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~~Evaluation the~~ Effect of three tillage implements on potato yield and water use efficiency

ABSTRACT

Aims: The objective of this study was to conduct field experiments in loamy sand soil to evaluate the effect of tillage implements on potato yield and water use efficiency.

Study design: Randomize complete block design with three replications.

Place and Duration of Study: The study was conducted at a private farm at Al-Kharj Governorate, Saudi Arabia during 2015.

Methodology: The main factor was three primary tillage implements commonly used in Saudi Arabia for seedbed preparation with different configurations: disk harrow, chisel plow and moldboard plow. The potato variety was Spunta type. Centre pivot system was provided irrigation water.

Results: The statistical analysis indicated that tillage implement had significant effect on yield and water use efficiency. The highest yield of 37.19 ton/ha was observed during plowing operation with moldboard and lowest (32.33 ton/ha) was observed during plowing operation with disk harrow plow. The highest water use efficiency of 7.91 kg/m^3 was observed during plowing operation with moldboard and lowest (6.88kg/m^3) was observed during plowing operation with disk harrow plow.

Conclusion: It could be concluded that the obtained results could be helpful to develop comprehensive information on potato yield and water use efficiency in semi-arid region like Saudi Arabia.

Keywords: Chisel plow, moldboard plow, disk harrow, tillage, potato, ~~water use efficiency~~

1.INTRODUCTION

Potato is one of the most important food crops worldwide. It comes in the forefront of tuber-crops and occupies the fourth position after wheat, sorghum and rice as the most ~~edible and consumed~~ crop~~s~~ in the world [1]. The crop is grown in about 140 countries, more than 100 of which ~~are~~ located in the tropical and subtropical zones [2]. ~~The potatoes production takes a very important place in world agriculture,~~ with a production potential of about 327 million tons ~~harvested and 18.6 million ha planted area~~ [3].

Saudi Arabia is currently ~~self-sufficient in terms of potatoes. It is~~ 121% self-sufficient in potatoes [4]. ~~In season 2010, potato crop was planted in~~ an area of 17665 ha ~~with a production of about 44413 tons~~ [5]. ~~There are hundreds of potato producers in Saudi Arabia comprising potato production units of all sizes and capabilities, growing many varieties for sale mainly to the wholesale markets.~~ Over 75% of the total potato production in Saudi Arabia comes from small farmers grouped in different regions, ~~and~~ who supply local wholesale markets [6].

~~The~~ potato production is ~~established under~~ different ~~patterns~~ of mechanization and soil type using different water ~~qualities for~~ irrigation as most ~~of~~ agricultural activities in Saudi Arabia ~~are dependent~~ mainly on ground water as a main source for irrigation. ~~However, potato variety,~~ irrigation and fertilizer ~~were~~ the most important factors affecting potato production [7]. ~~In contrast, the amount of tillage required to prepare soil for potato planting depends upon the soil type and the ability of the potato planter to operate properly in crop residues. Thus tillage should produce enough~~ loose soil to allow the potato planter shoe to penetrate to the desired depth [8].

Many types of tillage implements have been designed to accomplish the major objectives of tillage as reported in huge research papers. Tillage operation for seedbed preparation is often classified as primary or secondary [9]. The primary tillage is the initial or major soil working operation after harvest of the previous crops. Moreover, implements for such tillage are mainly of three basic types: moldboard, chisel and disk plows. In research on reduced tillage, many comparisons have been made between tillage with these different implement types, especially regarding the effects on soil properties and yield [9]. However, the most common tillage procedure is to plow down the previous year's crop residue with a moldboard plow in the fall or

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spring. Then a disk is used in the spring to break large soil clods. This is normally followed by a third operation with a spring tooth harrow [10, 11]. However, one of the most important factors that affect shape and other properties of potato are soil preparation practices prior to seeding [12].

Ogbodo [13] reported that plant shoot dry matter potato yield was significantly higher on the tilled plots by 16, 24, 27 and 39% for 10, 20, 30 and 40cm tillage depths, respectively when compared with the untilled plots. The plants in the 40cm treated plots produced 23, 15, and 11% significantly higher dry matter yield than the plants on 10, 20 and 30cm tillage depth plots, respectively. The improved soil physical conditions due to reduced bulk density, and penetration resistance, could have positively influenced the crop growth. The direct implication was that root growth and plant nutrient uptake was increased on tilled plots, and this was reflected in the significantly higher plant growth on the tilled plots when compared with the untilled plots. Chandler et al. [14] and Aina [15] also reported higher yields of potato and cassava on tilled plots than the untilled plots. The former observed that higher plant shoot growth was enhanced by the increased root feeding area, created by increased depth of tillage.

Conservation tillage improves soil and water conservation and reduces costly inputs and increase profits [16]. Conservation tillage may be executed by chisel plow or by moldboard plow or by disk plow, disk harrow and deep ripping could be used. Ghazavi et al. [12] conducted field experiments to study the effect of four treatments of plows, moldboard, chisel, disk, and a new one made by Iran Plow Tools (a combination of chisel and disk plows) on skin area averages, tubers weight, tubers size, tubers quantity, and potato product performance. The results showed that in comparing products from moldboard plow and Iran Plow Tools' plow no significant differences were observed in tubers size and product performance, but for tubers quantity and tubers weight averages, the differences were significant. In comparing the new plow with other tested plows for above mentioned factors, mostly the differences were significant. Briefly, the results showed that by means of the new combined plow, more uniform products can be obtained and it is a proper choice to replace moldboard plow nationwide.

Mohammadi and Shamabadi [17] conducted field experiment to study the effect of conservation tillage on energy consumption and potato yield. A strip block experimental design at Randomize Complete Block Design with 4 replications was used, that horizontal factor including tillage methods (moldboard plowing + disk harrow, disk plowing + disk harrow, fall chisel plowing + disk harrow and spring chisel plowing + disk harrow) and vertical factor including three potato cultivars (Agria, Deraga and Sante). Depth of spring moldboard and disk plowing were 20-25 cm. Depth of spring and fall chisel plowing were 25-30 cm. Potato cultivars planted, row spacing and plants space in row were 75 and 20 cm, respectively. Results showed that crop yield differences among tillage methods were significant (at 5%), Maximum of yield per hectare was related to spring chisel plowing (31.1 ton /ha). Ati et al. (2015) conducted field experiment to study effect of tillage system on growth and yield of potato. The tillage systems included moldboard plow and chisel plow. All treatment irrigation imposed at 35% depletion of available water, all agricultural processes for crop management were used according to Ministry of Agriculture recommendation. Results showed that the yields of potato were 32700 and 28780 kg/ha for moldboard plow and chisel plow, respectively.

Water is the prime mover in crop production [18]. They reported that for better use of water in agriculture in water-limited environments, efforts are needed from different research disciplines; agronomists, plant breeders, plant physiologists, plant biotechnologists, water engineers and others, to develop new approaches in water use. Among different approaches water productivity or water use efficiency (WUE) is an efficient approach. Water use efficiency can be increased by two ways, either by increasing yield or by saving water. Water use Water use efficiency is affected by a number of factors like climatic conditions, edaphic factors, nature of plant and agronomic practices. There are various techniques to increase water use efficiency in the rain fed ecosystem. Many options to improve water use efficiency are available and the target is to produce more biomass with minimum possible amount of water.

Water use efficiency (WUE) expressed as the ratio of potato yield to water supply from planting to harvest and varied typically for 11 to 9 kg/m^3 [19]. Yavuz et al. [20] investigated the effects of different irrigation methods on yield and yield components of potato and water use of methods. The methods were sprinkler, furrow and drip irrigation. The highest water use was obtained with drip irrigation plots while the lowest were obtained from sprinkler irrigation plots for both years. Mean WUE was calculated as 8.32 kg/m^3 in drip irrigation and 6.09 kg/m^3 in sprinkler irrigation, respectively. However, in Saudi Arabia, potatoes are mainly produced on

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coarse textured soils and under centre pivot irrigation systems and average yields vary between 20 and 40 ton/ha [21].

Tillage is defined as the mechanical manipulation of the soil for the purpose of crop production affecting significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes [22]. Furthermore, under water-limited conditions, increasing water use efficiency is essential for successful crop production [23].Consequently, any chosen tillage method for potato crop in Saudi Arabia should aim at increasing water use efficiency. Therefore, the objective of this study was to evaluate the effect of tillage implements on potato yield and water use efficiency.

2.MATERIALS AND METHODS

2.1. Experimental arrangements

The experiment was performed in a private farm at Al-Kharj Governorate, Saudi Arabia. No crop residues were found in the experimental field. The soil texture of the experimental field was classified by laboratory analysis according to standard methods. Sand, silt and clay contents and soil texture, organic matter (O.M), $CaCo_3$ percentage, initial soil moisture content and initial soil bulk density are shown in Table 1 for the soil in the experiment site.

Table 1. Soil texture, organic matter (O.M), $CaCo_3$ percentage, initial soil moisture content and initial soil bulk density for the soil in the experiment site.

Sand	Silt	Clay	Texture	O.M	Initial soil moisture content	Initial soil bulk density	$CaCo_3$
(%)	(%)	(%)	(---)	(%)	(%,db)	(g/cm^3)	(%)
82.9	13.08	4.02	Loamy sand	0.98	7.09	1.67	6.85

Different soil and water samples were gathered. The soil samples were analyzed in laboratory of Soil Department, College of Food & Agriculture Sciences, King Saud University for routine analysis. Chemical elements, pH and electric conductivity (EC) of the soil in the experiment site are shown in Table 2. Irrigation water was groundwater and water samples were analyzed in laboratory of IDAC Silliker, Riyadh, Saudi Arabia, Al-Kharj Road, Exit 9.Chemical elements, pH and electric conductivity of the used water are shown in Table 3.

Table 2. Chemical elements, pH and electric conductivity (EC) of the soil in the experiment site.

pH	EC	Na^+	K^+	Ca^{++}	Mg^{++}	SO_4	Cl	Nitrate
(---)	(dS/m)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
8.5	4.6	48.66	4.91	140.59	8.76	55.06	41.72	19.61

Table 3. Chemical elements, pH and electric conductivity (EC) of irrigation water.

pH	EC	Na^+	TDS	Ca^{++}	Mg^{++}	SO_4	NH_3
(---)	(dS/m)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
7.57	4.81	372.07	3204.79	404.75	109.78	1237.6	8.11

2.2. Treatments

The field was divided to different plots. The size of the plot was 12 m × 40 m and two meters between plots were considered to separate the plots. The studied treatments were arranged in a randomized block design with three replicates. Treatments comprised of three different types of plows as follows:

Tillage treatment 1: Plowing using a disk harrow, one pass.

Tillage treatment 2: Plowing using chisel plow, one pass.

Tillage treatment 3: Plowing using moldboard plow, one pass.

The disk harrow was trailed hitched and consisted of 24 disks (12 disks in the front and 12 disks in the back), distance among two disks was 24 cm and diameter of the disk 56 cm. Plowing depth was 12 cm. The chisel plow was mounted hitched and consisted of 15 shares in two rows (8 shares in the front row and 7 in the back raw), the distance among two shares was 54 cm and the width of the plow was 3.377 m. Plowing depth was 12 cm. The moldboard plow was mounted hitched and the width of each share was 40 cm and the width of the plow was 80 cm. Plowing

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depth was 25 cm. All the plows operated at one tractor forward speed of 5.4 km/h. MF399 tractor (74 kW power) was used in the field experiments. Centre pivot is the main source to supply irrigation water in the experimental field.

In the beginning, a small block of approximately 10 m long by 12 m wide was used to enable the tractor and plow to reach a steady state condition of the required plowing speed and plowing depth. Plowing depth was measured as the vertical distance from the top of the undisturbed soil surface to the plow's deepest penetration. After finishing the first test plot, the tractor was again driven straight to toward the second test plot with the same plow and the process was repeated. Similar procedure was repeated for all plows.

2.3. Potato planting

Potato was planted in autumn cycle at 2/10/2014 and harvested 14/2/2015. Spunta variety was utilized (growers No.1264, country of origin Netherland), however, the seeds size in mm was 35/55 treated with IMAZALIL. The planter (Type TEKYATAGANLI, Turkey) was used as shown in Fig. (1). The characteristics of the potato planter were two rows and the distance between them was 90 cm. No. of cups was 40. The distance between coups was 15 cm. Theoretical distance between seeds was 33.5 cm. The actual distance between seeds was 32 cm. Diameter of covering disk was 49 cm. Capacity: was 0.48 m^3.Machine width was1.8 m. Forward speed was 1.6 km/h. The distance between rows was 90 cm. Theoretical field capacity was 0.29 ha/h. After planting and the plants appear, rows must be ridged by the machine. After potato plants appeared, a tractor drawn machine for potato rows building was used. This machine consists of an array of ridges and furrows. The ridges are about 20 cm high and 75 cm apart (Fig. 2).

Fig. (1).The planter (Type TEKYATAGANLI, Turkey) was used

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Fig. (2).The ridge machine during operation.

2.4. Irrigation

Irrigation is essential for agricultural production in arid- and semi-arid regions where rainfall is inadequate to sustain crop growth [24]. Centre pivot is the main source to supply irrigation water in the experiment site. Performance parameters for centre pivot are shown in Table (4).

Table 4. Performance parameters for centre pivot.

Item	Value
Ambient temperature	13
Relative humidity	63%
Wind speed	Km/h
Type	Lockwood Crop
Age	15 years
No. of towers	7
No. of Nozzles	210
Speed at 50%	1.036
Cycle time at 50%	6 hr
Area	22 ha

The centre pivot was evaluated based on the ASAE standard S436.1 [25]. Number of catch cans with similar opening diameters and heights (i.e. same size) were used for collecting water applied by the irrigation system. A 500 ml graduated cylinder was used for measuring the volumes of water collected in the catch containers. The centre pivot was operated at 50% speed rate to apply a reasonable average depth of water and was allowed to completely pass over the catch cans. The amounts of water collected in the cans in (ml) were converted into depths of water in (mm), by using a conversion factor based on the area of the catch can.

2.5. Fertilizers, chemicals and harvesting

Urea was added with 350 kg/ha. DAB was also added (200 kg/ha). Dissolved fertilizer (25 kg/ha) was added. In addition, potassium was added (200 kg/ha) and pesticide (2 kg/ha) was added by sprayer. Potato digger was used. The machine was CARTTO (Fig. 3) with two rows.

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Fig. (3). Potato digger.

2.6. Yield

The tuber weight is important for yield determining and reflects the extent of tuber development. To determine potato yield, the 5 plants in each plot were harvested by hand and weighed. Then tubers were separated from the plants, weighed and tuber yield was recorded in terms of tones/ha.

2.7. Statistical analysis

The yield data were statistically analysed, using analysis of variance (ANOVA) for the randomized complete design with three replicates. The used software was [26] using ANOVA procedure.

3. RESULTS AND DISCUSSION

3.1. Field evaluation of centre pivot sprinkler irrigation system

Uniformity of a system is a measure of its ability to apply the same depth of water to every unit area. Without good uniformity, it is impossible to irrigate adequately and efficiently; parts of the field will be either over-irrigated or under-irrigated. Three uniformity measurements are to be considered in the evaluation; Coefficient of Uniformity (CU), Distribution Uniformity (DU) and Potential Application Efficiency of Low Quarter (PELQ) and application efficiency (Ea). A CU rating of 90%-95% is considered excellent and would only require regular maintenance. 85%-90%% is considered good and would not need major adjustments; regular maintenance and inspection are required. 80%-85% the system requires inspection and sprinkler package check. 80% or less the system requires an adjustment to the sprinkler package, change the default system, sprinkler pressure and conduct full maintenance for the whole system [27]. DU is useful as an indicator of the magnitude of the distribution problems. DU is calculated by dividing the weighted average of the lowest 25% of the catch cans by the weighted average of the entire catch cans. A of 85% or greater is considered excellent, 80% is considered very good, 75% is considered good, 70% is considered fair, and 65% or less is considered poor and unacceptable [28]. The evaluation parameters (CU, DU, Ea and PELQ) of the studied centre pivot are shown in Table 5. It is clear the systems need maintenance due to lower values of the evaluation parameters.

Table 5. Evaluation parameters (distribution efficiency, of the studied centre pivot in the experiment site.

Cu	Du	Ea	PELQ
%	%	%	%
79.96	72.04	88.94	64.07

3.2. Yield and water use efficiency

Water was applied by centre pivot; the irrigation was conducted for about 60 days from planting prior to harvesting. The applied water was added based on the practical experience of

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cultivation potato in the experiment site. The average applied water depth was about 10.74 mm. The total applied water during season was 6444 m^3/ha. Water use efficiency expressed as the ratio of potato yield to water supply from planting to harvest. Effect of tillage implements on yield and water use efficiency are illustrated in Fig. (4) and Fig. (5), respectively.

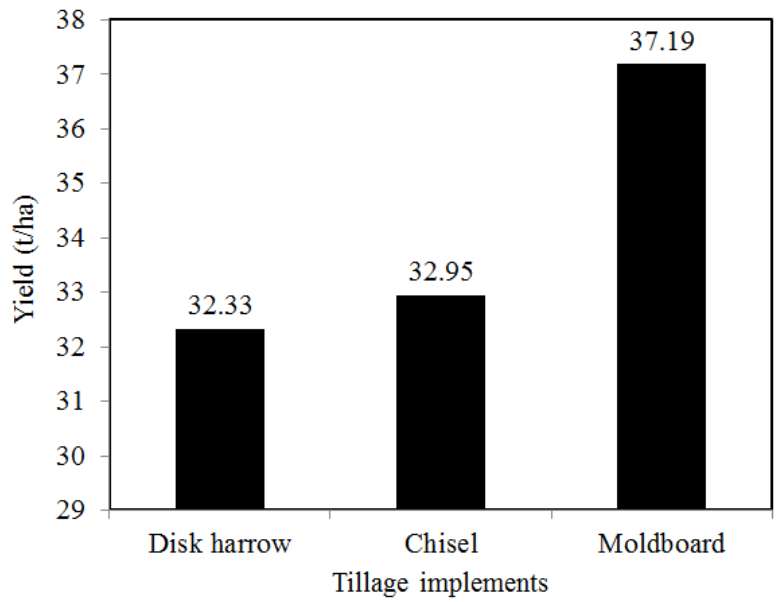

Fig. (4). Effect of tillage implements on yield.

The ANOVA analysis (Table 6) indicated that tillage implement had significant effect (at 5%) on yield and water use efficiency. The highest yield of 37.19 ton/ha was observed during plowing operation with moldboard and lowest (32.33 ton/ha) was observed during plowing operation with disk harrow plow. The highest water use efficiency of 7.91 kg/m^3 was observed during plowing operation with moldboard and lowest (6.88 kg/m^3) was observed during plowing operation with disk harrow plow. Ati et al. [29] reported that potato yield recorded 32700 kg/ha using moldboard plow for tillage purposes compared to chisel plow. Additionally, Amel et al. [30] reported that average yield of the potato crop was 39121.9, 24945.7, 19504.3 and 22010.15 kg/ha based on irrigation water quality. Moreover, average water use efficiency was in the range of 10. 82-11.5 kg/m^3 based on irrigation water quality. It could be concluded that the obtained results could be helpful to develop comprehensive information on potato yield and water use efficiency in semi-arid region like Saudi Arabia.

Table 6. Summary of the analysis of variance for the effect of tillage implements on potato yield and water use efficiency.

Source of variation	Degree of freedom	Pr> F	
		Yield	Water use efficiency
Replicates	2	0.3263	0.3173
Tillage implements	2	<.0001	<.0001

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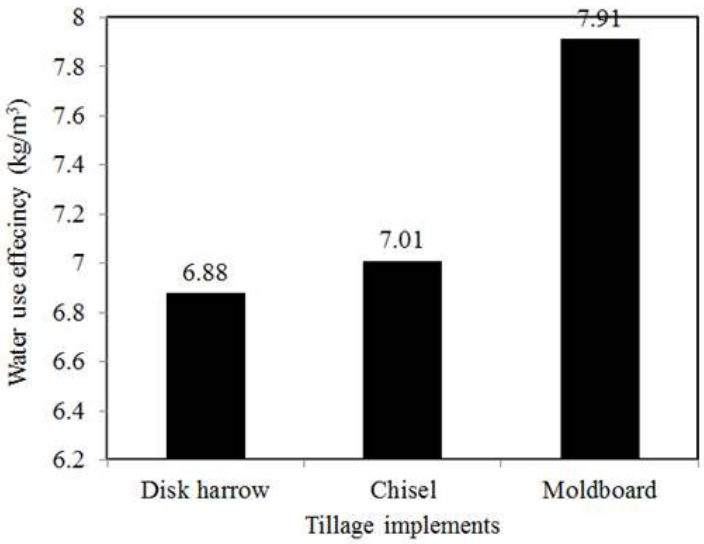

Fig. (5). Effect of tillage implements on water use efficiency.

4. CONCLUSION

Tillage implement had significant effect on potato yield and water use efficiency. The highest yield and water use efficiency were 37.19 ton/ha and 7.91 kg/m^3, respectively, obtained during plowing operation with moldboard.

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