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UTILIZATION OF PULSE SPRINKLER TECHNIQUE FOR FLAX FIBER EXTRACTION

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Abstract

This study was performed to assess flax fiber extraction by pulse sprinkler technique compared with traditional method (submerged). For this purpose, an experiment was performed in fiber crops research department, Gemmiza Research Station, Gharbeiah Governorate, middle of the Nile Delta, Egypt during September and October, 2019. The micro-sprinkler system was applied with four values of pulses at cycle ratio of ½ namely (one, two, three and four) under two fiber extraction environment conditions (open field and in greenhouse) and two flax varieties Sakha 3 and Giza 12 were applied. The results showed that fiber extraction by T_G treatments saved applied water and increased fiber yield rate, fiber length and water productivity comparing with T_F treatments and T_W. T_{F4} and T_{G4} saved applied water comparing with T_W by about 17.2 and 25.2 % respectively for Sakha 3 and by about 28.7 and 34.5 % for Giza 12. T_W increased fiber yield rate more than T_{F4} for two varieties Sakha 3 and Giza 12 by 2.6 and 5.3 % respectively, while decreased fiber yield rate less than T_{G4} by 2.9 and 6.0 % for two varieties respectively. The highest fiber length achieved by T_W and T_{G4} with value of 90.0 cm for variety Sakha 3 and by T_{G4} with value of 87.0 cm for variety Giza 12. T_{G4} had the highest water productivity with values of 27.5 and 21.2 kg/m^3 for two varieties Sakha 3 and Giza 12 respectively.

Key words**:** *pulse, fiber yield, water productivity, applied water*

INTRODUCTION

Fiber extraction process is defined separating the fibers from non-fiber tissues in stalks also separating the fibers from each other. There are many methods to extract fibers for example steam explosion, enzymes retting, osmosis, electrolysis and redox pretreatment. But due to restriction such as high maintenance costs and environmental safety criteria it may is hard to apply these methods [19]. In Egypt the flax straw is submerged with water about 24 h then the water was drained. This operation repeated every day through 4 to 7 days for leaching out the soluble materials. Retting process is considered the main problem in extracting flax fibers [15]. In Europe water retting replaced by dew retting; stalks are distributed in the field and attacked by pectinolytic enzymes which excreted by fungi. In spite of dew retting cheaper but it has many negatives as high labor costs, takeover agricultural land for many weeks, differences in fiber quality caused by uncontrollable factors as moisture, temperature and activity of the microbial flora [11]. Water retting take less time and produces superior quality fiber comparing with dew retting, but it consumes large amount of water and retting liquor can cause contamination of ground water if it is not treated properly before discharging [2] and [17]. To overcome the problems of traditional retting methods (water and dew) new methods especially enzyme retting are being pursued [3]. Separation of fibers from stalks involves the degumming it in a water environment in a chemical, physical or biological process [5]. Effect of chemical, water, microbiological and enzymatic extraction methods on fiber quality of stalk nettle was evaluated and compared. Microbiological method unlike expected did not minimize the extraction time in comparison with traditional water method. Generally microbiological and enzymatic methods improved fiber quality comparing with traditional water method [7]. Extraction of the fibers from fibrous plants involves the degumming of stalk in an aqueous environment where biological, chemical or physical processes take place [12]. The method of extracting fibers is one of the important factors that quality of fibers depends on it, thus it is essential to sequence studies to introduce new retting methods more eco-friendly, short time, save water and produce superior quality fibers [13]. Impact of dew retting and osmotic degumming on bast fiber properties was investigated. The results proved that osmotic degumming improved significantly the fiber quality comparing with dew retting [14]. Traditional chemical degumming causes critical fiber damage and also consider an environmental risk, so it is fundamental to find a new chemical degumming method to overcome these disadvantages [10].

In previous work sprinkler system was applied for extraction flax fibers (called sprinkler retting) to overcome disadvantages of water retting in Egypt. Sprinkler retting consumed less water, improved fiber fineness and more eco-friendly where no odor and less labor; but it was not increase fiber percentage or fiber length and take more time ranged from (14 -24) days [6]. It is not necessary to immerse the flax straw with water for several days to obtain a successful fiber extraction process as it happen in traditional method, but it is possible to use the sprinkler network for extracting the fibers where the straw is wetted for a certain period daily which stimulates the activity of retting bacteria. With the daily addition of water the bacterial activity continues and the fiber extraction process takes place thus, the benefit of added water can be maximized. Intermittent irrigation is modern technique to manage irrigation systems and has been studied in many articles. It has been used since the 1980s with surface irrigation and called surge irrigation; recently it was applied with pressurized irrigation systems under the name of pulse irrigation. Surge/pulse irrigation is defined as 'the intermitted application of irrigation water to soil surface, creating series of on/off intervals at constant or variable time [20]. Sprinkler irrigation performance depend on main two factors; design factors include (sprinkler type and height, single or double nozzles, nozzle diameters and sprinklers overlapping) and operation factors include (operating pressure, irrigation duration and environmental conditions) [16] and [4]. Square layout increased uniformity and decreased the average of wind drift and evaporation losses comparing with rectangular layout [18]. To enhance distribution uniformity and water application efficiency the sprinkler irrigation system must be manage correctly, maintain regularly and operate at the design operating pressure [8]. Performance of mini-sprinkler irrigation system with nozzle sizes ranged from 0.85 to 2.0 mm under operating pressure ranged from 0.5 to 3.0 bar was evaluated. The results concluded that for all tested nozzle sizes increasing operating pressure from 0.5 to 2.0 bar increased uniformity coefficient; after that uniformity decreased [22]. The factors that affect sprinkler irrigation distribution uniformity are divided into three main factors; design factors such as sprinkler characteristics (number of nozzles, size and shape), operating pressure and sprinkler spacing; environmental factors such as humidity and more importantly wind direction and speed and management factors such as irrigation duration, time of day irrigation is performed and practicing of offsetting laterals [1] and [9]. The spatial distribution of irrigation water in sprinkler irrigation system based on; design properties, meteorological factors and crop canopy construction [21].

The present research was designed to: (1) evaluate the appropriateness of pulse sprinkler technique for extracting flax fibers comparing with traditional/water method, (2) evaluate the effect of extracting fibers under different environmental conditions on total applied water and fiber yield rate.

MATERIALS AND METHODS

Experimental layout

This study was performed in Gemmiza Research Station, Gharbeiah Governorate, middle of the Nile Delta, Egypt (31°07′ longitude and 30°43′ latitude and altitude 20 m above sea level) during September and October, 2019. Air temperature (max. and min.) relative humidity and wind speed for experiment period were obtained from Agricultural Research Center, EL-Giza, Egypt (Fig. 1).

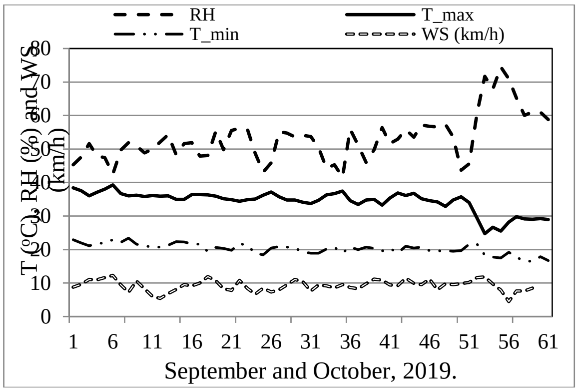

Fig. 1. Maximum and minimum air temperature (°C), relative humidity (RH, %) and wind speed (WS, km/h) for September and October, 2019.
Source: Own calculation.

Properties of irrigation water of the experimental site were analyzed by Soil Sciences Department, Faculty of Agriculture, Kafrelsheikh University, Egypt (Table 1).

Table 1. Some Properties of irrigation water from open channel for experimental site.

Properties	concentration
Potential of hydrogen, (PH)	7.38 mg.l^{-1}
Electrical conductivity, (EC,)	717 mg.l^{-1}
Total dissolved solids, (TDS)	198 mg.l^{-1}
Ammonia, (NH_3)	0.012 mg.l^{-1}
Nitrite, (NO_2)	0.022 mg.l^{-1}
Nitrate, (NO_3)	0.68 mg.l^{-1}
Biological oxygen demand, (BOD)	2.5 mg.l^{-1}
Total suspended solids, (TSS)	99 mg.l^{-1}
Dissolved oxygen, (DO)	3.0 mg.l^{-1}
Total count of bacteria	3.6 X10^5 cfu/ml

mg.l^{-1}: milligram per litter.
cfu = colony forming unit
Source: Own calculation.

Preparation of flax straw bundles

Flax varieties Sakha 3 and Giza 12 were grown in winter season 2018/2019 in Gemmeiza Research Farm, Agricultural Research Center (ARC), Egypt. All agronomic practices were accomplished according to agricultural recommendations for flax. Flax was pulled manually in April, 2019 and dried for several days in open field and seeds were separated mechanically. The straw was stored inside protected sheds to inhibit any effect by indigenous micro-organisms. Before starting fiber extraction process directly straw was packed into initial bundles weighing 500g/bundle; every 30 initial bundles were collected in main bundle with 0.7 m diameter. The main bundle was installed vertically in the distance between sprinklers. Traditional retting was carried out using 8inch (20.32 cm) outer diameter and 130 cm height polyvinyl chloride (PVC) pipes; three initial bundles (500g/bundle) were submerged with water into the pipes. For all the treatments, extraction process stopped when all pectin materials were dissolved. The bundles were dried in open field; the woody materials were broken away machinery to form cellulose fibers.

Micro-sprinkler network

Components of micro-sprinkler network are summarized in Table 2.

Table 2. Components of micro-sprinkler network

Items	Specifications
Control unit	Centrifugal pump (30 m^3/h nominal discharge and 3 "inlet and outlet diameters) powered by 3.75kW internal combustion engine (four-stroke, single-cylinder, Gasoline engine), control valve prevention device, pressure gauges and flow-meter.
Lines :	
Main line	Aluminium pipes with 75 mm outer diameter,70 mm inside diameter and 6 m in length; the pipes connected together by quick couple with rubber ring jointing.
Sub-main lines	Poly Vinyl Chloride (PVC) pipes with 32 mm outer diameter connected with main line by PVC saddles (75 × 32 mm) and 32 mm control valves.
Laterals	Poly Ethylene (PE) pipes with 16mm outer diameter connected with manifold lines by PVC saddles (32 × 16 mm) and 16 mm control valves.
Sprinklers	Rotator micro-sprinkler with 110 l/h flow rate, 2.5 m wetted radius at15 m operating pressure head. The sprinklers joined to lateral lines by 8 mm outer diameter spaghetti tube and fixed on 120 cm stake height.

Source: Own description.

Sprinklers were arranged in square layout, 100% overlapping and operated for two hours daily for all treatments.

Hydraulic performance terms of relationship between operating pressure head (m), flow rate (l/h) and radius of throw (m) was evaluated (Fig. 2).

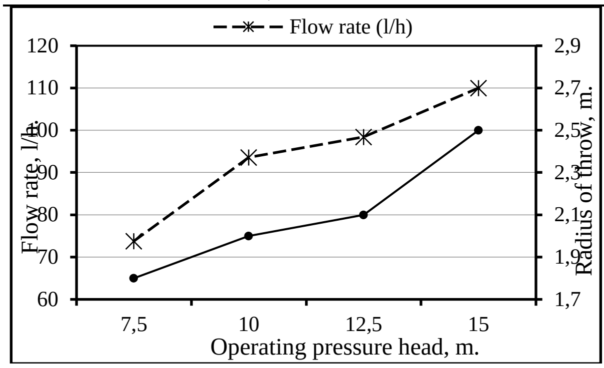

Fig. 2. Relationship between operating pressure head (m), flow rate (l/h) and radius of throw (m) for rotator micro-sprinkler
Source: Own calculation.

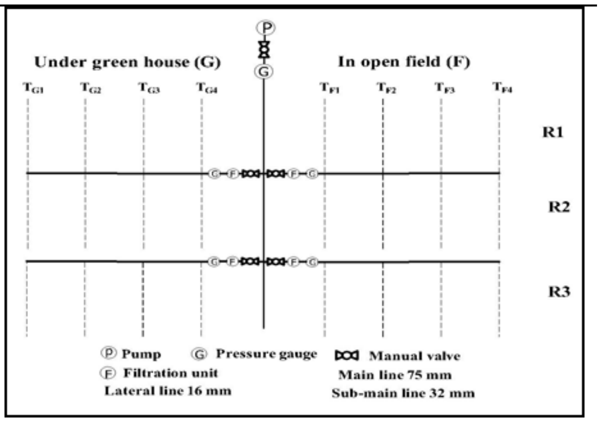

Fig. 3. The experimental field layout and the treatments distribution
Source: Own calculation.

Study variables

a) Fiber extraction environment: two different environment conditions were applied to extract fibers; in open field (F) and under greenhouse (G).

b) Fiber extraction method: pulse sprinkler technique with four numbers of pulses at cycle ratio of ½ was applied; one pulse (continuous; 1), two pulses (2), three pulses (3) and four pulses (4).

c) Flax variety: two varieties Sakha 3 and Giza 12 were used.

Water/Submerged retting (W) was applied as a traditional fiber extraction method. The abbreviations of different treatments are shown in Table 3.

Table 3. The symbols of different treatments

No	Symbol	Treatment
1	T_{F1}	Extraction in open field by one pulse
2	T_{F2}	Extraction in open field by two pulses
3	T_{F3}	Extraction in open field by three pulses
4	T_{F4}	Extraction in open field by four pulses
5	T_{G1}	Extraction under greenhouse by one pulse
6	T_{G2}	Extraction under greenhouse by two pulses
7	T_{G3}	Extraction under greenhouse by three pulses
8	T_{G4}	Extraction under greenhouse by four pulses
9	T_W	Extraction by water/submerged method

Source: Own calculation.

Experimental field layout and treatments distribution are shown in Fig. 3.

Nine experimental treatments for every flax variety were arranged in randomized complete block design with three replicates. The statistical analysis was carried out by Co-Stat program for windows. Least significant difference (LSD) at 5% significance level was carried out to compare the means of different treatments.

Measurements

Total applied water: Total applied water for every treatment from beginning of fiber extraction process until the end of it was calculated and related to ton of flax straw (m^3/ton_{straw}).

Fiber yield rate: It was calculated using following equation:

$$F = (Y^{\backslash}/Y)\ x\ 100$$

where:
F = the fiber yield rate
$Y^{\backslash}$ = the final weight of fiber after retting process (g)
Y = the initial weight of straw sample, 500g.

Flax fiber length: Average length for 20 fiber ribbons from each replication were measured and the average for each treatment were recorded

Fiber water productivity: It was calculated for ton of straw using following equation:

$$WP = Y_f/W$$

where:
WP = the fiber water productivity, kg_{fiber}/m^3
Y_f = the total fiber yield, kg
W = the total applied water for ton of straw, m^3.

RESULTS AND DISCUSSIONS

Total applied water

The total applied water (m^3/ton $_{straw}$) for two flax varieties Sakha 3 and Giza 12 in relation to fiber extraction method and environment are listed in Table 4. Analysis of variance referred to high significant difference between treatments. T_W treatment had the highest effect in applied water while T_{G4} treatment had the lowest effect for two varieties Sakha 3 and Giza 12. The total applied water was affected by fiber extraction method and environment. Using sprinkler method decreased applied water comparing with traditional method; this result was in agreement with that resulted by [6]. At sprinkler method; pulse technique decreased applied water comparing with continuous technique. Fiber extraction under greenhouse recorded lowest applied water comparing with fiber extraction in open field; this is may be due to the presence of saturated environment with moisture around the clock by greenhouses. For sprinkler system, using intermittent technique helps to minimize evaporation losses from the straw surface, thus increasing number of pulses from one to four decreased total applied water at two environment conditions. Two pulses treatments saved water comparing with one pulse (continuous) by 3.7 and 3.2 % at two environment conditions open field and greenhouse respectively for variety Sakha 3 and by 10.2 and 5.6 % respectively for variety Giza 12. Three pulses treatments saved water comparing with two pulses by 7.4 and 7.2 % at two environment conditions respectively for variety Sakha 3 and by 6.6 and 8.8 % for variety Giza 12. Four pulses treatments saved water comparing with three pulses by 5.0 and 7.5 % at two environment conditions respectively for variety Sakha 3 and by 9.7 and 7.3 % for variety Giza 12. Extraction the fibers under greenhouse saved applied water comparing with extraction in open field at different number of pulses from one to four as fallow: Sakha 3 (7.8, 7.3, 7.1 and 9.5) % and Giza 12 (12.0, 7.4, 9.5 and 8.0) %. The lowest applied water was 7.49 and 7.91 m^3/ton $_{straw}$ for two varieties Sakha 3 and Giza 12 which resulted at T_{G4} treatments; while the highest applied water was 10.01 and 12.07 m^3/ton $_{straw}$ for two varieties which resulted at T_W treatments. T_{F4} and T_{G4} treatments saved applied water comparing with water/submerged retting T_W by about 17.2 and 25.2% respectively for Sakha 3 and by about 28.7 and 34.5% for Giza 12. The results indicated to that; design factors, operating factors and weather conditions are specific factors that affect the performance of sprinkler system in extracting the fibers under any environment conditions.

Table 4. Total applied water (m^3/ ton $_{straw}$) and compare means for two flax varieties under different fiber extraction methods and environments

Treatment		Total applied water (m^3/ ton $_{straw}$)	
		Sakha 3	Giza 12
1	T_{F1}	9.78 ^{b}	11.25 ^{b}
2	T_{F2}	9.42 ^{c}	10.10 ^{c}
3	T_{F3}	8.72 ^{e}	9.43 ^{d}
4	T_{F4}	8.28 ^{f}	8.60 ^{e}
5	T_{G1}	9.02 ^{d}	9.90 ^{cd}
6	T_{G2}	8.73 ^{e}	9.35 ^{d}
7	T_{G3}	8.10 ^{g}	8.53 ^{e}
8	T_{G4}	7.49 ^{h}	7.91 ^{f}
9	T_W	10.01 ^{a}	12.07 ^{a}
LSD $_{0.05}$		*0.08*	*0.61*

The same letters indicated not significantly different at 0.05 level

Source: Own calculation.

Fiber yield rate

The fiber yield rate (%) in relation to fiber extraction method and environment for two varieties Sakha 3 and Giza 12 are listed in Table 5. Analysis of variance showed high significant difference in fiber yield rate between different treatments. Comparing means showed that T_{G4} treatment had the highest effect in fiber yield rate with values of 20.6 and 16.8 % for two varieties Sakha 3 and Giza 12 respectively; while T_{F1} treatment had the lowest effect with values of 17.8 and 13.4 % for two varieties respectively. Using pulse sprinkler technique magnify fiber yield rate comparing with traditional method. Fiber extraction under greenhouse improved fiber yield rate comparing with fiber extraction in open field; where the greenhouse provides saturated and regularly environment all the time. Adding the water by pulse technique helps the straw to absorb the moisture and distribute regularly, thus increasing number of pulses from one to four enhance fiber yield rate. At sprinkler retting; two pulses treatment produced fiber yield rate more than one pulse (continuous) as fallow: for Sakha 3 ($T_{F2} > T_{F1}$ = 2.2 % and $T_{G2} > T_{G1}$ = 3.3 %) and for Giza 12 ($T_{F2} > T_{F1}$ = 3.0 % and $T_{G2} > T_{G1}$ = 0.0 %). Two pulses treatment produced fiber yield rate more than one pulse (continuous) as fallow: for Sakha 3 ($T_{F2} > T_{F1}$ = 2.2 % and $T_{G2} > T_{G1}$ = 3.3 %) and for Giza 12 ($T_{F2} > T_{F1}$ = 3.0 % and $T_{G2} > T_{G1}$ = 0.0 %). Three pulses produced fiber yield rate more than two pulses as fallow: for Sakha 3 ($T_{F3} > T_{F2}$ = 3.3 % and $T_{G3} > T_{G2}$ = 5.9 %) and for Giza 12 ($T_{F3} > T_{F2}$ = 2.2 % and $T_{G3} > T_{G2}$ = 7.1 %). Four pulses produced fiber yield rate more than three pulses as fallow: for Sakha 3 ($T_{F4} > T_{F3}$ = 3.7 % and $T_{G4} > T_{G3}$ = 4.6 %) and for Giza 12 ($T_{F4} > T_{F3}$ = 6.4 % and $T_{G4} > T_{G3}$ = 12.0 %).

Table 5. Fiber yield rate (%) and compare means for two flax varieties under different fiber extraction methods and environments

Treatment		Fiber yield rate (%)	
		Sakha 3	Giza 12
1	T_{F1}	17.8 [i]	13.4 [d]
2	T_{F2}	18.2 [g]	13.8 [d]
3	T_{F3}	18.8 [e]	14.1 [cd]
4	T_{F4}	19.5 [d]	15.0 [bc]
5	T_{G1}	18.0 [h]	14.0 [cd]
6	T_{G2}	18.6 [f]	14.0 [cd]
7	T_{G3}	19.7 [c]	15.0 [bc]
8	T_{G4}	20.6 [a]	16.8 [a]
9	T_W	20.0 [b]	15.8 [ab]
$LSD_{0.05}$		*0.03*	*1.08*

The same letters indicated not significantly different at 0.05 level
Source: Own calculation.

These results may be due to that, increasing number of pulses gives a chance for straw to absorb the water more efficiently. Extraction the fibers under greenhouse increased fiber yield rate comparing with extraction in open field at different number of pulses from one to four as fallow: Sakha 3 (1.1, 2.2, 4.8 and 5.6) % and Giza 12 (4.5, 1.4, 6.4 and 12.0) %. Water/Submerged (T_W) retting produced fiber yield rate more than one pulse (continuous) as fallow: for Sakha 3 ($T_W > T_{F1}$ = 12.4 % and $T_W > T_{G1}$ = 11.1 %) and for Giza 12 ($T_W > T_{F1}$ = 17.9 % and $T_W > T_{G1}$ = 12.9 %). T_W increased fiber yield rate more than T_{F4} for two varieties Sakha 3 and Giza 12 by 2.6 and 5.3 % respectively, while T_W decreased fiber yield rate less than T_{G4} for two varieties by 2.9 and 6.0 % respectively.

Fiber length

The fiber length (cm) in relation to fiber extraction method and environment for two varieties Sakha 3 and Giza 12 are listed in Table 6. Analysis of variance showed significant difference in fiber length between different treatments. Comparing means showed that the highest effect in fiber length for variety Sakha 3 obtained by T_W and T_{G4} treatments with value of 90.0 cm and the highest effect in fiber length for variety Giza 12 obtained by T_{G4} treatment with value of 87.0 cm. The lowest effect in fiber length with value of 65.0 cm obtained by T_{F1} for variety Sakha 3 and obtained by T_{F1} and T_{F2} for variety Giza 12.

Table 6. Fiber length (cm) and compare means for two flax varieties under different fiber extraction methods and environments

Treatment		Fiber length (cm)	
		Sakha 3	Giza 12
1	T_{F1}	65.0 [e]	65.0 [d]
2	T_{F2}	80.0 [c]	65.0 [d]
3	T_{F3}	80.0 [c]	70.0 [c]
4	T_{F4}	85.0 [b]	80.0 [b]
5	T_{G1}	75.0 [d]	70.0 [c]
6	T_{G2}	75.0 [d]	80.0 [b]
7	T_{G3}	80.0 [c]	80.0 [b]
8	T_{G4}	90.0 [a]	87.0 [a]
9	T_W	90.0 [a]	80.0 [b]
$LSD_{0.05}$		*4.9*	*4.5*

The same letters indicated not significantly different at 0.05 level
Source: Own calculation.

The obtained results referred to that for two varieties fiber length were affected by fiber extraction method and environment. Under sprinkler retting, increasing pulses from one to four enhanced fiber length for different treatments. Fiber extraction under greenhouse improved fiber length comparing with the extraction in open field where the greenhouse provides a permanently saturated environment. The results explained that T_{F4} not enhanced fiber length comparing with T_W where for Sakha 3 the fiber length decreased by 5.6% and for Giza 12 fiber length not changed; these results are consistent with that obtained by previous research work [6]. T_{G4} produced the same fiber length obtained by T_W for Sakha 3 while achieved 8.8% increase for Giza 12.

Water productivity

Water productivity (kg/m^3) in relation to fiber extraction method and environment for two varieties Sakha 3 and Giza 12 are listed in Table 7. Analysis of variance showed high significant difference in water productivity between different treatments. Comparing means showed that T_{G4} treatment had the highest effect in water productivity with values of 27.5 and 21.2 kg/m^3 for two varieties Sakha 3 and Giza 12 respectively which increased by about 37.5 and 61.8% more than T_W treatment for two varieties; while T_{F1} treatment had the lowest effect with values of 18.2 and 11.9 kg/m^3 for two varieties respectively which decreased by about 9.0 and 9.2% less than T_W treatment for two varieties respectively. Application of pulse sprinkler technique improved water productivity comparing with traditional method; this is may be due to its effect on total applied water and fiber yield rate as mentioned above.

Table 7. Water productivity (kg/m^3) and compare means for two flax varieties under different fiber extraction methods and environments

Treatment		**Water productivity (kg/m^3)**	
		Sakha 3	Giza 12
1	T_{F1}	18.2 ^{h}	11.9 ^{f}
2	T_{F2}	19.3 ^{g}	13.7 ^{de}
3	T_{F3}	21.6 ^{d}	15.0 ^{c}
4	T_{F4}	23.6 ^{c}	17.4 ^{b}
5	T_{G1}	20.0 ^{f}	14.1 ^{d}
6	T_{G2}	21.3 ^{e}	15.0 ^{c}
7	T_{G3}	24.3 ^{b}	17.6 ^{b}
8	T_{G4}	27.5 ^{a}	21.2 ^{a}
9	T_W	20.0 ^{f}	13.1 ^{e}
LSD $_{0.05}$		*0.16*	*0.65*

The same letters indicated not significantly different at 0.05 level

Source: Own calculation.

Increasing number of pulses from one to four enhances water productivity as fallow: Sakha 3 ($T_{F2} > T_{F1}$ = 6.0%, $T_{F3} > T_{F2}$ = 11.9%, $T_{F4} > T_{F3}$ = 9.3%, $T_{G2} > T_{G1}$ = 6.5%, $T_{G3} > T_{G2}$ = 14.1% and $T_{G4} > T_{G3}$ = 13.2%) and Giza 12 ($T_{F2} > T_{F1}$ = 15.1%, $T_{F3} > T_{F2}$ = 9.5%, $T_{F4} > T_{F3}$ = 16.0%, $T_{G2} > T_{G1}$ = 6.4%, $T_{G3} > T_{G2}$ = 17.3% and $T_{G4} > T_{G3}$ = 20.0%). Extracting the fiber under greenhouse improved water productivity comparing with extracting in open field as fallow: Sakha 3 ($T_{G1} > T_{F1}$ = 9.9%, $T_{G2} > T_{F2}$ = 10.4%, $T_{G3} > T_{F3}$ = 12.5% and $T_{G4} > T_{F4}$ = 16.5%) and Giza 12 ($T_{G1} > T_{F1}$ = 18.5%, $T_{G2} > T_{F2}$ = 9.5%, $T_{G3} > T_{F3}$ = 17.3% and $T_{G4} > T_{F4}$ = 21.8%).

CONCLUSIONS

Flax fiber extraction using pulse sprinkler technique can be considering an alternative method to overcome the problems of traditional method. Application pulse sprinkler under greenhouse saved applied water and enhanced fiber yield rate and water productivity comparing with pulse sprinkler in open field. The best result was obtained by T_{G4} treatment. It achieved fiber yield rate 3.0 and 6.3% and water productivity 37.5 and 61.8% more than T_W treatment for two varieties Sakha 3 and Giza 12 respectively. Application sprinkler method not occupies area and needless labor like retting basin in traditional method.

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