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EFFECT OF MULCHING TYPE AND DURATION ON THE PRODUCTIVITY AND WATER USE EFFICIENCY OF POTATO

Zayton, A. M.; A. E. GUIRGUIS and KH. A., ALLAM
Agric. Eng. Res. Inst., Agric. Res. Center, Cairo

ABSTRACT

Field experiments were conducted during the winter season of 2014/2015 at EL- Tahrir Provence, Behera Governorate, west of Nile Delta of Egypt to study the effect of mulching type and duration on the productivity and water use efficiency of potato. Sixteen treatments comprising of four level of mulching (no- mulch (M_O) - Rice straw mulch (RSM), Black polyethylene (BPM) and transparent polyethylene (TPM)) and four mulching time (T_1-T_4) were investigated. All treatments were repeated three times in complete randomized block design. Soil temperature, soil water content, seasonal water applied and seasonal crop evapotranspiration were monitored throughout the growing season, while the harvested potato tuber were weighted and sampled to determine some quality parameters. Results revealed that, mulching practices influenced the soil temperature. Applying Rice straw mulch moderates the soil temperature throughout the growing season and offered the most favorable potato growing condition. In contrast, polyethylene mulch materials increased the soil mean temperature by about 4-5 °C throughout the growing season which hampered tuber initiation, bulking and consequently the total potato tuber yield. Both mulching types and duration affects potato tuber yield, quality and water use efficiency. $RSMT_4$ treatment had the maximum tuber number per plant, tuber mass, tuber yield, starch and total soluble solids (TSS) content of 8.14, 105.35 g, 17.45 Mg/fed., 14.68 and 5.63%, respectively as compared with the other mulched and non- mulched treatments. Retaining the polyethylene mulch materials up to the end of growing season negatively influenced the growth parameters, tuber yield and the measured quality parameters. Concerning the seasonal applied water (SAW) and crop evapotranspiration (ET_C), M_O treatment had the maximum SAW and ET_C values of 522 and 438 mm, respectively. Mulching practices saved irrigation water by 14.08, 19.65 and 18.48% with RSM, BPM and TPM, respectively as compared with the control treatment. $RSMT_4$ treatment had the maximum irrigation water use efficiency (IWUE) and water use efficiency (WUE) of 10.39 and 13.02 kg/m^3, respectively However, BPM and TPM mulch materials inhabited the maximum IWUE and WUE values of 10.03, 12.54 and 7.89 and 8.89 kg/m^3, respectively when it was retained over the soil surface up to the end of the tuber formation stage (T_3), suggesting that the PM should be removed early in order to avoid their negative effects on the tuber yield, quality and water use efficiencies.

Keywords: Organic mulch materials, In-organic mulch materials, Potato, Quality parameters, Water consumptive use and Water use efficiencies.

INTRODUCTION

Irrigation water deficit and the global temperature increasing are the primary factors limiting crop productivity, accounting for more than a 50% reduction in yields worldwide. Compounding the problem of reduction yields is the prediction that the world population will exceed 8 billion by 2030, requiring a doubling of the world food production on the current cultivated areas by using the available limited irrigation water resources. So, our challenge is to increase food production while reducing water consumption.

This can be achieved by introducing advanced irrigation methods and improved agricultural management practices (Yaghi *et al*., 2013; Zaman *et al*., 2001). Optimal soil moisture content and soil temperature can be maintained by proper irrigation management and agricultural practices. Among the water management practices for increasing water use efficiency is mulching. The practice of mulching has been widely used as a management tool in many places of the world. It dampens the influence of environmental factors on soil by regulating soil temperature and controlling diurnal/seasonal fluctuations in soil temperature (Raskar and Bhoi 2003 and Pawar, 2004). However, the effect varies with soil, climate, kind of mulch materials used and application rates. Ning and Hu (1990) stated that mulch may be organic (crop residue, stubble mulch) or inorganic (plastic sheet, gravel, etc.). Plastic or straw mulch may efficiently improve the microclimate and growth conditions by promoting plant transpiration at the expense of evaporation from the soil. Khalifa and El-nemr (2011) reported that the rice straw, as organic mulch, is inexpensive, available under Egyptian condition, insulates well, and conserve moisture. In addition, it acts an environmental problem during the latest years in Egypt resulting from burning rice straw. So using it for mulching could offer a solution for this problem. They mentioned that three straw mulch thicknesses namely 2.5, 3.8 and 5.0cm were tested. Mulching over 5 cm thickness was avoid to reduce mulching coast and over mulching problems. Also, the use of rice straw mulch led to decrease the soil moisture depletion by 66, 57, 48 and 38% compared with non-mulch treatments for 70, 80, 90 and 100% of crop evapotranspiration (ET_c), respectively for trickle irrigated cucumber crop in sandy soil. Also, the mulched treatments showed productivity increase compared to non-mulched treatments. Gouranga and Ashwani (2007) stated that rice straw mulch application increased the potato tuber production with 24-42% depending on the irrigation treatments and reduced the crop evapotranspiration by about 77-103 mm when applying rice straw mulch at a rate of 6 t/ha. Plastic mulch is the most widely used inorganic materials in many countries. Mulching with the help of plastic film has played a major role in crop production by creating mechanical protection at the soil surface and microclimate favorable in terms of temperature distribution, retention of humidity and supply of CO_2 to the stomata of lower leaves of small plants (Ghosh *et al*., 2006). Potato (*Solanum tuberosum L.*) is the most important vegetable commodity in Egypt in terms of planted area and crop value, about 300 thousand feddan areas produced about 4.758 million tones (FAO,2012). There are specific problems in the management of sandy soils including their excessive permeability, low water and nutrient holding capacity. Therefore, managing the use of irrigation water and plant nutrients is a major challenge of sandy soils amelioration efforts. Potato is about 110- 130 days duration crop and it may divide into four stages, namely initial, 25 days; development, 30 days; middle,45days; and tuber maturity stages, 30 days. The crop coefficient during the growth season was 0.50, 0.65, 1.15 and 0.75 at initial, development, middle and tuber maturity stages, respectively (Allen *et al*., 1998). Furrow irrigation is the most common irrigation method for potato production in Egypt. However, alternative irrigation method such as trickle irrigation combined with proper agricultural managements like mulching practices, offer what is probably the ultimate in control of irrigation water and nutrient management for crop production (Thompson *et al*., 2000; Unlu *et al*., 2006). Soil- water depletion and plant water use efficiency are critical factors affecting agricultural productivity in arid and semi-arid areas. Crop yield and water use efficiency (WUE) have been reported to be increased by mulching treatments, because of favorable soil water and soil temperature, earlier emergences, more flower and proper maturity conditions, lower bulk density and less weeds (Wang *et al*., 2009). Kang *et al*. (2000) found that yield and water use efficiency response to irrigation varied considerably with differences in soil water content and irrigation schedules. Because potato has a sparse root system and approximately 85% of the root length is concentrated in the upper 30 cm of the soil depth, it has critical periods of growth when irrigation is a necessity for optimal yield and quality (Kang *et al*., 2002). Drought severity, timing and duration of water stress during the different growth stages especially tuber formation stage, influence the crop productivity by reducing growth of the crop canopy, biomass and tuber grade by increasing the occurrence of tuber malformation and spindled tubers, which make the availability of soil water one of the most important factors affecting the yield and quality of potato, (El-Ghamry and El-shikha, 2004; Wang *et al*., 2006; Ati and Nafaou, 2012). Being a temperature crop, potato growth and yield are highly affected by higher temperature, especially a mean temperature above 18°C. Tuberization occurs at low temperatures and is delayed or even inhibited at higher temperatures, tubers rarely being formed above 30°C. Soil temperature between 15 and 18°C were optimal for tuberiziation of potato. High soil temperature increased stem elongation, branching, haulm weight, foliage development and root growth but decreased the accumulation of the dry matter in tubers, leading to production of small malformed tubers (Gouranga and Ashwani, 2007). With increasing the water demand and increasing the warnings of water scarcity, there is an urgent need to achieve higher output per unit of water consumed. Fortunately, there is ample scope to improve crop water productivity, particularly in areas where yield are currently low. There are few studies relating to the mulching type and duration or timing and their effects on potato growth, yield, tuber quality, water consumptive use and water use efficiency.

Therefore, the present study aimed to: 1-assesse the best mulching management option for evaluating productivity of potato. 2-compare the performance of organic and inorganic mulch in terms of plant growth, productivity, some quality parameters, water consumptive use and water use efficiency of potato.

MATERIALS AND METHODS

Location and growth conditions

Field experiments were carried out during the winter season of 2014/2015 at EL- Tahrir Provence, Behera Governorate, west of Nile Delta of

Egypt in a commercial grower's field. The geographical location of the farm is 30° 65' N; longitude 30° 7' E and 16 m above the sea level, to study the effect of mulching type and duration on the productivity and water use efficiency of potato (*Solanum tuberosum L.*) . Soil samples were collected at 20 cm increments to a depth of 60 cm to determine some physical and chemical properties of the experimental site. Obtained results are presented in Tables (1) and (2). The climate of the experimental site is usually dry with ineffective rainfall amount. Necessary metrological data throughout the growing season were provided by the Central Laboratory for Agricultural Climate (CALC) of Egypt and summarized in Table (3).

Experimental design and treatments

The field experiments comprised of sixteen treatments composed of four mulching practices or types representing the organic and inorganic mulching materials which consisted of, no- mulching treatment or bare soil (M_O) which served as the control treatment , rice straw mulch (RSM); black polyethylene (BPM) and white transparent polyethylene mulch (TPM), besides four mulching time treatments (T_1 – T_4) . The four mulching duration time treatments were designated as follows:

- From sowing to the end of initial stage (T_1).
- From sowing to the end of development stage (T_2).
- From sowing to the end of tuber formation stage (T_3).
- From sowing to the end of growing season (T_4).

All treatments were replicated three times in two factorials randomized complete block design (RCBD).

Table (1): Some physical properties of the soil at experimental site

Soil depth (cm)	Mechanical analysis			Texture class	FC (%)	WP (%)	ASM (%)	BD g/cm^3
	Sand (%)	Silt (%)	Clay (%)					
0-20	88.2	8.2	3.6	Sandy	12.7	6.3	6.4	1.62
20-40	87.1	8.8	4.1	Sandy	13.1	6.4	6.7	1.66
40-60	87.1	8.9	4.0	Sandy	13.3	6.3	7.0	1.68

Table (2): Some chemical properties of the soil at experimental site

Soil depth (cm)	EC (dS/m)	pH	Soluble cations (meq/l)				Soluble anions (meq/l)		
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{-2}	Cl^{-}
0-20	1.23	7.73	0.90	0.47	0.65	0.35	0.45	0.82	1.10
20-40	1.12	7.80	0.95	0.41	0.65	0.35	0.48	0.78	1.10
40-60	1.03	7.95	1.00	0.40	0.62	0.35	0.48	0.75	1.15

Crop management

Tuber pieces of the late maturity potato, cultivar 'Spunta' were hand cultivated using a stand density of about 4- 4.2 plant / m^2 on 1st of October 2014 in rows 40m length, 0.7m apart and about 0.3m spacing between plants within rows. The experimental area was about 2400 m^2, divided into four equal blocks each was 520m^2. Each block consisted of four plots, 2.5*40 m each. Every plot contained three rows, that represented one replicate. Buffer zones of 2m and 1m separated between replicates, and between plots, respectively to avoid the interference and to facilitate the movement between the treatments. Rice straw mulch was spread uniformly over plots just after sowing at a rate of 500 g/m^2. For the plastic mulching treatments, the plastic films (Black polyethylene, 50 µm and transparent polyethylene, 50 µm) were applied on the soil surface after sowing with the edges held tightly under the soil on both sides to facilitate its protection from damage. The polyethylene materials were cut to size and placed over rows. Holes were created in accordance with plant spacing and potato seedlings were passed through the holes. A small hole, about 0.5 cm in diameter, was also made on the top of the plastic film to make the environment the same under and over the plastic film. A trickle irrigation system was used for the experiment. Drip tubing, twin- wall GR, 15 mm inner diameter, with discharge rate of 2.7 L/h at operating pressure of 100 kPa, were laid for each plant row at 70 cm apart and 30cm within the lateral line. The control head located at the source of the water supply consisted of centrifugal pump, media filter of 100 mesh followed by screen filter of 120 mesh, pressure gauges, pressure regulator, fertilizer tank and flow meter. Irrigation water was supplied from an open channel irrigation system in the experimental area and classified by pH value of 7.7 and average electrical conductivity of 1.35 dS/m. Plants were received the same amount of irrigation water in the first irrigation to insure good plant establishment. All agricultural practices followed the recommendations of the Egyptian Ministry of Agriculture. Care was taken during the removal of the mulch materials. The plastic film mulch should be cut at the top middle along the rows and set aside before removing it from the field.

Table (3): Average monthly metrological data throughout the growing season

Month	Air tem. (°c)		Soil tem. (°C)		RH (%)	ET_O (mm)	Wind speed (m s^{-1})
	$T_{max.}$	$T_{min.}$	$T_{max.}$	$T_{min.}$			
October	29.4	15.8	20.8	17.7	68	4.01	2.3
November	24.0	12.3	19.1	17.2	74	2.45	2.1
December	21.7	10.6	17.2	15.8	70	1.41	0.9
January	20.3	13.2	16.5	15.0	75	2.18	1.2

Soil temperature

Soil temperature variations among the mulched and non-mulched treatments were measured by installing soil mercury thermometers at soil surface and 0.10 m soil depth. Average soil temperatures were then measured at 8.00 am and 14.00 pm twice a week. Measurements were taken for M_O and T_4 treatments only, because among the mulched treatments soil temperature was almost the same before removing the mulch materials.

Yield and yield components measurements

Potato tuber yields were harvested at the end of the growing season on 2nd of February (125 DAP), when all plants reached physiological maturity stage. Plant growth component were determined from 10 randomly selected plants from each plot included average tuber number per plant, tuber weight (g), and total fresh tuber yield for each treatment (Mg/fed.).

Tuber analysis

A random sample of three plants from each plot were chosen and prepared for chemical analysis. Specific gravity of tubers was calculated as (g/cm^3) according to the method described by Smith (1979). Total soluble solids (TSS) were estimated using hand refract meter method, and the starch content was calculated according to the following formula of Burton (1948).

$$\text{Starch (\%)} = 17.546 + 199.07\ (\text{specific gravity} - 1.0988)$$

Where:

$$\textbf{Specific gravity} = \frac{\textbf{weight in air}}{\textbf{weight in air} - \textbf{weight in water}}$$

Estimation of crop water requirement

The quantities of irrigation water (I, mm) at each application were based on the soil moisture deficit up to field capacity to a depth of 60 cm shortly before each irrigation event. Soil moisture contents were determined gravimetrically shortly before and 24 hours after irrigation to determine the amount of irrigation water to be applied and crop water consumptive use. Actual crop evapotranspiration of potato (ETc, mm/day) was estimated using the following form of the balance equation (Allen *et al*., 1998).

$$ET_c = \frac{(I + P - D) + \sum_{i=1}^{n} (\theta_1 - \theta_2)\Delta s_i}{\Delta t}$$

Where: I is the irrigation water (mm), P is the precipitation (mm), D is the deep percolation (mm), n is number of the layers, Δs is the thickness of each layer (mm) θ_1 and θ_2 are the volumetric soil water content 24 hours after irrigation and shortly before the next irrigation and Δt is the time interval between two consecutive measurements (days). Since the climate of the experimental site is usually dry with ineffective rainfall amount of 12 mm throughout the growing season and the amount of irrigation water was controlled, precipitation was negligible, runoff was assumed to be zero and deep percolation below 60 cm soil depth was negligible, therefore, one dimensional water balance equation can be used for estimation crop evapotranspiration.

Water use Efficiencies

Water use efficiency (WUE, kg/m^3) and irrigation water use efficiency (IWUE, kg/m^3) were calculated as follows:

$$\textbf{WUE} = \frac{\textbf{Y}}{\textbf{ETC}}$$

$$\textbf{IWUE} = \frac{\textbf{Y}}{\textbf{SAW}}$$

Where:

Y is the marketable yield (kg/fed.), ETC and SAW are the seasonal crop evapotranspiration and the seasonal applied irrigation water (m^3/fed.), respectively.

Statistical analysis

Statistical analysis of the data was performed using a randomized complete block design with three replicates. Costat (version 6, 311, CoHort, USA, 1998-2005) was used for data analysis. Comparison of treatment means was carried out using the least significant difference (LCD) at 0.05 probability.

RESULTS AND DISCUSSION

Soil temperature

The maximum air temperature ranged from 29.4 to 20.3 °C, while the minimum air temperature ranged from 15.8 to 10.6 °C as presented in Table (3). It was noticed that the bare soil mean temperature followed a similar pattern to mean air temperature. Applying RSM increased the minimum soil mean temperature by 2-3°C recorded at 8.0 am especially during the early growth period, while it reduced the maximum soil mean temperature recorded at 14.0 pm by about 2- 4°C during tuber initiation and bulking growth stages, resulting in the most favorable potato growth condition. In contrast polyethylene mulch materials increased the soil mean temperature by about 4-5 °C throughout the growth stages as presented in Table (4) and Fig. (1).

Table (4): The average soil temperature (°C) of various mulching type and period treatments at each growth stage.

Growth stages	Average soil temperature (°C)							
	RSM		BPM		TPM		M_O	
	$T_{max.}$	$T_{min.}$	$T_{max.}$	$T_{min.}$	$T_{max.}$	$T_{min.}$	$T_{max.}$	$T_{min.}$
Initial Oct 1st to Oct 25th	21.20	19.9	24.2	20.30	25.1	20.8	22.1	17.8
Development Oct 26th to Nov.24th	19.1	18.5	23.8	19.80	24.1	20.3	21.5	16.5
Tuber formation Nov 25th to Jan. 6th	18.4	17.5	24.1	18.6	24.7	20.8	21.2	15.1
Maturity Jan. 7th to Feb. 2ed	18.1	17.2	22.2	18.1	21.9	19.9	19.9	15.3

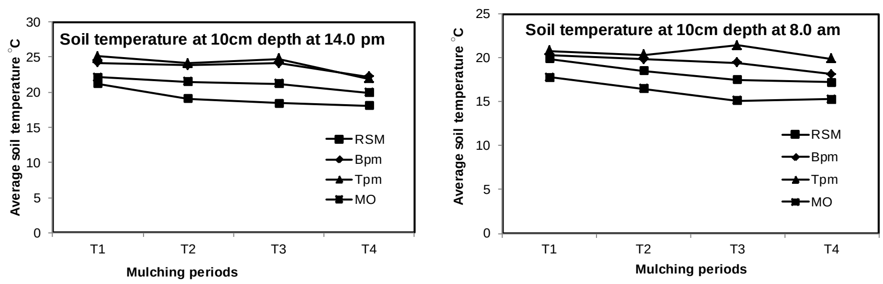

Fig. (1): Average soil temperature as affected by mulching types and periods.

High soil temperature enhanced germination in the early growth stage and inhibited tuber initiation and bulking. These results were consistent with Gouranga and Ashwani (2007), they reported that temperature between 15 and 18°C were optimal for tuber formation of potato. High soil temperature increased stem elongation, branching, haulm weight, foliage development and root growth but decreased the accumulation of the dry matter in tubers, leading to production of small malformed tubers. As the plant canopy enlarged more soil surface was shaded and the soil temperature differences between mulched and non-mulched soil became less.

Average tuber number per plant

Average potato tuber number per plant values in relation to mulching types and period are presented in Table (5). Results show highly significant effect of the different mulching materials on the average tuber number per plant. $RSMT_4$ treatment had the maximum average tuber number per plant of 8.14, which did not significantly differ than $RSMT_3$ and $RSMT_2$ treatments. The lowest tuber number per plant of 7.35 was recorded under the control treatment (M_O). The performance of various mulching treatments in regarding to tuber number per plant followed the order of RSM>BPM>TPM> M_O as shown in Table (5). A significant interaction of mulching type and period on the average tuber number per plant was noted. However, the effect of the mulching type on the average tuber number was more pronounced than the effect of the mulching duration, which showed non-significant differences among the different mulching period treatments (T_1-T_4).

Tuber mass (g)

Average potato tuber mass under different mulching treatments was investigated. Results pointed out a highly significant effect of treatments on the tuber weight as shown in Table (5). RSM treatment recorded the greater tuber mass of 105.35g when retained over the soil surface throughout the growing season ($RSMT_4$), which considered the most favorable potato growth condition. Also, duration of polyethylene mulching materials significantly influenced potato tuber mass. The maximum tuber mass of 103.30g and 84.30g were obtained by BPM and TPM, respectively, when it was kept in the field up to the end of tuber formation stage (T_3).

However, retention of polyethylene mulching materials throughout growing season (T_4) reduced the average tuber mass by about 21.25% and 7.47% for BPM and TPM treatments, respectively over its retention up to the end of tuber formation stage (T_3). On the other hand, the minimum tuber mass of 75.67 g was recorded under $TPMT_1$treatment. A significant interaction of mulching type and period on the average tuber mass was noted. The analysis of variance test indicated highly significantly differences among the tested treatments, which reflects a highly effect of the mulching materials and duration on the average tuber mass. Retaining the mulching materials up to the end of the initial stage (T_1) did not enhance the average tuber mass. Also, there was no significant difference in the average tuber mass among TPM and M_O treatments.

Table (5): Average tuber number per plant, tuber mass, tuber yield, starch and TSS content of potato as affected by different mulching types and duration.

Factors		Tuber Number	Tuber mass (g)	Tuber Yield (Mg/fed.)	Starch %	TSS %
RSM		8.05a	93.50a	15.15a	13.72a	5.41a
BPM		7.76b	87.08b	13.95b	13.62b	5.34b
TPM		7.65c	80.00c	12.45c	13.50c	5.28c
MO		7.35d	78.50c	12.40c	13.68ab	5.30d
Significance		***	***	***	***	***
T1		7.70ab	78.54c	12.10d	12.90d	5.16c
T2		7.75a	84.33b	13.30c	13.29c	5.26b
T3		7.70ab	91.82a	14.82a	13.98b	4.40a
T4		7.65b	85.17b	13.74b	14.34a	5.43a
Significance		ns	***	***	***	***
RSM	T1	7.90	81.00	12.15	12.74	5.15
	T2	8.05	90.67	14.25	13.23	5.31
	T3	8.10	100.33	16.75	14.22	5.57
	T4	8.14	105.35	17.45	14.68	5.63
BPM	T1	7.84	77.30	12.15	12.62	5.23
	T2	7.96	86.25	13.75	13.19	5.25
	T3	7.66	103.30	16.85	14.16	5.42
	T4	7.60	81.350	13.05	14.54	5.46
TPM	T1	7.78	75.67	11.70	12.58	5.14
	T2	7.66	82.00	12.80	13.09	5.19
	T3	7.60	84.30	13.25	13.90	5.33
	T4	7.53	78.00	12.10	14.44	5.43
MO	T4	7.35	78.50	12.40	13.68	5.30
Interaction		**	***	***	***	***

Means within each column followed by the same letter/s are insignificant at 0.05 level of probability. n.s.: not significance at the 0.05 probability level, ∗ : significance at the 0.05 probability level, ∗∗: significance at the 0.01 probability level, ∗∗∗: significance at the 0.001 probability level.

Tuber yield (Mg/fed.)

The results presented in Table (5) demonstrated a highly significant effect of tested treatments on potato yield. The RSM treatment recorded the maximum tuber yield of 17.45 Mg/fed. as compared to other mulching materials treatments and non- mulched treatment, when it was retained up to the end of the growing season.($RSMT_4$). Retaining the polyethylene mulching materials up to the end of the tuber formation stage (T_3) enhanced the average tuber yield. A slightly decrease in the average tuber yield of 3.44% was recorded by $BPMT_3$ treatment; meanwhile $TPMT_3$ resulted in considerable decrease in tuber yield by about 24.07% as compared to $RSMT_{4.}$ .The $TPMT_4$ treatment had the minimum average tuber yield of 12.10 Mg/fed. . The reduction in potato yield by $BPMT_4$, $TPMT_4$ and M_O treatments corresponds to the reduction in the average tuber number per plant and average tuber mass. However, the effect of the average tuber mass on the potato tuber yield was more pronounced than the effect of the average tuber number per plant as shown in Fig. (2).

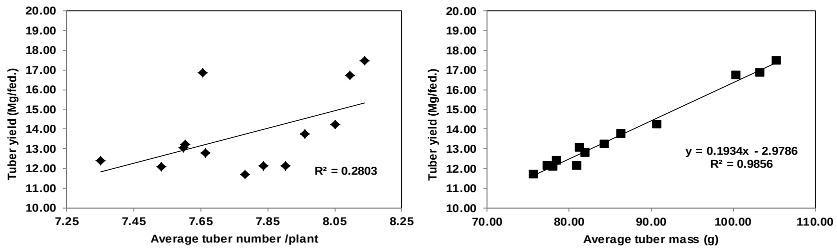

Fig.(2):The relationship between total tuber yield and average tuber number and the average tuber mass as affected by mulching types and period treatments.

A significant interaction of mulching materials and duration on the average tuber yield was observed. The performance of various mulching types and periods treatments in regarding to the average tuber yield followed the order of RSM >BPM > TPM > M_O and T_3>T_4>T_2> T_1, respectively as shown in Table (5). These results are consistent with those reported by Ghosh *et al*., 2006; they mentioned that mulching with RSM or BPM enhanced the average tuber yield compared to a non-mulched treatment. TPM materials were not as effective in suppressing weed compared to RSM and BPM. Thus potato tuber yield under TPM are not significantly different from the control treatment (M_O). Also, the experimental results are in harmony with Acharya *et al*., 2005, they declared that the higher yield under RSM was related to favorable soil temperature and soil water content throughout the growing season. Also, soils under RSM had lower bulk density than under plastic materials or the control treatment. The surface residue mulch generate more favorable habitats for soil and surface dwelling earthworm, microorganisms insects and pathogens, which might have contributed to low bulk density resulted in reducing the mechanical resistance to growing roots encouragement plant vegetative growth ,increasing tuber number, enhancing the tuber formation and development and consequently increasing the average tuber yield.

Potato tuber quality

The effect of the different mulching treatments on some potato tuber quality indicators such as starch content (%) and the total soluble solid (TSS, %) were investigated. Results indicated significant effect of the different mulching treatments on both tested quality parameter. The non- mulched treatments had the minimum starch and TSS content values of 13.68 and 5.30 %, respectively. Comparison among the different mulching treatments indicated slight improvement of the studied quality parameters as shown in Table (5). Retaining the mulch materials throughout the growth season enhanced the tested quality parameters. $RSMT_4$ treatment had the maximum starch and TSS content values of 14.68 and 5.63%, respectively. Many studies have indicated that retaining the organic mulch materials whole growth season enhanced both potato tuber yield and quality , meanwhile keeping in the plastic mulch materials over the growth season can cause over excessive N mineralization and might decreased crop yield , but improved starch and TSS content (Ghosh *et al*., 2006). Concerning the interaction effect between the mulching materials and duration revealed a significant effect on the tested quality parameters.

Seasonal applied water (SAW)

Results of SAW as affected by the different mulching treatments were presented in Table (6), which reflected highly significant difference among the treatments. The non-mulched treatment had the maximum SAW value of 522 mm; meanwhile, the minimum SAW value of 378 mm was associated with $BPMT_4$ treatment. Considering the highly significant interaction of mulching type and duration on the SAW, results confirmed that, applying RSM, BPM and TPM saved irrigation water by about 14.08, 19.65 and 18.48%, respectively as compared to the control treatment. Also the effect of mulching times on the SAW followed the order of $T_1>T_2>T_3>T_4$.

Seasonal crop evapotranspiration (ET_C)

Results of seasonal water consumptive use (ET_C) had the same trend of SAW. ET_C increased as the SAW increased. The control treatment had the maximum ET_C value of 438 mm; however the minimum ETc value of 302 mm was recorded by $BPMT_4$ treatment as shown in Table (6). A significant interaction among mulching treatments on ET_C was recorded. The performance of various mulching treatments in regarding to ET_C followed the order of M_O >TPM >BPM ≥ RSM and $T_1>T_2> T_3>T_4$, respectively. These results suggest that mulching could save irrigation water and reduce evapotranspiration, and are in agreement with Feng *et al*, 2009.

Crop water use efficiencies (Kg/m^3)

Results of crop irrigation water use efficiency (IWUE) and water use efficiency (WUE) were illustrated in Table (6) and Fig. (3). Data demonstrated a highly significant effect of mulching treatments on both of IWUE and WUE. $RSMT_4$ treatment had the greatest IWUE and WUE values of 10.39 and 13.02 kg/m^3, respectively. Meanwhile, retaining the polyethylene mulch materials up to the end of the growing season (T_4) adversely influenced both IWUE and WUE. A considerable decrease in IWUE and WUE values of 12.3% were recorded under $BPMT_4$ treatment as compared to $BPMT_3$. The same trend was observed under TPM treatments. These results exposed the negative effect of retaining the polyethylene mulch materials throughout the growing season (T_4) on the potato tuber mass and the total yield. So, we emphases the necessity of removing the plastic mulch materials at the end of tuber bulking growth stage (T_3) to avoid the negative effects on the plant development and productivity. M_O treatment had the lowest IWUE and WUE values of 5.11 and 6.10 Kg/m^3, respectively. A highly significant interaction of mulching materials type and duration among all treatments on the water use efficiencies was recorded as shown in Table (6).

Table (6): Seasonal applied water, water consumptive use and water use efficiencies of potato as affected by different mulching treatments.

Factors		SAW (mm)	SAW (m^3/fed.)	ETC (mm)	ETC (m^3/fed.)	IWUE (kg/m^3)	WUE (kg/m^3)
RSM		448.5b	1883.7	354.58b	1489.24	8.2a	10.35a
BPM		419.42c	1761.56	335c	1407	8.13a	10.19b
TPM		425.5c	1787.10	360.33b	1513.38	7.03b	8.28c
MO		522a	2192.4	438.00a	1839.60	5.11c	6.10d
Significance		***		***		***	***
T1		487a	2045.40	394.5a	1656.9	5.79d	7.17d
T2		470.9b	1977.78	382b	1604.4	6.59c	8.18c
T3		436.25c	1832.25	364.75c	1531.95	8.15a	9.85a
T4		421.25d	1769.25	346.83d	1456.68	7.93b	9.71b
Significance		***		***	***	***	***
RSM	T1	495	2079	395	1659	5.84	7.32
	T2	476	2000	363	1524.6	7.13	9.35
	T3	423	1776.6	341	1432.2	9.43	11.70
	T4	400	1680	319	1340	10.39	13.02
BPM	T1	460	1932	365	1533	6.29	7.93
	T2	442	1856.4	353	1482.6	7.41	9.27
	T3	400	1680	320	1344	10.03	12.54
	T4	378	1587.6	302	1268.4	8.79	11.00
TPM	T1	471	1978.2	380	1596	5.91	7.33
	T2	446	1873.2	375	1575	6.83	8.13
	T3	400	1680	355	1491	7.89	8.89
	T4	385	1617	308	1293.6	7.48	8.78
Mo	T4	522	2192.4	438	1839.6	5.11	6.10
Interaction		***		***		***	***

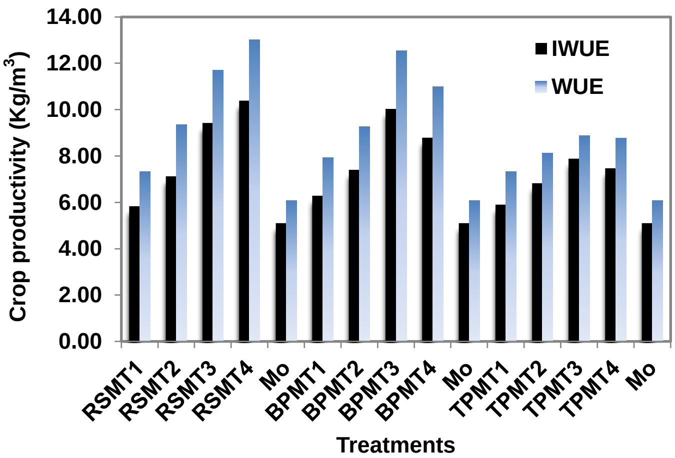

Fig. (3): Water use efficiency (WUE) and irrigation water use efficiency (IWUE) as affected by mulch type and duration.

Similar results have been reported by Wang *et al*. (2009). While, Feng, x. W., *et al* (2009) mentioned that removing the plastic mulch materials 60 days after sowing is the best for potato production in northwest China. This discrepancy could be attributed to the different environmental conditions and the cultivar used.

CONCLUSION

Based upon results, the following can be concluded:

- Organic and in-organic mulching materials, efficiently improved the microclimate and crop growth conditions by promoting plant transpiration at the expense of evaporation from the soil. Therefore, crop yield, quality and water use efficiencies increased under mulching treatments.
- Rice straw mulch throughout the growing season and removing the plastic mulch materials after tuber formation stage was found to be the best for potato production under local condition at EL- Tahrir Provence.
- Black polyethylene mulch performed better than the transparent polyethylene.

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تأثير نوع و فترة التغطية علي الإنتاجية و كفاءة إستخدام المياه للبطاطس

عبد الحليم محمد زيتون ، آمون القمص جرجس و خليل عبد الحليم علام
معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية – الجيزة

يهدف هذا البحث الي دراسة تأثير نوع مادة الغطاء و مدة التغطية علي الإنتاجية وبعض صفات الجودة و الإستهلاك المائي و كفاءة إستخدام المياه لمحصول البطاطس. تم إستخدام أربع مستويات من مواد الغطاء (غطاء من مادة عضويه , قش الأرز(RSM) غطاء غير عضوي من مادة البولي إثيلين الأسود(BPM) و البولي إثيلين الشفاف ,(TPM)) بالإضافة الي معاملة الكنترول (بدون غطاء، M_O) . كذلك فقد تم إستخدام أربعة أزمنه للتغطية (T_1-T_4)، بالتزامن مع مراحل نمو المحصول. لتحقيق هذا الهدف أجريت تجارب حقلية بمنطقة التحرير بمحافظة البحيرة خلال الموسم الشتوي ٢٠١٥/٢٠١٤م. تم تصميم التجربة إحصائياً بإستخدام القطع كاملة العشوائية في ثلاث مكرارات تحت نظام الري بالتنقيط.

وكانت أهم النتائج المتحصل عليها كالآتي:

- أدي إستخدام قش الأرز كغطاء لسطح التربه الي تهيئة بيئة مناسبة لنمو محصول البطاطس علي مدار موسم النمو مما أدي الي زيادة عدد الدرنات بالنسبة للنبات و كذلك زيادة وزن الدرنه و بالتالي إجمالي الإنتاجية للمحصول. بينما أدي إستخدام غطاء البولي إثيلين الي إرتفاع في درجة حرارة التربه من ٤-٥ م° مما أدي الي الحد من إكتمال نمو و تكوين الدرنات مما انعكس سلباً علي الإنتاجية للمحصول .
- أظهرت النتائج أن هناك فروقاً معنويةً بين المعاملات حيث حققت معاملة التغطية بقش الأرز علي مدار موسم النمو ($RSMT_4$) أعلي عدد من الدرنات للنبات و كذلك متوسط وزن الدرنه و إجمالي المحصول بقيم و قدرها ٨.١٤ ، ١٠٥.٣٥ جم و ١٧.٤٥ميجاجرام/للفدان علي الترتيب، يليها معاملة التغطية بمادة البولي إثيلين الأسود ثم البولي إثيلين الشفاف. بينما إحتلت معاملة الكنترول(M_O) المرتبة الأخيرة بقيم و قدرها ٧.٣٥ ، ٧٨.٥٠ جم و ١٢.٤٠ميجاجرام/للفدان علي الترتيب. كما لوحظ ان هناك تحسناً بسيطاً في محتوي الدرنات من النشا ونسبة المواد الصلبة مع وجود تبايناً معنوياً لهذه القيم بين المعاملات.
- أظهرت النتائج وجود فروقاً معنويةً في كميات مياة الري المضافة وكذلك الإستهلاك المائي للنبات حيث سجلت معاملة الكنترل أقصي قيمة للمياه المضافة و كذلك الاستهلاك المائي بقيم و قدرها ٥٢٢ و ٤٣٨ مم علي الترتيب. بينما أدت التغطية بقش الأرز وغطاء البولي إثيلين الأسود و الشفاف الي توفير في كميات مياه الري بنسب و قدرها ١٤.٠٨ ،١٩.٦٥ و ١٨.٤٨% علي الترتيب مقارنةً بمعاملة الكنترول.
- سجلت معاملة التغطية بقش الأرز علي مدار موسم النمو أعلي كفاءة لإستخدام مياة الري(IWUE) وإستخدام المياه(WUE) بقيم و قدرها ١٠.٣٩ و ١٣.٠٢ كجم/م٣ . بينما سجلت معاملات التغطية بمادة البولي إثيلين الأسود و الشفاف حتي نهاية مرحلة النمو الثالثة (T_3) اعلي كفاءة لإستخدام مياة الري وإستخدام المياه بقيم و قدرها ١٠.٣٠ ، ١٢.٤٥ كجم/م٣ و ٧.٨٩، ٨.٨٩ كجم/م٣ علي الترتيب، مما يلقي الضوء علي ضرورة ازالة غطاء البولي إثيلين في مرحلة مبكرة قبل نهاية موسم النمو.

- **هذا و لقد خلصت النتائج الي:**

١- استخدام تقنية التغطية بالمواد العضوية و الغير عضوية قد يؤدي الي زيادة المحصول و توفير مياة الري و تحسن صفات الجودة اذا ما اتبعت الإرشادات الخاصة لكل منطقة وفقاً لظروفها البيئية والمناخية و اذا ما روعيت الظروف الملائمة لنمو المحصول.

٢- بالنسبة لمنطقة التحرير فان التغطية بقش الارز بمعدل ٥٠٠ جم/م٢ علي مدار موسم النمو لمحصول البطاطس أدت الي توفير بيئة مناسبة للنمو و ما ترتب علي ذلك من زيادة في المحصول و خصائص الجودة و توفير في مياه الري.

٣- استخدام المواد الغير عضوية في هذه المناطق مرهوناً بإزالتها في مرحلة مبكره تجنباً للأثار الضاره لارتفاع درجة حرارة التربة في مرحلة تكوين وتمام نضج الدرنات. كما يفضل إستخدام غطاء البولي إثيلين الأسود عن غطاء البولي إثيلين الشفاف.