Effect of a combined machine parts depths, soil depths and manure application on soil saturated hydraulic conductivity

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Abstract. Field experiments were conducted to study the effect of a combined machine parts depths, soil depths and application of manure (cow residual) on the soil saturated hydraulic conductivity (Ks). The soil was plowed and disturbed at two levels. The top layer were plowed by the two bodies of moldboard plow which they were one of the combined machine parts, the deep soil layers were disturbed by two subsoilers which were the second part of the combined machine. The manure was mixed with plowed and the disturbed soils by the three shallow tines of the combined machine (third part). Manure was broadcasted by the manure feeding mechanism which the machine was provided with. Randomize Complete Block design (RCBD) was used with three replicates to carry out the experiments. The experiments parameters were two moldboard plow depths (20cm (M20) and 30cm (M30)), three subsoiler depths (20 (S20), 30 (S30) and 40cm (S40)). These three subsoiler depths were used with moldboard plow depth of 20cm only, whereas, the other three subsoiler depths (10 (S10), 20 (S20) and 30 (S30)) were used with moldboard depth of 30cm. The combination of the moldboard plow depths and the subsoiler depths gave three machine depths (40, 50 and 50cm) i.e M20S20, M30S30, M20S40, M30S10, M30S20 and M30S30. These treatments were conducted without and with manure application of 45.5 ton ha⁻¹. The experiments were conducted in silty laom soil. The soil saturated hydraulic conductivity (Ks) was measured after soil plowing and crop harvesting (two periods) for soil depths of d₁ (0-10), d₂ (10-20), d₃ (20-30), d₄ (30-40), d₅ (40-50) and d₆ (50-60). The results showed that Ks increased with machine depth. It increased by 20.39% and 41.18% and by 12.90% and 21.03% after soil plowing and crop harvesting (the beginning and the end of the season) respectively, when the operating depth of machine was increased from (M20S20) to (M30S30) and (M30S40). M depth remained constant at 20cm whereas, the subsoiler depth increased from 20 to 30 and 40cm. However, increasing the machine depths from (M30S10) to (M30S20) and (M30S30), Ks increased by 19.44 and 36.11% and by 15.15 and 33.33% at the beginning and end of the season respectively, (the operating depth of M increased to 30cm and remained constant whereas S depth increased from 10 to 20 and 30cm). Compared with operating depth of 10cm. K, of the soil treated with manure decreased by 4.65% after plowing operation. However, K, increased by 35.48% after crop harvesting compared with untreated soil. K, decreased after soil plowing and at the end of crop growth season with plowing depth. However, Ks decreased as the soil depth increased.

Keywords: soil saturated hydraulic conductivity, manure (animal waste), operating depths and soil depths, period (A) (after soil plowing), Period (B) (After harvesting)
1. Introduction

Soil saturated hydraulic conductivity is a method used to evaluate the water movement in the soil. It depends on the geometrical shape of the pores, soil total porosity and pores sizes distribution (Hillel, 1980; Johnson et al., 2005). In the sandy clay loam soil, $K_s$ increased in the soil deeply plowed by double tines and chisel plow (30-40cm) compared with conventional plowing carried out by single disc plow followed by disc harrow of four discs and plowed soil. $K_s$ values obtained are 0.04, 0.03 and 0.02 for the three treatments respectively (Iqbal et al., 2005). Alzady (2006) mentioned that $K_s$ decreased with soil depth in clay loam soil. It was higher in the depth of 0-15cm compared with depth of 15-30cm. The reason was the soil bulk density increased with soil depth because the top soil layers confined the deep layers. However, $K_s$ increased with plants growth and that was because the soil structure improved due to roots growth and distribution in the soil which increased the pore sizes distribution (Al-tahan and Al-Irhayim, 2010).

Using the subsoiler to disturb the soil resulted in lower $K_s$ in silty clay soil with the operating depth, $K_s$ value decreased from 0.15 to 0.07m dy$^{-1}$ when the operating depth increased from 20 to 40cm respectively. This was because the high disturbance of the soil in depth of 20cm.

Jabro et al (2010) found that $K_s$ increased in sandy loam soil by 68 and 56% with strip plowing compared with conventional plowing. Using the subsoiler with moldboard plow in silty clay soil, $K_s$ increased by 23.9 and 25.4% at the beginning and the end of the growth season compared moldboard plow respectively. The reason was that the subsoiler disturbed the hard pan and improved soil physical properties. Application the sheep waste to the sandy loam soil (gypsum desert soil) increased $K_s$. The reason was that the organic carbon improved soil aggregates and structure (Al-Hadithy et al., 2008).

The results obtained by (Abdulhamza, 2010) showed that application crows waste of 32ton ha$^{-1}$ to the silty clay loam soil increased $K_s$ from 0.34m day$^{-1}$ for control treatment to 0.80m day$^{-1}$. This was related to the improvement in the total soil porosity as well as the increase in the soil organic carbon which improved soil structure due to the increase in the soil mean weight diameter.

Application 20 ton ha$^{-1}$ of organic residual to sandy clay loam soil and plowing the soil by chisel plow (deep plowing), disc plow (shallow plowing) and without plowing, $K_s$ of the soil increased by 0.54, 0.46 and 0.44m day$^{-1}$ for the three treatments respectively (Iqbal et al., 2005). Muqadas et al (2005) showed that there was a significantly difference between the values of $K_s$ for sandy clay loam soil which was deeply plowed, conventional and minimum plowing with application 40ton ha$^{-1}$ animals residual, the values of $K_s$ are 0.82, 0.72 and 0.62m day$^{-1}$ respectively. Zhang and Fang (2007) mentioned that application the organic residual and chemical fertilizer with deep plowing increased $K_s$ by 76% in the loamy clay soil compared with application organic residual and chemical fertilizer with shallow plowing.

The aims of this research was to study the changes in $K_s$ values when the soil plowed at different depths and application of organic residual. In additional to that determining the best depth giving the highest value of $K_s$ using new design machine which plows the top soil layers (pulverizing the top layers) and disturbs the soil deep layers (bigger soil clods).

2. Materials and methods

Afield experiments were conducted in south of Iraq (Basra district) which exists in dry region. The soil texture was silty loam soil. The soil physical and chemical properties are shown in table (1). The soil samples were collected for depths of (0-10) $d_1$, (10-20) $d_2$, (20-30) $d_3$, (30-40) $d_4$, (40-50) $d_5$ and (50-60) $d_6$ (cm). The samples were air dried and some samples were sieved by 2mm sieve. The soil texture was determined by Pipette method, real density by the Pycnometer method, soil bulk density by Core sampler. The total porosity was calculated from the bulk density and real density values using the methods described in Black et al. (1965). Soil penetration resistance (cone index) was
measured by the field Cone penetrometer (Gill and Vandenberg, 1968). The chemical properties, which include electrical conductivity of the soil water extraction (ECe) using the Ec-meter and the method described in (Page et al., 1982). The organic matter was measured using the Walkely and Black method. The total soil carbonates and pH were measured using the methods described in Jackson (1958). The soil cation exchangeable capacity (CEC) was measured by Papanicolaou (1976) which described in Page et al. (1982).

Table (1) some physical and chemical properties of the soil for the depths (0-10), (10-20), (20-30), (30 - 40), (40 - 50), (50 - 60) cm and irrigation water salinity.

| Properties                  | Units | Soil depths (cm) |  
|-----------------------------|-------|------------------|
|                             |       | (0-10) | (10-20) | (20-30) | (30-40) | (40-50) | (50-60) |
| sand                        | g kg\(^{-1}\) | 200.51 | 139.15 | 173.74 | 151.89 | 162.61 | 67.69  |
| silt                        | g kg\(^{-1}\) | 599.97 | 612.74 | 610.87 | 653.17 | 600.45 | 628.18 |
| clay                        | g kg\(^{-1}\) | 199.52 | 248.11 | 215.39 | 194.94 | 236.94 | 304.13 |
| Texture                     |       | Silty  | Silty  | Silty  | Silty  | Silty  | Silty clay |
| Real density                | Mg m\(^{-3}\) | 2.61   | 2.61   | 2.62   | 2.65   | 2.65   | 2.65   |
| Bulk density                | Mg m\(^{-3}\) | 1.26   | 1.27   | 1.28   | 1.29   | 1.30   | 1.30   |
| Total porosity              | %     | 51.34  | 50.95  | 51.14  | 51.32  | 50.94  | 50.94  |
| Penetration resistance      | kN m\(^{-2}\) | 1300   | 1480   | 1640   | 1744   | 1900   | 1966   |
| ECe                         | dS m\(^{-1}\) | 7.69   | 12.50  | 13.89  | 18.67  | 18.72  | 20.17  |
| Total carbonate             | g kg\(^{-1}\) | 339.12 | 338.41 | 316.51 | 300.35 | 290.45 | 280.11 |
| Organic matter              | g kg\(^{-1}\) | 11.46  | 10.15  | 10.01  | 3.33   | 1.42   | 1.03   |
| pH                          |       | 7.23   | 7.63   | 7.79   | 7.80   | 7.80   | 7.80   |
| CEC                         | cmolc kg\(^{-1}\) | 29.21  | 30.12  | 29.11  | 28.32  | 27.50  | 27.11  |
| Ec of water                 | dS m\(^{-1}\) | 2.06   |        |        |        |        |        |

2.1. Experiments layout

The soil was plowed and disturbed in two levels by combined machine. The combined machine consists of two moldboard plow bodies and two subsoilers. The moldboard bodies plow the top soil layers whereas the subsoilers disturb the deep layers. The machine operating depths were 40, 50 and 60cm. These operating depths are the summation of moldboard plow operating depth and the operating depth of the subsoilers. The combinations of the operating depths are:

The moldboard plow operating depths were 20cm (M\(_{20}\)) and 30cm (M\(_{30}\)), three subsoilers operating depths were used with first operating depth namely 20cm (S\(_{20}\)), 30cm (S\(_{30}\)) and 40cm (S\(_{40}\)). However, with moldboard operating depth of 30cm (M\(_{30}\)), three operating depths were used which they are 10cm (S\(_{10}\)), 20cm (S\(_{20}\)) and 30cm (S\(_{30}\)). The machine operating depths combinations are shown in table (2). The experimental field was plowed with and without application manure (cow waste). The amount of manure added was 45.5ton ha\(^{-1}\). The manure was mixed with soil by the shallow tines which they were provided to the implement.

After soil plowing by the combined machine the soil was divided into plots, the area of each plot was 5m\(^2\) (5m x 1m). The plots were separated by one meter. Drip irrigation system was used for irrigation. The pipes used were of internal dripper (GR). The dripper discharge was 81 kg ha\(^{-1}\). The distance between the dripper was 45cm. Each plot was provided with two pipes, the distance between them was 70cm. N-element was added as urea fertilizer (46%N) by amount of 160kg ha\(^{-1}\) and
superphosphate was also added (\(P_2SO_4 \, 47\%)\) by amount of 80kg ha\(^{-1}\). The potassium fertilizer was added by amount of 80kg ha\(^{-1}\) as potassium sulphate (\(K_2SO_4 \, 52\%\)).

Sunflower crop seeds of Varieties (confection types) were planted, 4 seeds per hill, the distance between the hills was 25cm. The added water amount was determined according the amount of water evaporated from American evaporation basin (Evaporation pan class A) which equal to 100% of evaporated amount plus 20% as leaching requirement. The water amount added for experimental units calculated according to Eq. (1).

\[
W = \frac{E}{(1000)} \ast A \quad \text{................(1)}
\]

Where

- \(W_A\) = amount of irrigation water per plot (m\(^3\))
- \(E_W\) = evaporation from basin (mm)
- \(A\) = Area of plot (m\(^2\))

The crop thinning carried out after 15 days from planting date, one plant left per hill. The crop harvesting was conducted after 90 days.

2.2. \(K_S\) measurement

The soil \(K_S\) was measured after plowing and harvesting for all treatments of the experiments. The constant water column method which was mentioned by Kluet (Black et al, 1965) was used for measuring soil \(K_S\). The water column was fixed at 2cm above the soil column. The soil column diameter was 5cm. The soil column was saturated with water using water capillary. The amount of water passed through the column was collected until the water amount became constant. \(K_S\) was calculated using Darsy equation (Eq-2)

\[
K_S = \frac{Q}{A \ast t \ast L} \quad \text{...............(2)}
\]

- \(K_S\) = saturated water conductivity (m day\(^{-1}\))
- \(Q\) = amount of water passed through the soil column (m\(^3\))
- \(L\) = soil column length (m)
- \(A\) = soil cross-section width (m\(^2\))
- \(t\) = time (day)
- \(h\) = soil column height + water height over the soil surface (m)

2.3. Experimental design

Experiments were carried out using randomized complete Block Design (RCBD). The results were analyzed using the Gen stat software for analysis of variance. The mean of the parameters was analyzed and tested using the least significant difference (R LSD) at a probability level of 0.05. The mean of the coefficients at the beginning and the end of the planting season were compared using the t-test at the probability level (0.05).
Table (2) The depth of plowing and the symbols of the treatments used in the experiment

| Samples          | Depths of plowing (cm) (implement) | Depths of subsoiler (cm) | Depths of moldboard (cm) | Treatments                    |
|------------------|------------------------------------|--------------------------|--------------------------|-------------------------------|
| M₂₀              | 20                                 | ----                     | 20                       | Implement Part                |
| M₃₀              | 30                                 | ----                     | 30                       | (moldboard plow)              |
| M₂₀S₂₀sh         | 40                                 | 20                       | 20                       | all Implement parts           |
| M₂₀S₃₀sh         | 50                                 | 30                       | 20                       | (moldboard + subsoiler+)      |
| M₂₀S₄₀sh         | 60                                 | 40                       | 20                       | shallow tines                 |
| M₂₀S₁₀sh         | 40                                 | 10                       | 30                       |                               |
| M₂₀S₂₀sh         | 50                                 | 20                       | 30                       |                               |
| M₂₀S₃₀sh         | 60                                 | 30                       | 30                       |                               |

M = moldboard plow  S = subsoiler  sh = shallow tines

3. Results and discussion

3.1. Effect of the operating depths of the machine parts on the soil saturated hydraulic conductivity

The plowing operation by the machine improved $K_s$ significantly at the beginning of the season, before planting. $K_s$ increased by 500% compared with the control treatment (uncultivated and unplanted soil). This was related to high soil total porosity, distribution of the pore sizes and the reduction in the soil cohesion and bulk density due to the plowing operation (Al-Nassar, 2015). $K_s$ increased as the machine depth increased with high significant difference between the depths in the beginning and end of the season (table 3). The results also showed that the $K_s$ increased by 20 and 40% for operating depths 50 and 60cm respectively compared with operating depth of 40cm in the beginning of the season (figure 1, A). At the end of the season, after harvesting the crop, $K_s$ increased by 15.63% and 31.25% respectively (figure 1, B). This improvement in $K_s$ can be related to the disturbance of the compacted layers in depths, decreasing in the soil bulk density and increasing in the total porosity.

Table (3) statistical analysis of the test (F) of the values for soil saturated hydraulic conductivity

| Source          | df | Beginning of the season | End of the season |
|-----------------|----|-------------------------|-------------------|
| dt              | 5  | 249.58**                | 217.83**          |
| ds              | 5  | 2415.22**               | 3267.10**         |
| OM              | 1  | 63.16**                 | 1684.89**         |
| dt xds          | 25 | 58.48**                 | 40.67**           |
| dt x OM         | 5  | 1.21**                  | 13.53**           |
| ds x OM         | 5  | 17.84**                 | 203.32**          |
| dt x ds x OM    | 25 | 0.78**                  | 2.18**            |

dt = depths of machine main parts;  OM = organic manure levels  
ds = soil depths  ** = significant differences at level 0.01  
ns = no significant differences
3.2. The effect of soil depths in the soil saturated hydraulic conductivity

$K_s$ decreased significantly as the soil depth increased (table 3). Fig. (2) showed that the depths 10 and 20cm gave higher $K_s$ compared with remaining depths. $K_s$ values for the soil depth of 10cm are 0.65 and 0.54m day$^{-1}$ whereas, for soil depth of 20 are 0.61 and 0.53m day$^{-1}$ for both periods (A) and (B) respectively. $K_s$ values decreased as the depth of the soil increased. The reduction in $K_s$ values with soil depths are 0.04, 0.15, 0.05,0.16 and 0.10m day$^{-1}$ for period (A), for period (B) are 0.01, 0.07, 0.10, 0.15 and 0.10m day$^{-1}$ when the soil depth increased from 10 to 20, 30, 40, 50 and 60cm respectively. The reduction in $K_s$ can be related to increase in the soil bulk density and the reduction in the soil total porosity with depth due to the effect of the weight of the top layers which compact the deep layers. In additional to that the downward movement of soil fine particles filled the soil pores, which reduced the soil total porosity. The irrigation water retained the soil clods to their origin positions and the soil cohesion build up again which increased soil bulk density and therefore reduced the soil water downward movement (Young et al. 1994; Aday et al, 2018).

Figure 2. Effect depths of soil on $K_s$ (m day$^{-1}$) for soil (A) at beginning season (B) after harvesting
3.3. Effect the manure levels on the soil saturated hydraulic conductivity

The manure (cow residual) application significantly affected $K_s$ (table 2). $K_s$ decreased by 4.65\% when the manure was applied at the beginning of the season (fig. 3A) compared with untreated soil. This was related to the increase in the soil water retention ability which reduced downward movement of the water compared with untreated soil. At the end of the season (fig. 3B) $K_s$ for the treated soil increased by 35.48\% compared with untreated soil. This would be related to the improvement in the physical properties of the treated soil. The improvement in the soil physical properties and the soil fertility due to the manure application positively affected the plant growth and roots distribution in the soil, vertical and horizontally. The intensive roots growth improved the soil total porosity and therefore, the downward water movement (Abdul kareem et al, 2018)

![Figure 3. Effect levels of manure on $K_s$ (m day$^{-1}$) for soil (A) at beginning season (B) after harvesting](image)

3.4. The interaction effect of machine parts depths and the soil depths on soil saturated hydraulic conductivity

The interaction between the machine parts depths and soil depth significantly affected $K_s$ at the beginning and the end season (table 3). Tables (4 and 5) showed that $K_s$ increased with machine parts depth whereas, it decreased with soil depths. The highest value of $K_s$ was recorded for $M_{30}S_{30}$ treatment, while the lowest value was recorded for $M_{20}S_{20}$ treatment. Soil depth $d_1$ and machine depth $M_{30}S_{30}$ recorded the highest values of $K_s$ 0.69 and 0.57m day$^{-1}$ at the beginning and the end of the season respectively. The lowest values of $K_s$ 0.05 and 0.04m day$^{-1}$ were recorded for depth $d_6$ and $M_{20}S_{20}$ for periods A and B respectively.

The machine parts depths gave different values of $K_s$ when the soil depth remained constant. For example, at soil depth of $d_1$ and M depth of 20cm, $K_s$ increased by 3.28 and 11.48\% at period A, whereas, at period B, it increased by 1.92 and 5.77\% for S depths of 30 and 40cm compared with depth of S of 20cm, i.e. the machine depth increased from $M_{30}S_{10}$ to $M_{30}S_{30}$ and $M_{30}S_{40}$ respectively.

When depth of the M increased to 30cm, $K_s$ increased by 4.76 and 9.52\% at period (A), whereas, at period (B), it increased by 3.70 and 5.56\% when depth of S increased from 10 to 20 and 30cm, i.e. machine depth increased from $M_{30}S_{10}$ to $M_{30}S_{20}$ and $M_{30}S_{30}$ respectively. The results of the other soil depths coincided to the above results. This is a positive indicator for the improvement in the soil physical properties when the machine was used which increased the water movement in the soil, and this results are controversy to that of soil depth on $K_s$, $K_s$ decreased with soil depth and that was because the soil suffered from the existence of the compacted layers at depth.
Table (4) Effect of interaction between depths of the implement parts and soil depths in the $K_s$ (m day$^{-1}$) for soil at beginning season

| Depths of implements Components (M) | M$_{20}$S$_{20}$ | M$_{20}$S$_{30}$ | M$_{20}$S$_{40}$ | M$_{30}$S$_{10}$ | M$_{30}$S$_{20}$ | M$_{30}$S$_{30}$ | Average of Soil depths |
|-------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------------------|
| Depths of soil                      |                 |                 |                 |                 |                 |                 |                        |
| d$_1$                               | 0.61            | 0.63            | 0.68            | 0.63            | 0.66            | 0.69            | 0.65                   |
| d$_2$                               | 0.56            | 0.59            | 0.65            | 0.59            | 0.63            | 0.65            | 0.61                   |
| d$_3$                               | 0.43            | 0.44            | 0.46            | 0.44            | 0.46            | 0.48            | 0.45                   |
| d$_4$                               | 0.36            | 0.40            | 0.41            | 0.39            | 0.44            | 0.45            | 0.41                   |
| d$_5$                               | 0.05            | 0.35            | 0.36            | 0.05            | 0.35            | 0.37            | 0.25                   |
| d$_6$                               | 0.05            | 0.05            | 0.34            | 0.04            | 0.04            | 0.35            | 0.15                   |
| Average depths Of implement Components | 0.34 0.41 0.48 0.36 0.43 0.5  |  | 0.42          |                  |                  |                  |                        |
| RLSD 0.05                           |                 |                 |                 |  |                  |                  |                        |

Table (5) Effect of interaction between depths of the implement parts and soil depths in the $K_s$ (m day$^{-1}$) of the soil after harvesting

| Depths of implements Components (M) | M$_{20}$S$_{20}$ | M$_{20}$S$_{30}$ | M$_{20}$S$_{40}$ | M$_{30}$S$_{10}$ | M$_{30}$S$_{20}$ | M$_{30}$S$_{30}$ | Average of Soil depths |
|-------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------------------|
| Depths of soil                      |                 |                 |                 |                 |                 |                 |                        |
| d$_1$                               | 0.52            | 0.53            | 0.55            | 0.54            | 0.56            | 0.57            | 0.55                   |
| d$_2$                               | 0.50            | 0.52            | 0.54            | 0.53            | 0.54            | 0.55            | 0.53                   |
| d$_3$                               | 0.41            | 0.44            | 0.46            | 0.46            | 0.48            | 0.52            | 0.46                   |
| d$_4$                               | 0.32            | 0.35            | 0.36            | 0.34            | 0.36            | 0.42            | 0.36                   |
| d$_5$                               | 0.05            | 0.24            | 0.27            | 0.06            | 0.30            | 0.33            | 0.21                   |
| d$_6$                               | 0.04            | 0.05            | 0.20            | 0.05            | 0.05            | 0.22            | 0.10                   |
| Average depths Of implement Components | 0.31 0.36 0.40 0.33 0.38 0.44  |  | 0.37          |                  |                  |                  |                        |
| RLSD 0.05                           |                 |                 |                 |  |                  |                  |                        |

3.5. The effect of the interaction between the machine parts depths and manure levels on the saturated hydraulic conductivity

The effect of the interaction between the machine parts depths and manure application levels did not significant effect $K_s$ at period (A), whereas, the interaction between the mentioned parameters significant affected $K_s$ at period (B) (table 3).

$K_s$ increased with the machine parts depths for OM$_{0}$ and OM$_{1}$. The effect was rated to the depth of the machine parts, so when the operating depth of (M) kept constant at 20cm and depth of (S) increased from 20 to 30 and 40cm, $K_s$ values increased to 0.30 and 0.34m day$^{-1}$ for machine depths of M$_{20}$S$_{30}$ and M$_{30}$S$_{40}$ compared with the machine depth of M$_{20}$S$_{20}$ (S depth of 20cm) respectively, The shallow machine depth of M$_{30}$S$_{20}$ gave lower $K_s$ value of 0.27m day$^{-1}$. This improvement in $K_s$ values is related to the soil disturbing at depth which improved soil total porosity considerable. However, $K_s$
improved further when the depth of (M) increased to 30 cm and the depth of (S) increased from 10 to 20 and 30 cm. Its value became 0.33 and 0.36 m day\(^{-1}\) for machine depths of M\(_{30}\)S\(_{20}\) and M\(_{30}\)S\(_{30}\) respectively compared with machine depth of M\(_{30}\)S\(_{10}\) which recorded value of 0.28 m day\(^{-1}\) for treatment of OM\(_{0}\) (fig. 4). Thus to improve the soil drainage the soils which suffer from compacted layers should be plowed at surface and disturbed at depth using deep operating machines.

The application of manure to the soil improved K\(_{S}\) even further, it increased for all machine depths and its values are 0.34, 0.40 and 0.45 m day\(^{-1}\) for machine depths M\(_{20}\)S\(_{20}\), M\(_{30}\)S\(_{30}\) and M\(_{20}\)S\(_{40}\) m day\(^{-1}\) respectively. Whereas, its values are 0.38, 0.44 and 0.50 m day\(^{-1}\) for machines depths M\(_{30}\)S\(_{10}\), M\(_{30}\)S\(_{20}\) and M\(_{30}\)S\(_{30}\) m day\(^{-1}\) respectively (increasing M depth by 10 cm and decreasing S depth by 10 cm).

This was related to the soil disturbance which increased soil the total porosity and the reduction in the soil bulk density as well as due to manure application which helped in forming large soil aggregates, big pores. The manure prevented the big soil clods at depth to retain their origin position which is the case without manure application and that render the soil to maintain its big pores at depth. And that helped the soil to get rid of the excess water to the deep layers.

![Figure 4](image_url)

**Figure 4.** Effect of the interaction between depths of implement parts and manure levels on the K\(_{S}\) (m day\(^{-1}\)) for soil at beginning season (A) after harvesting (B)

3.6. **Effect of the interaction of the soil depths and manure application levels in the soil saturated hydraulic conductivity**

The interaction between the soil depth and manure application levels significantly affected K\(_{S}\) at both periods (A and B). K\(_{S}\) decreased in general with increasing soil depth for both period and for two levels manure OM\(_{0}\) and OM\(_{1}\) (fig. 5). At period (A), fig 5A), K\(_{S}\) values significantly higher than that for manure applicator treatment for depths d\(_{1}\) and d\(_{2}\) whereas, no significant difference between the values of K\(_{S}\) for both treatments with remainder depths. The reduction in K\(_{S}\) values for soil treated with manure was because the manure increased the soil water retention ability as well as blockage the soil pores.

However for period (B), fig (5B), the soil treated with manure surpassed the untreated soil in giving higher K\(_{S}\) values. This supervision remained to depth d\(_{5}\) for d\(_{6}\) there was significant difference between the two treatments (OM\(_{0}\) and OM\(_{1}\)). The reason was the decomposition of the manure at period (B) for depths of d\(_{1}\), d\(_{2}\), d\(_{3}\), d\(_{4}\), and d\(_{5}\) improved soil structure and hence increased the water down ward movement and there for K\(_{S}\).
Figure 5. Effect of the interaction between depths of soil and manure levels on $K_s$ (m day$^{-1}$) for soil at beginning season (A) after harvesting (B).

3.7. Effect of the interaction of the machine parts depth, the soil depths and manure application levels in the soil saturated hydraulic conductivity

The interaction of three parameters were not significantly affect $K_s$ at period (A), whereas, they significantly affected $K_s$ at period (B) (table 3).

Table (6) showed that $K_s$ values increased with depth of the machine parts, soil shallow depths and with manure application. The highest $K_s$ values were recorded for treatments M$_{30}$S$_{30}$ and M$_{30}$S$_{20}$, soil depth of $d_1$ and manure application. It did not significantly different from the remaining treatments. The highest values of $K_s$ for above interacted treatments are 0.68 and 0.67 m day$^{-1}$ respectively.

3.8. Effect of the measuring period (A and B) on the soil saturated hydraulic conductivity

T-test showed that $K_s$ at period (B) significantly lower than that at period (A), it was lower by 15.03% compared with value of period (A), fig.(6). The reduction in $K_s$ values after crop harvesting related to the reduction in the pores size due to the participation of the small soil particles into the soil pores as well as the pressure applied by the top layers on the deeper layers. The drying and wetting process helped in reducing the pore sizes. However, $K_s$ for period (B) remained higher than that for unplowed and disturbed (Sandin et al., 2017).

Figure 6. Effect of the measurement period on saturated hydraulic conductivity.
Table (6) Effect of the interaction between the depths of the implement components and soil depths and the levels of manure in the Ks (m day−1) of the soil after harvest

| Levels of manure | OM₀ | OM₁ |
|------------------|-----|-----|
| Depths of implements Components |       |     |
| MₛS₀M₂SₐM₃S₀ | 0.43 | 0.43 |
| MₛS₀M₃S₀ | 0.44 | 0.44 |
| MₛS₀M₃S₀ | 0.45 | 0.45 |
| MₛS₀M₃S₀ | 0.46 | 0.46 |
| MₛS₀M₃S₀ | 0.47 | 0.47 |
| MₛS₀M₃S₀ | 0.48 | 0.48 |
| MₛS₀M₃S₀ | 0.49 | 0.49 |
| MₛS₀M₃S₀ | 0.50 | 0.50 |

Average of Soil depths
Depths of soil

| Levels of manure | RLSD 0.05 |
|------------------|-----------|
| Average depths    | 0.31      |
| Average of implement Components | 0.42      |

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