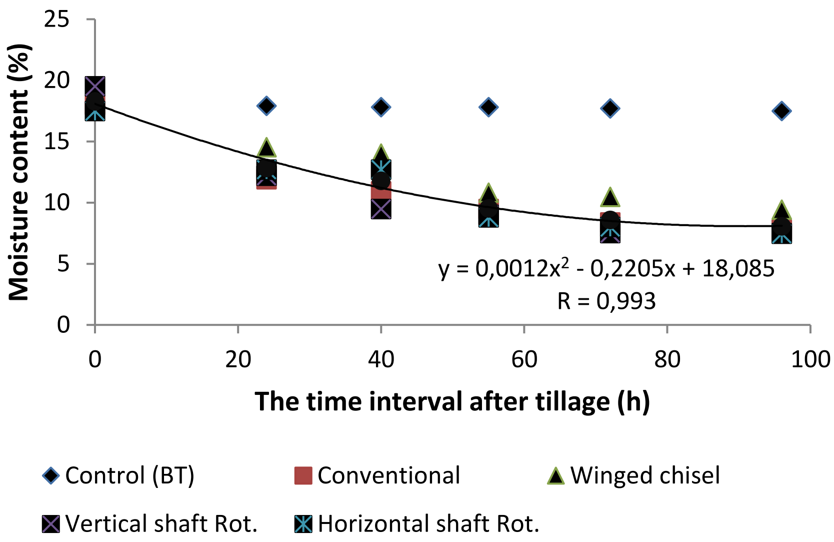

Figure 6. Changes in soil moisture values depending on the treatments

CONCLUSION

The following evaluations can be made as a result of conventional and alternative tillage practices;

- The effects of active parts of machines on penetration resistance, shear stress of soil and surface roughness of soil were found to be significant.
- The effect of the applications on the amount of stubble remaining on the soil surface after tillage and the rate of stubble being buried in the soil was found to be significant.
- The lowest amount of stubble and the highest burial rate were obtained from rotary cultivators with vertical
- While the surface coverage rates of the stubble remaining after tillage varied between 2.85-26.57%, the highest surface coverage rate (26.57%) was obtained from the equipment with winged chisel with a change of 48.3%.
- In the winged chisel treatment, it was found that soil moisture was preserved approximately 25% more than the other alternative treatments approximately 4 days after tillage.

-When the treatments It was evaluated in terms of conservation tillage technique, it can be said that the machine with the winged chisel organ is more suitable both for the preservation of soil moisture and for the higher stubble coverage rates on the surface (although the limit value is below 30%).

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