Effect of Different Tillage Depths and Practices on Growth and Productivity of Potato (*Solanum tuberosum* L.)

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ABSTRACT

The effect of different tillage practices with different plowing depth on some potato(Solanum tuberosum L.), growth, yield and quality parameters such as (leaf area, number of stems /plant, plant height /cm) and (tuber size, tuber numbers/ plant, and total productivity, dry matter and starch content), Were studied in aclay soil of privet field at Yahmoor- Tartous city, Syria, during (2018 and 2019).

Randomized split-plot Design with three replicates were used. Three different tillage practices were effectuated as a main plot {(No tillage (NT) as control, Inversion tillage with Moldboard plow (Mp), Non-inversion tillage with Chisel plow(Cp)}, then these main plots except control were splited into three blocks of tillage depths (D_1(0-10) cm, D_2 (10-15) cm, D_3(15-25 cm).The results showed that All tillage practices increased significantly growth parameters (stems number, leaf area and plant height), yield parameters(tuber numbers, big and medium tubers, total productivity ton/ha), and tuber quality (tuber content of dry matter and starch) compared to the control (NT). Inversion tillage with Moldboard plow (MP) increased significantly stems number, leaf area, tubers number, big and medium tubers, total productivity (ton/ha), percentage of starch and dry matter), by (1.02 stems /plant, 1290.99 cm^2 / plant, 0.94 tuber / plant, 107.23 g/ plant, 39.67 g/ plant, 4.763 ton /ha, 0.7 % and 0.94 %) respectively, compared to the Chisel plow (Cp). Deep tillage D_3 (15-25 cm) increased significantly number of stems, plant height (3.80 stems /plant, 51.63 cm) and gave the highest leaf area (9410.305 cm^2 / plant) compared to other depths. D_3 (15-25cm) as well increased significantly big and medium tubers with (827.39, 192.14 g/plant) respectively and gave the best productivity (40.15 ton/ha) compared other depths. Tubers content of dry matter and starch (15.44, 19.51 %) respectively were improved as well compared to other tillage depths. The interaction between tillage type and depth (MpxD_3) improved all growth, yield and quality parameters.

Keyword: *Mold board plow, Chisel plow, leaf area, potato tuber, Tillage.*

I. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops over the world [1]. It takes the fourth position after wheat, rice and corn ([2], [3]). Potato is cultivated in 140 countries over the world, 100 of them are located in the tropical and subtropical zones [4], with 327 million tons/ha [5]. Potato tuber has high content of dry mater and considered as essential source of starch, protein, vitamins, simple sugars and minerals ([6], [7]).

Potato is a very sensitive to environmental conditions, such as soil properties, because of its has fine, branching root system which damage in compact soils. Under good soil conditions, potato roots grow about1/2 inches per day during the first three weeks after germination [8]. Potato requires loose, deep, aerated and moist soil to product a high yield and marketable tubers. So soil tillage is required prior to potato seeding [9].

Soil tillage is among the most important factors affecting soil physical and mechanical properties [10]. It is defined as mechanical manipulation by creating pressure of the hull plow to provide a suitable germination conditions and provides a good environment for growing roots [11]. The multiplicity of soil types and different climatic conditions have led to use different types of tillage practices, such as (no tillage, inversion tillage, non-inversion tillage) [12]. Which have different effects on soil fertility, therefore the correct tillage equipment suitable to soil type will be choised ([13], [14], [15]).

Inversion tillage with Mold board plow is one of the most important practices, which controls weeds, buries fertilizers and plant residues [16]. Non-inversion tillage with Chisel plow is used in dry and solid soils to reverse soil without inversion, and

keeps plant residues in the soil and prevent their erosion by water or wind [17].

To produce potato tubers with a high quality, soil must be well prepared prior seeding. Re. [18] indicated that tillage implement had significant effect on potato yield and the highest yield (37.19 t/ha) was obtained when plowing with moldboard plow was used, compared with chisel plow (32.95 t/ha). Similar observation was noticed by re.[19].

Re. [20] observed with using four tillage depths (zero tillage, 10, 20, 30 and 40cm) in potato culture that tilled soil significantly increased crop growth and yield compared to untilled soil. And plants growing in 40cm tillage depth produced the highest fresh potato tuber yield (14.5 t ha^{-1}).

Re. [21] reported that all tillage methods reduced soil bulk density and penetration resistance depending on the depth of tillage. In other studies, water infiltration was greater in tilled soil than in untilled soil ([22], [21]). Re. [19] reported that Moald board plow significantly affected soil properties and it decreased bulk density, increased mean weight diameter and hydraulic conductivity by (0.04 g/cm^3, 0.04 cm/hour, 0.05mm) respectively compared to Chisel plow .

Re. [23] reported that deep tillage had the greatest effect on soil bulk density, organic carbon, infiltration rate, and crop yield compared to semi deep and shallow tillage systems. They also concluded that soil bulk density, infiltration rate, and crop yield improved with increasing the plowing depth.

Re. [24] reported that deep tillage reduced penetration resistance as a result of the dismantling of the soil, and increased pores compared to shallow tillage. As well as, bulk density has also decreased by increasing the depth of tillage as a result of increased micro pores. Similar observation were made by re.[23] who noted that soil bulk density, infiltration rate, and crop yield improved with increasing plowing depth.

This study consequently performed to evaluate the effect of different tillage practices with different plowing depth on some growth parameters of potato such as (leaf area, number of stems /plant, plant height/cm), yield parameters such as (tuber size, tuber numbers / plant, and total productivity) and tuber quality parameters such as (dry weight and starch content), in a clay soil. And to determine as well the relationship between the plowing depth and tillage type and their effect on the studied parameters.

II. MATERIALS AND METHODS

A. Experimental site:

The experiment was carried out during 2018 and 2019 in a private field at Tartous Governorate, Syria. This region is characterized by a typical Mediterranean climate, with an average temperature ranging from 14.5 °C in January to 25.9 °C in June. The annual rainfall is 675.7 mm/year.

Soil samples were collected by soil sampling tool from the field at 0-25 cm before tilling and then analyzed in laboratory of Soil Department, Faculty of Agriculture, Tishreen University, Syria. To determinate some physical and chemical soil properties. The Soil is classified as clay soil, and Soil properties are presented in Table (1).

Table(1) : Some physical - chemical soil properties before tilling

Parameters	Value	Rating
Sand(%)	38.11	-
Silt(%)	18.33	-
Clay(%)	45.56	-
Textural class	Clay	-
pH	7.546	Little Alkaline
EC ds/m	0.736	Low salinity
Organic Matter%	1.95	low
CEC	43.20	high
Bulk density(g/cm^3)	1.42	high
Particle density(g/cm^3)	2.60	medium
Total Porosity(%)	45.38	high
Available P ppm	30.073	high
Available K ppm	467.871	high
Total N %	0.193	medium

B. Treatments and Experimental Design Used:

The field was divided into different plots. With 14.7 m^2(7 m × 2.1m) size, and 2 m separating plots, and 5 m between replicates. Randomized split- plot design with three replicates was used . Three different practices tillage were used as a main plot {(No tillage (NT) as control, Inversion tillage with Moldboard plow (MP), Non-inversion tillage with Chisel plow (Cp)}, then these main plots except

control plot were splited into three blocks of tillage depths (D_1 (0-10) cm , D_2 (10-15) cm, D_3 (15-25) cm. The treatments were as follows:
1-NT: without tillage (control).
2-MpD_1: Inversion tillage with Moldboard plow at 10 cm depth.
3-MpD_2: Inversion tillage with Moldboard plow at 15 cm
4-MpD_3: Inversion tillage with Moldboard plow at 25 cm
5-CpD_1: Non-inversion tillage with Chisel plow at a depth of 10 cm.
6 -CpD_2: Non-inversion tillage with Chisel plow at a depth of 15 cm .
7 -CpD_3: Non-inversion tillage with Chisel plow at a depth of 25 cm .
In no tillage treatment, rows were made without tilling the soil,. The moldboard Plow used for inversion tillage, consisted of 3 shares of 30 cm Length, and 31 cm distance between shares. Plow width was 90 cm and maximum plowing depth was 30 cm. The chisel plow used for non-inversion tillage consisted of 5 shares, and 36 cm as distance between two shares. Plow width was 170 cm and maximum plowing depth was 25 cm. **New Holland tt56** type (Italian-origin) was used for all plows operation.

C. Potato Planting:
Potato (Spunta variety) seed tubers of 35/55 mm were used (Holland- origin) and planted in 11 February at 8-10 cm depth for both cultivating seasons (2018 and 2019).
Plots were divided into three rows, with 70 cm distance between rows, and 35 cm between tubers. Therefore the experimental plot contained 60 plants.
Fertilizers were implicated as (0.026,0.026 and 0.024 kg/m^2 for Urea 46%, P_2O_5 46% and, $K_2SO_4$50% respectively) according to re. [25] and the plants were frequently irrigated by surface system every 15 days. DITHANE and RIDOMIL (250 g /100 L) and SENCOR (700 g/ ha) were used against Rodent worms, mildew and weed control respectively.

D. Potato harvest:
Potato plants were detached and tubers were collected at 30 May after 100 days of planting.

E. Growth parameter:
Five plants were randomly selected for growth parameters measurement. The mean of plant height /cm, number of stems/plant and leaf area were calculated [26].
Yield parameter were effectuated using ten plants from each treatment, Mean tuber numbers / plant, tuber size, total productivity, tuber dry weight and tuber starch were measured.
Tuber size: According to re.[27], tubers of 10 plants per replicates were graded and divided by weight into three categories: 1) Small tubers <35g); 2), medium tubers (35 to 80 g), 3) large tubers (> 80 g).
Tuber dry matter (%): Determined weight of fresh tuber, weighted and dried at (105 C^o) until stabilization, then calculated as:
Dry matter %= (weight of dry tuber / weight of wet tuber)*100
Starch tuber content: was measured according to re. [28] method.

F. Data Analysis:
Analysis of variance (ANOVA) was performed by using COSTAT [29]. Least significance difference (LSD) was used to differential means at the 5%level.

III. RESULTS AND DISCUSSION

A. Effect of tillage practices and depths tillage on growth parameters of potato:

Effect of tillage practices and depths on leaf area, number of stems and plant height:

The results presented in table (2) showed, that leaf area, number of stems / plant and plant height increased significantly with type of tillage compared to the control (NT). Mold board plow treatment (Mp) increased significantly leaf area, number of stems / plant by (16.6, 39.87%) respectively, compared to Chisel plow, while no significant difference was recorded between the two types of tillage for plant height. The increase in plant parameters using different tillage types, is due to breaking compaction layer and increase the availability of water and mineral nutrients, as well as improvement soil physical properties (as decrease soil bulk density and increase porosity). Improving soil physical properties lead to a good development of root and shoot system, and as consequence, increase photosynthesis and plant growth ([30], [19]).

The results of table (2) showed that leaf area, number of stems/ plant and plant height increased with the depth of tillage compared to no-tillage treatment. The number of stems and plant height were highest (3.80 /plant, 51.63 cm) when Deep tillage D_3 were used compared with other depths. As well as, leaf area (9410.31) cm^2/plant was significantly higher when depth D_3 was used. Deep tillage play an important role in dismantling the soil layers, and then increase the exploitation of water and mineral nutrients by plants, leading to increase root size, and facilitate the spread of root system which improve plant growth and lead to increase leaf area and stems number. These results are agree with ([31], [32]), who found that the depth of tillage improve the physical properties of soil and thus plant growth rate and productivity**.**

Table (2): Effect of tillage practices and depths on leaf area, number of stems and plant height average of two years 2018 and 2019).

Treatments	growth parameters		
Tillage treatments	**leaf area (cm^2/plant)**	**number stems/plant**	**plant height(cm)**
NT	5247.714 c	2c	39.23c
Mp	9062.170a	3.55a	51.25a
Cp	7771.178b	2.538b	45.94ab
LSD5%	**337.841**	**0.314**	**5.483**
D0	5247.714c	2 d	39.233c
D_1(0-10)cm	7127.495b	2.424c	46.091b
D_2(10-15)cm	8712.221a	2.912b	48.066b
D_3(15-25)cm	9410.305a	3.80a	51.633a
LSD5%	**891.294**	**0.309**	**3.005**
NT D0	5247.713f	2f	39.23c
MpD_1	7642.987d	2.731d	49.5a
MpD_2	9122.736b	3.458b	52.066a
MpD_3	10420.786a	4.466a	52.183a
CpD_1	6612.003e	2.116ef	42.683b
CpD_2	8301.707cd	2.366e	44.066b
CpD_3	8399.825c	3.133c	51.083a
LSD5%	**704.430**	**0.277**	**3.397**

P>0.05, Different letters indicated significant differences within columns.

Interaction between type and depth of tillage showed significant differences in plant high (cm), number of stems/plant and leaf area (cm^2/plant) compared with no tillage (table 2). Highest leaf area and stem numbers (10420.78 cm^2/ plant, 4.46 stems/ plant) were recorded with (Mp x D_3) interaction compared with other treatments. Plant height (52.183cm) recorded significant differences compared with ($CpxD_1$ and $CpxD_2$), while there were no significant differences with other treatments.

B.) Effect of tillage practices and depths tillage on yield parameters of potato:

Effect of tillage practices and depths and their Interaction on (tuber size and their number

The results presented in Table (3) showed that using Mp tillage gave highest big and medium tubers with (791.095, 182.69 g/ plant) respectively, while this treatment resulted less small tubers (36.15g/plant) compared to the NT and Cp. The increase of big and medium tubers when using the Mold board tillage can be attributed to its role of mixing the surface layer that contain organic matter and nutrients compared to deeper soil layers, and Improve soil physical properties which lead to increase root system and increase nutrients and water absorption efficiency, this is reflected positively on shoot growth and plant photosynthesis and carbohydrate translocation toward the tubers. These results are in agree with ([33], [34]).

Concerning tillage depth, the results showed that D_3(15-25) cm increased significantly big and medium tubers with (827.39, 192.14 g/ plant) respectively. While small tubers were less (32.55 g/plant) compared to D_0. This result could be attributed to the fact that deep tillage improve soil property like soil aeration and porosity, which is favorable to potato growth. this is in agree with re.[35] who showed that deep tillage (30 cm) gave the greatest weight of big tubers.

Table (3): Effect of tillage practices and depths tillage on Tuber gradient by weight and tuber numbers (average of two years 2018 and 2019).

Treatments	tuber numbers	Tuber gradation					
		Big tubers (weight>80g)		medium tubers (35 <tuber weight <80g		small tubers (weight<35g)	
Tillage treatments	Tuber/plant	g/plant	%of plant productivity	g/plant	%of plant productivity	g/plant	%of plant productivity
NT	5.41c	301.116c	45.85b	130.31c	19.84a	225.43a	34.31a
Mp	7.365a	791.095a	78.35a	182.69a	18.031b	36.158c	3. 611c
Cp	6.436b	683.873b	75.183a	143.024b	15.745c	80.26b	9.07b

LSD5%	**0.268**	**96.099**	**4.402**	**9.448**	**1.091**	**38.274**	**4.546**
Tillage depths							
D0	5.41b	301.116c	45.85c	130.31c	19.84a	225.43a	34.31a
D_1(0-10)cm	5.952b	668.036b	73.32b	135.765c	14.92c	104.34b	11.75b
D_2(10-15)cm	7.152a	717.023b	78.412a	160.68b	17.46b	37.73c	4.126c
D_3(15-25)cm	7.60a	827.393a	78.578a	192.14a	18.275ab	32.55c	3.143c
LSD5%	**0.66**	**89.498**	**4.402**	**19.036**	**2.386**	**33.976**	**3.480**
Interaction treatments							
NTD_0	5.41d	301.116d	45.85c	130.31de	19.843a	225.43a	34.31a
MpD_1	6.143c	756.603b	80.233a	144.69d	15.33c	42.056c	4.43c
MpD_2	8.126a	726.61b	76.58a	188.92b	19.906a	33.373c	3.513c
MpD_3	7.826ab	890.073a	78.256a	214.486a	18.85ab	33.046c	2.88c
CpD_1	5.76cd	579.47c	66.406b	126.84e	14.52c	166.62b	19.07b
CpD_2	6.176c	707.436b	80.243a	132.44de	15.016c	42.093c	4.74c
CpD_3	7.37b	764.713b	78.9a	169.793c	17.69b	32.06c	3.40c
LSD5%	**0.524**	**81.629**	**4.211**	**15.29**	**1.906**	**31.428**	**3.384**

P>0.05 Different letters indicated significant difference within columns.

The interaction between type and depth of tillage showed an increase of big and medium tubers weight (890.07- 214.49 g/ plant) respectively for MpD_3, compared to other treatments. While small tubers were decreased and weighted (33.04g/ plant) compared to NTD_0. Concerning Cp tillage, CpD_3 gave higher big and medium tubers (764.71- 169.79 g/plant) compared to the control (301.11 and 130.31 g/plant) respectively. The results of the table (3) showed as well a significant increase in the number of tubers according to tillage practices compared with no tillage. Mold board plow(Mp) and chisel plow tillage (Cp), increased significantly tubers numbers (7.36- 6.43 tuber/plant) Respectively compared to the control (5.41 tuber/plant). Mold board plow (Mp) tillage gave better tuber numbers than chisel plow (7.36 and 6.43 Tuber/plant). The increase in tuber numbers/ plant is due to the increase in the stems number, which reached the highest value when using the Mold board plow (Mp), ([36], [37]).

Tillage depths played an important role in influencing tuber numbers formed by the plant, tuber numbers increased according to tillage depth, D_3 achieved the highest value (7.60 tuber/plant) compared to D_1 (5.95 tuber/plant), these results are in agree with re.[38] who confirmed that there was a significant interaction between the depth of tillage and the number of tubers released in the soil and plant production.

Interaction between ($MpxD_2$) gave the highest number of tubers / plant (8.216) compared to NTD0. CpD_3 increased as well tuber numbers (7.37) compared to NTD_0 and CpD_1 and CpD_2.

Effect of tillage practices and depths on potato yield:

Potato yield increased significantly when Mold board plow tillage was used. MP and Cp gave higher tuber yield (39.57 and 34.81 ton/ha) respectively (table 4). Marketable yield showed the same results. These results are due to the increase of tuber numbers and weight. the results agreed with re.[39] who confirmed that plant productivity increased according to tillage type.

Table (4): Effect of tillage practices and depths on the potato yield (average of two years 2018 and 2019).

Treatments	**Yield**			**MarketingYield**	
Tillage treatments	g/plant	Kg/m^2	$ton.ha^{-1}$	g/plant	%of plant productivity
NT	656.85c	2.496c	24.98c	481.99c	73.38c
Mp	1009.951a	3.958a	39.568a	974.216a	96.388a
Cp	907.156b	3.48b	34.805b	843.57b	92.828b
LSD5%	**77.425**	**0.15**	**1.54**	**98.588**	**2.566**
Tillage depths					
D0	656.85c	2.496c	24.98c	481.99c	73.388d
D_1(0-10)cm	908.142b	3.54b	35.395b	829.035b	91.155c
D_2(10-15)cm	915.43b	3.603b	36.02b	874.93b	95.54b
D_3(15-25)cm	1052.085a	4.015a	40.146a	1022.72a	97.131a
LSD5%	**97.567**	**0.107**	**1.091**	**93.37**	**1.823**

Interaction treatments					
NT D0	656.85d	2.496e	24.98e	481.99e	73.38e
MpD_1	943.35bc	3.646c	36.453c	895.31bc	94.926bc
MpD_2	948.9bc	3.81b	38.06b	916.403bc	96.576ab
MpD_3	1137.603a	4.42a	44.193a	1110.936a	97.663a
CpD_1	872.933c	3.43d	34.34d	762.76d	87.383d
CpD_2	881.96c	3.396d	33.98d	833.456cd	94.503c
CpD_3	966.567b	3.61c	36.1c	934.506b	96.6ab
LSD5%	**83.042**	**0.10**	**0.943**	**84.763**	**1.926**

P>0.05 Different letters indicated significant difference within columns.

Soil physical properties change with tillage type, this is in agree with ([18], [19]), who indicated that Mold board plow treatment (Mp) gave the highest tuber productivity compared to other tillage practices, because of its role in establishing the suitable environment for root growth and nutrient absorption, which is reflected positively on shoot growth, and increased leaf area which eventually produce large amounts of carbohydrates trans located and stored in potato tubers, and then increased productivity.

Productivity of potato tubers increased significantly as well according to tillage depth. D_3 depth gave the best productivity (40.15 ton/ha) compared to D_0 (24.98 ton/ha), D_1 (35.39ton/ha) and D_2 (36.02 ton/ha). The increase in tuber yield using the deepest tillage, is due to dismantling the soil and improving its physical properties, which induces better root growth and improves photosynthesis and carbohydrate production and accumulation in tubers. These results agreed with re.[38] who showed a significant interaction between the tillage depth and the number of tubers liberated at the soil and plant productivity. Marketing tuber yield showed the same results as total yield.

The interaction between ($MpxD_3$) gave the highest significant yield of potato tubers(44.19 ton/ha) compared to NTD0 (24.98 ton/ha), MpD_1 (36.45 ton/ha) and MpD_2 (38.06 ton/ha). Concerning Cp tillage, the results showed that ($CpxD_3$) gave the best yield of potato (36.1 ton/ha) compared to NTD_0 (24.98 ton/ha), CpD_1 and CpD_2(34.34 and 33.98 ton/ha) respectively. Marketing yield showed the same results as total yield.

Effect of tillage practices and depths on (tuber content of dry matter and starch):

Tubers content of dry matter and starch increased significantly with type of tillage compared to the control (NT).Mp tillage increased tubers content of dry matter and starch (18.29, 14.49%) respectively, compared to the control(16.08- 12.28%). Cp tillage increased as well dry matter and starch compared to the control(17.35, 13.49%), but this increase was less than Mp tillage.

Tillage depth D_3 (15-25 cm) increased significantly tubers content of dry matter and starch by (19.51, 15.44 %) respectively compared to other tillage depths. Interaction between type and depth of tillage ($MpxD_3$ -$CpxD_3$) improved significantly tubers content of dry matter and starch (19.656-15.73% and 19.35 – 15.16%)respectively, compared to the control and other interaction treatments. The high content of tuber dry matter in the Mp tillage may be attributed to the amelioration of soil properties which cause better root growth, that reflect on the leaf area development, which allowed the plant to receive most of solar radiation and improve organic matter translocation from green shoot to tubers. Generally, starch content is related to dry matter, so, the amelioration in dry matter percentage will increase starch percentage. ([40], [41]).

These results are in agree with [18], who indicated that increasing tillage depth to40 cm depth improve the physical soil properties, which positively affect crop yields and quality.

Table (5): Effect of tillage practices and depths in the tuber contentof dry matter and starch% (average of two years 2018 and 2019).

Treatments	**dry matter%**	**Starch%**
Tillage treatments		
NT	16.068c	12.283c
Mp	18.29a	14.494a
Cp	17.346b	13.493b
LSD5%	**0.526**	**0.443**
Tillage depths		
D0	16.068c	12.283c
D_1(0-10)cm	16.83b	13.451b

D_2(10-15)cm	17.117b	13.086b
D_3(15-25)cm	19.507a	15.44a
LSD5%	**0.808**	**0.556**
Interaction treatments		
NT D0	16.068d	12.283f
MpD_1	17.244c	14.386c
MpD_2	17.969b	13.366d
MpD_3	19.656a	15.73a
CpD_1	16.415d	12.516ef
CpD_2	16.264d	12.806e
CpD_3	19.358a	15.156b
LSD5%	**0.66**	**0.473**

P>0.05 Different letters indicated significant difference within columns

IV. CONCLUSIONS

1- Tillage type improved growth and yield parameters such as (stems number, leaf area, plant height) and total and marketable yield. Mold board plow was better in increasing these parameters.

2- A positive effect of D_3 was recorded in Shoot growth and yield parameters.

3- Potato tuber quality (dry matter and starch) were improved by using Deep mold board tillage compared to Chisel plow.

4- The interaction between ($MpxD_3$) gave the highest leaf area, stem numbers, Plant height and potato tubers yield, and ameliorate tuber quality like dry matter and starch compared to other interactions.

Recommendations

1- It is recommended to use Mold board plow at (25) cm depth, when preparing thesoil for potato planting, to have suitable soil for potato growth and development. Because, this plow improve water and nutrient exploitation.

2- Advancing this research by using other types of plows and other economic crops.

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