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ABSTRACT

In order to stimulate the germination and enhancing growth parameters and yield components of flax, Seeds of three cultivars were exposed by a Helium-Neon laser power using HUAFEI system with 1Hz of repetition rate, 10 ns of the width of the pulse with three powers of intensity 40, 60, and 80 mW/m^2 set on laser beam for 2, 4 and 6cycles per minute as pre sowing seed priming technique. The field experiment was conducted during the winter season2018/ 2019. The cultivars showed variation in their response to the laser exposure when the Egyptian and Iraqi cultivars were the most responsive to laser application. Laser power 60 was more effective in improving growth and yield components compared to the other two powers. Laser cycling beam at 4cyclesper minute showed more consistency to utilize laser energy. The results conclusively support using laser exposure as an efficient, low-cost, and highly stable pre sowing seed priming technique.

Keywords: Laser techniques; *Linum usitatissimum* L.; physical pre-sowing treatment.

INTRODUCTION

Essential growth inputs in crop production are light, water, carbon dioxide and Nutrients. However, the availability of these components is useless without strong seedlings to invest in order to build a strong and healthy plant. Laser technology is one of the most promising ways to stimulate seeds and increase their efficiency in exploiting the available growth components. Murase [1] reported a developed laser application which promoted to expect some reduction of running cost in seed lighting requirements. The phenotypical, biochemical and proteome data show that the single-wavelength laser light is suitable for plant growth and therefore, potentially able to unlock the advantages of this next-generation lighting technology for highly energy efficient horticulture [2]. It can be concluded that the application of physical factors in appropriate doses can be an effective way to enhance many plant parameters that increase their productivity. The beneficial effects of seed stimulation are mainly related to the first stages of plant life, (i.e. – germination, emergence and growth of seedlings) [3].

Chen et al. [4] suggested that the Helium-Neon laser irradiation in *Isatis indogotica* seeds improved photosystem II (chlorophyll content, Hill reaction, chlorophyll fluorescence parameters, electron transport rate (ETR), and yield), the thylakoid (optical absorption ability, cyclic photophosphorylation, Mg2+-ATPase, and Ca2+-ATPase) and some enzymes in the dark reaction (phosphoenolpyruvate carboxylase (PEPC), carbonic anhydrase (CA), malic dehydrogenase (MDH), and chlorophyllase and the plants have lower expression of proteins diagnostic for light and radiation stress.

Metwally et al. [5] found that time of exposure possessed efficiency on morphological traits celosia results indicated that, plant height (cm), number of leaves per plant, stem diameter (mm), root length (cm), number of days from planting to flower (delaying the flowering), number of vascular bundles, dimension of bundles (length–wide) (μ) thickness of lamina (μ) and thickness of midvein (μ) recorded a significant increase by using 2 and 3 min. Danaila et al. [6] indicated that *Petunia* plants the most effective dose of radiation was found to be $0.88 J/cm^2$, corresponding to the suitable variant V1, because they have significant positive differences in terms of growth rate, number of formed shoots and number of leaves formed. Influence of laser radiation is therefore beneficial for all studied and determined characteristics. The maximum dose of $1.75\ J\ cm^{-2}$ selected in V3 does not increase the number of shoots and flowers, and also it does not affect the plant height.

Rassam et al. [7] mentioned that Helium-Neon and diode lasers enhanced the germination percentage of wheat cultivars after two days a maximum of 95% and 93% and found that the second harmonic generations neodymium-doped yttrium aluminum garnet (SHG Nd-YAG) laser Irradiation could be an alternative method to control seed infection by fungi of hard wheat seeds. Abu-Elsaoud [8] showed that the germination and growth of wheat grains were enhanced after seed pretreatment with double shots and oxidative stress were decreased and antioxidant activities enhanced at some irradiation doses as double-pulse He-Ne laser treatment of Egyptian common wheat cultivar. the combined treatment (with 7 min irradiation) induced obvious growth stimulation, leading to enhanced seedling growth rates, specifically, 71.8% for wheat, 54.5% for beans and 47.61% for corn, as compared to the control samples measured 72 h after planting [9]. According to this, the study aimed to evaluate the effect of laser power as seed priming treatments on growth parameters and yield components of the three flax cultivars.

MATERIALS AND METHODS

Cultivars Seeds Laser Irradiation

Three cultivars of the flaxseeds; Iraqi, Syrian, and Egyptian cultivars were exposed to Q-switched neodymium-doped yttrium aluminum garnet; $Nd{:}Y_3Al_5O_{12}$ (Nd-YAG) laser using Huafei system equipment. Briefly, this technology which is a double wavelength laser treatment system adopts laser nd: yag and q-switch laser as well as laser multi-frequency technology. Using instant light resulted in exploding principle to make laser set free in a short time (about 10 ns) then producing the ipl with light density with 1 Hz of repetition rate, 10 ns of the width of pulse and (4, 6, and 8) mW/m^2 of intensity. One layer of seed samples (50 seeds) were put in a rotating stage with 2 rad/min of speed. Each sample was exposed to a laser beam for 2, 4 and 6cycles. Fig. (1) show the setup of the experimental exposure system.

Field Trial

Field experiment was performed in the research field of the College of Agriculture – University Of Anbar – Iraq33°25′11″N 43°18′45″Eduring the winter season 2018/ 2019. The experiment was done by RCBD design with three replications to evaluate seed priming application by laser power and cycles on three cultivars of Flax *Linum usitatissimum* which were; Egyptian, Iraqi and Syrian cultivars. Flax seeds were planted in rows as 15 cm between rows and 25cm between plant and each other.

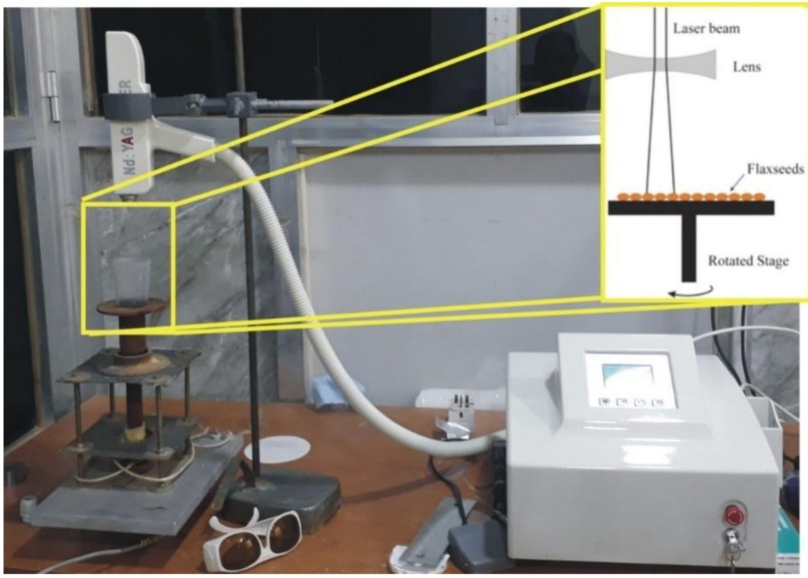

Fig. 1. Illustration the setup of experimental exposure setup system

Crop management including watering and fertilizing were done as recommended [10]. When flax plants reached the mature stage, traits of root length, Plant height, Branch per plant, Silique per plant, Seeds per silique, 10^{-3} Seed weight, Seed yield per m^2 and Seed yield per hectare was measured. Statistical analysis was performed using Student's *t*-test with Microsoft Excel 2010. Significance was set to a threshold of $P < 0.05$ and *n* values represent the number of biological replicates.

RESULTS

Root Length

Table (1) stated that cultivars, laser power and its cycle and their interaction possessed significant differences on root length of flax. Syrian cv. possessed the longest root of8.26cm followed by Iraqi cv. of 8.04cm while Egyptian cv had reduced length of the root which accounted for 6.75 cm. laser power of P40 had the longest root of 8.19cm, followed by P60 of 7.78 cm. While P80 reduced root length by 7.11 cm. Laser cycles also were different in terms of affecting root length. Using laser in 4cycles gave the highest root length of 8.37cm, followed by 6cycles of 7.93cm. Moreover, binary interaction of Iraqi cv. x P40extended longest root of 9.11 cm, followed by Syrian one xP60 of 8.78 cm. while Egyptian cv. xP60 extended the longest root of 6.67 cm.

For the interaction of cultivars with laser cycles, there wasn't significant. However Syrian cv. x 4 cycles had the lowest one of 5.78 cm. interaction of P40 x 4cycles lengthened root of 9.33 cm, followed by P60 x6 cycles of 9.22 cm, while P60 x 2cycles shorted root length of 6.00 cm.

Plant Height (cm)

Table (2) pointed that cultivars, laser power, laser cycles and their interaction resulted in a significant difference of plant height of flax cultivars where, Syrian cultivar (local) possessed the highest continuities plant height of 84.85 cm, followed by Iraqi on 82.00 cm and last one the Egyptian (Balady) of 77.96 cm. The laser power of P60 caused the tallest plants of 87.78 cm, followed by P80 at 81.41 cm, after that P40 which accounted for 78.63 cm. Laser cycles hadn't significant differences.

However, 6 cycles per minute gave the tallest plants of 81.74 cm. The interaction of Iraqi cv. x P60 significantly increased plant height to 92.56 cm, followed by Syrian cv. x P60 of 89.67 cm while Egyptian cv. x P40 minimized plant height of 68.89 cm. The binary interaction of Syrian cv. x

4 cycles maximized plant height of 84.44 cm, followed by Iraq cv. x 6 cycles of 89.33 cm. Whereas Iraqi cv x 4 cycles lowered plant height of 73.56 cm. The interaction of laser power P60 x laser cycles (2cycle) maximized plant height of 92.00 cm, followed by P60 x 6cycles of 87.44 cm, while P40 x 2cycles reduced plant height by 73.89 cm. Furthermore, Iraqi cv x P60 x 6cycles and Syrian cv x P60 x 2 cycles Significant augmented plant height at 101.67 cm, for each one. Whereas, Egyptian cv x P40 x 2 cycles reduced plant height of 63.33 cm.

Table 1. Effect of laser application (power and cycles) on root length (cm) of the three flax cultivars

Laser Power	Cycles	Cultivars			Power ×Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	7.33	7.67	7.33	7.44
	Cy4	7.33	11.33	9.33	9.33
	Cy6	5.67	8.33	9.33	7.78
P60	Cy2	2.67	8.00	7.33	6.00
	Cy4	7.67	7.33	9.33	8.11
	Cy6	9.67	8.33	9.67	9.11
P80	Cy2	7.33	7.33	6.00	6.89
	Cy4	6.67	7.00	9.33	7.67
	Cy6	6.67	7.00	6.67	6.78
	L. S. D % 5		1.52		0.51
Cycles					**Cycles average**
×	Cy2	5.78	7.67	6.89	6.78
Cultivars	Cy4	7.22	8.56	9.33	8.37
	Cy6	7.33	7.89	8.56	7.93
	L.S.D % 5		n.s.		0.51
Power					**Power average**
×	P40	6.78	9.11	8.67	8.19
Cultivars	P60	6.67	7.89	8.78	7.78
	P80	6.89	7.11	7.33	7.11
	L.S.D % 5		0.88		0.51
	Cultivars average	6.78	8.04	8.26	

Table 2. Effect of laser application (power and cycles) on plant height (cm) of the three flax cultivars

Laser Power	Cycles	Cultivars			Power ×Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	63.33	78.33	80.00	73.89
	Cy4	78.33	70.67	81.67	76.89
	Cy6	65.00	81.67	81.67	76.11
P60	Cy2	78.33	96.00	101.67	92.00
	Cy4	80.00	80.00	91.67	83.89
	Cy6	85.00	101.67	75.67	87.44
P80	Cy2	88.33	75.00	74.33	79.22
	Cy4	85.00	70.00	95.00	83.33
	Cy6	78.00	84.67	82.00	81.67
	L. S. D % 5		8.24		N.S
Cycles					**Cycles average**
×	Cy2	76.67	83.11	85.33	81.70
Cultivars	Cy4	81.11	73.56	89.44	81.37
	Cy6	76.11	89.33	79.78	81.74
	L.S.D % 5		4.76		N.S
Power					**Power average**
×	P40	68.89	76.89	81.11	75.63
Cultivars	P60	81.11	92.56	89.67	87.78
	P80	83.89	76.56	83.78	81.41
	L.S.D % 5		4.76		2.75
	Cultivars average	77.96	82.00	84.85	

Branch per Plant

Table (3) showed the average trendy of flax affected by cultivar, power, cycle and their interactions. Where its extracted from the table that cultivar, didn't differ significantly from each other. However Iraqi cv. high of gave numbers of branches of 1.85 branch plant followed by Syrian one of 1.70 branches. Whereas Egyptian cv. possessed the lowest branches per plant of 1.63 branches per plant.

Laser power P60 and P80 significantly achieved the highest branches per plant of1.85 and 1.82 branches per plant. P40 gave the lowest branches of 1.52 branches per plant. The cycles haven't significant difference branches per plant but 6cycles possessed the highest branches of 1.78 branches plant, 4cycles had lowest one of 1.63 branches plant. Binary interaction between cultivars and laser power possessed significant differences on branches where Iraqi xP80 gave the highest branches of branches plant. Binary interaction of cultivar x cycles possessed the highest significant differences on branches when Iraqi x 2cycles achieved branches of 2.67 branches plant. Binary interaction of laser power x explosion cycle caused the significant difference. Thus, P60 x 6cycles produced the highest branches of 2.22 branches plant. Tertiary interaction wasn't significant.

Silique per Plant

Table (4) referred that cultivars, laser power, cycles and their interactions significantly affected siliques per flax plant. Syrian cv. possessed the highest siliques per plant of 17.11 silique plant, followed Iraqi cv. at 15.96 silique plant. While the Egyptian one had the lowest number of 14.59 silique plant. The laser power of P80 achieved the largest siliques per plant of 17.56 silique plant, followed by P60 of 16.04 andP40 of 14.07 silique plant. Laser cycles at 6 cycles per minute gave the highest siliques per plant of 16.56 silique plant, followed by 2 cycles per minute of 16.04, while 4cycles lowered siliques per plant of 15.07 siliques plant. Furthermore, the interaction of Iraqi cv x P80 produced the largest silique per plant of 19.11 siliques plant. Egyptian cv. x P40 gave the lowest number at 11.44 siliques plant. The interaction at Syrian cv. x 2cycles possessed the biggest number at 18.44 siliques plant while Egyptian cv.x2cycles had the lowest number at 12.89 siliques plant. The interaction at laser P80 x laser 2cycles caused significant silique, per plant at 19.78 siliques plant. Tertiary interaction significantly increased siliques per plant. Thus, Iraqi x P80 x 6cycles and Egyptian x P80 x 2 cycles achieved the highest siliques per plant at 22.67 siliques plant, while Egyptian cv. x P40 x 2 cycles had the lowest number of siliques per plant of 8.00 siliques per plant.

Seeds per Silique

Table (5) showed that cultivars, laser power, cycles and its interaction hadn't significant increase on seeds per Silique. However Egyptian cv. numerically possessed seeds per Silique of 8.05, followed by Iraqi cv. of 7.35 seed Silique. Syrian one gave the lowest number at 7.71 seeds Silique. P40 and P60 non-significant produced in terms of seeds Silique which accounted for 7.89 for each one while P80 reduced seed per Silique at 7.33 seeds Silique. Laser cycles also gave non-significant seeds per silique. So,6 cycles per minute numerically gave the highest seeds per silique at 8.05 seeds silique and 4 cycles gave the lowest seeds number at 7.31seeds silique.

All binary interactions had a non-significant increase in the number of seeds however, Egyptian cv. x P60, Egyptian cv. x 2cycles and P60 x 6cycles numerically increased seeds per Silique of 8.41, 8.38 and 8.19 seeds Silique respectively. Furthermore, tertiary interaction of Egyptian cv. x P60 x 2 cycles and Iraqi cv. x P80 x6 cycles statistically gave the highest number of seeds at 8.80 seeds Silique for each one, while Syrian cv. x P80 x 4cycles set lowest seeds of 7.10 seeds Silique.

Seed Weight (10^{-3})

Table (6) referred that cycle time and cultivars possessed significant effect while the laser power wasn't showed any significance on 10 seed weight. Egyptian cv. possessed highly 10 seed weight reached to 7.8 g followed by Iraqi cv. of 6.89 g and Syrian cv. gave least 10 seed weight at 6.62 g. Four cycles per minute gave the highest seed weight accounted for 8.55 g, followed by 6 cycles of 6.68 g and 2cycleswhich comes as the lowest one of 6.09 g.

Table 3. Effect of laser application (power and cycles) on plant per branch of the three flax cultivars

Laser Power	Cycles	Cultivars			Power ×Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	1.33	3.00	1.67	2.00
	Cy4	2.67	1.00	1.00	1.56
	Cy6	1.00	1.00	1.00	1.00
P60	Cy2	1.33	2.33	1.00	1.56
	Cy4	2.67	1.33	1.33	1.78
	Cy6	2.00	1.33	3.33	222
P80	Cy2	1.33	2.67	1.33	1.78
	Cy4	1.33	1.33	2.00	1.56
	Cy6	1.00	2.67	2.67	2.11
	L. S. D 5%		n.s.		0.48
Cycles					**Cycles average**
×	Cy2	1.33	2.67	1.33	1.78
Cultivars	Cy4	2.22	1.22	1.44	1.63
	Cy6	1.33	1.67	2.33	1.78
	L.S.D % 5		0.48		n.s.
Power					**Power average**
×	P40	1.67	1.67	1.22	1.52
Cultivars	P60	2.00	1.67	1.89	1.85
	P80	1.22	2.22	2.00	1.82
	L.S.D % 5		0.48		0.28
	Cultivars average	1.63	1.85	1.70	n.s.

Table 4. Effect of laser application (power and cycles) on Silique per plant of the three flax cultivars

Laser Power	Cycles	Cultivars			Power ×Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	8.00	15.00	22.00	15.00
	Cy4	12.67	12.33	14.67	13.22
	Cy6	13.67	13.67	14.67	14.00
P60	Cy2	16.00	10.67	13.33	13.33
	Cy4	14.33	22.00	14.33	16.89
	Cy6	22.33	12.67	18.67	17.89
P80	Cy2	22.67	16.67	20.00	19.78
	Cy4	11.67	18.00	15.67	15.11
	Cy6	10.00	22.67	20.67	17.78
	L. S. D %		1.41		0.81
Cycles					**Cycles average**
×	Cy2	15.56	14.11	18.44	16.04
Cultivars	Cy4	12.89	17.44	14.89	15.07
	Cy6	15.33	16.33	18.00	16.56
	L.S.D % 5		0.81		0.47
Power					**Power average**
×	P40	11.44	13.67	17.11	14.07
Cultivars	P60	17.56	15.11	15.44	16.04
	P80	14.78	19.11	18.78	17.56
	L.S.D % 5		0.81		0.47
	Cultivars average	77.96	82.00	84.85	

Furthermore, binary interaction significantly differed where Egyptian cv. x P60 possessed the highest seed weight of 9.06 g while Syrian cv. x P60 gave the lowest 10 seed weight of 6.07 g. Egyptian cv. x 4 cycles gave biggest seed weight of 9.95 g where Syrian cv. x 2cycles had the lowest seed weight of 4.69 g. Laser P60 x 4cycles achieved the highest seed weight of 9.42 g the lowest seed weight occurred as seeds of flax were treated by P80 x 2 cycles binary combination of interaction while gave 5.70 g. Moreover, the tertiary interaction was significantly increased seed weight where the Egyptian cv. x P60 x 6 cycles which possessed maximum seed weight of 13.28 g, while combination of Syrian cv. x P80 x 2 cycles had the lowest thousand seed weight of 4.17 g.

Table 5. Effect of laser application (power and cycles) on Silique per plant of the three flax cultivars

Laser Power	Cycles	Cultivars			Power × Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	8.67	6.93	7.87	7.82
	Cy4	7.77	7.67	8.27	7.90
	Cy6	8.00	7.80	8.00	7.93
P60	Cy2	8.80	7.47	7.67	7.98
	Cy4	7.73	7.47	7.33	7.51
	Cy6	8.70	7.90	7.97	8.19
P80	Cy2	7.67	7.13	7.53	7.44
	Cy4	7.50	5.00	7.10	6.53
	Cy6	7.60	8.80	7.67	8.02
	L. S. D % 5		n.s.		n.s.
Cycles					**Cycles average**
×	Cy2	8.38	7.18	7.69	7.75
Cultivars	Cy4	7.67	6.71	7.57	7.31
	Cy6	8.10	8.17	7.88	8.05
	L.S.D % 5		n.s.		n.s.
Power					**Power average**
×	P40	8.14	7.47	8.04	7.89
Cultivars	P60	8.41	7.61	7.66	7.89
	P80	7.59	6.98	7.43	7.33
	L.S.D % 5		n.s.		n.s.
	Cultivars average	77.96	82.00	84.85	

Table 6. Effect of laser application (power and cycles) on 10^{-3}Seed weight of the three flax cultivars

Laser Power	Cycles	Cultivars			Power × Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	5.58	6.09	5.47	5.72
	Cy4	7.82	7.61	8.73	8.05
	Cy6	5.97	6.97	8.73	7.23
P60	Cy2	6.65	9.46	4.42	6.84
	Cy4	13.28	8.12	6.87	9.42
	Cy6	7.26	4.21	6.91	6.13
P80	Cy2	5.40	7.53	4.17	5.70
	Cy4	8.77	6.53	9.19	8.16
	Cy6	9.48	5.49	5.11	6.69
	L. S. D % 5		0.15		0.09
Cycles					**Cycles average**
×	Cy2	5.88	7.69	4.69	6.09
Cultivars	Cy4	9.95	7.42	8.26	8.55
	Cy6	7.57	5.56	6.92	6.68
	L.S.D % 5		0.09		n.s.
Power					**Power average**
×	P40	6.46	6.89	7.64	7.00
Cultivars	P60	9.06	7.26	6.07	7.46
	P80	7.88	6.52	6.16	6.85
	L.S.D % 5		0.09		n.s.
	Cultivars average	7.80	6.89	6.62	0.05

Seed Yield per Square Meter

Table (7) revealed that cultivars, leaser power, cycles and their interaction possessed significant difference in seed yield per m^2. Egyptian cv. comes with the highest seed yield perm^2 125.01g followed by Iraqi then Syrian cv. 114.23 and 104.47 g respectively. Laser P60 has achieved the highest seed which accounted for 132.79 g while P40 came with the lowest value when accounted for 72.82 g. Laser cycling also contributed in seed per m^2 and 4 cycles showed the best value accounted for 126.36 followed by 2cycles and 6cycles and 111.36 and 105.99 seed per m^2 respectively.

Table 7. Effect of laser application (power and cycles) on Seed yield (g.m2) of the three flax cultivars

Laser Power	Cycles	Cultivars			Power × Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	96.97	90.72	67.86	85.18
	Cy4	116.14	112.36	64.65	97.72
	Cy6	85.42	175.12	85.93	115.49
P60	Cy2	108.15	105.16	180.99	131.43
	Cy4	231.06	148.06	107.97	162.36
	Cy6	145.47	108.06	109.41	120.98
P80	Cy2	89.37	166.96	96.08	117.47
	Cy4	154.06	50.73	152.23	119.00
	Cy6	98.48	50.95	75.11	81.51
	L. S. D % 5		1.85		1.07
Cycles					**Cycles average**
×	Cy2	98.16	120.95	114.98	111.36
Cultivars	Cy4	167.09	103.71	108.28	126.36
	Cy6	109.79	118.04	90.15	105.99
	L.S.D % 5		1.07		0.62
Power					**Power average**
×	P40	72.82	99.51	126.07	72.82
Cultivars	P60	132.79	161.56	120.42	132.79
		107.80	113.97	96.21	107.80
	L.S.D % 5		1.07		0.62
	Cultivars average	125.01	114.23	104.47	0.62

The binary interaction significantly maximized seed yield whereas Iraqi cv. x P60 possessed the biggest seed yield of 161.56 g, while Syrian cv. x P80 reduced seed yield of 96.21 g. Egyptian cv. x 4cycles also achieved the highest yield of seed of 167.09g, where Syrian cv. xP80 gave the lowest seed yield of 90.15 g. Additionally, P60 x 4cycles augmented seed yield of 162.36 g while P80 x 6cycles had less seed yield of 81.51 g. Tertiary interaction combination also significantly increased seed yield, so Egyptian cv. x P60 x 4 cycles achieved the maximum am seed yield of 231.06 g followed by Iraqi cv. x P40 x 6 cycles of 175.12 g. Whereas Iraqi cv x p80 x4cycles gave the minimum seed yield of 50.73 g only.

Seed Yield per Hectare

It extracted from (Table 8) that cultivars energetic power at laser cycles exposure in yield per hectare and their interactions were significantly different. Egyptian cv. was dominant in comparison with the other two cultivars when achieved 1251.9 $kg.ha^{1}$ followed by Iraqi cv. 1143.6 then Syrian cv. 1073.1kg. ha^{-1}. Seed yield per hectare was differed significantly by Laser power when P60outperformed to the other powers with an average of 1408.50 kg. ha^{-1}. Setting laser beam cycle in various cycles per minute also contributed to increasing seed yield and 4cycles was the best with seed yield reached to1292.20 $kg.h^{-1}$.

Furthermore, binary interaction combinations maximized seed yield per hectare. Egyptian cv. at P60 achieved the maximum seed yield of 1615.06 $kg.h^{-1}$ while Syrian cv. x P40 gave the lowest seed yield at 729.80 $kg.h^{-1}$. Egyptian cv. x 4 cycles had the biggest seed yield of 1672.8 $kg.h^{-1}$and the lowest seed yield per hectare occurred in the combination of Syrian cv. x 6cycles of 903.3 $kg.h^{-1}$. Laser P60 x4cycles resulted in the highest seed yield of 1704.8 $kg.h^{-1}$while P80x 6 cycles minimized seed yield to 818.30 $kg.h^{-1}$. Trinary Combination Egyptian cv. x P60 x 4cycles achieved the highest seed yield per hectare of 2310.6. Whereas Syrian cv x P40 x 4cycles minimized seed yield of 644.9 $kg.h^{-1}$.

Table 8. Effect of laser application (power and cycles) on yield ($kg.h^{-1}$) of the three flax cultivars

Laser Power	Cycles	Cultivars			Power × Cycles
		Egypt	Iraqi	Syrian	
P40	Cy2	974.50	907.20	681.90	854.60
	Cy4	1167.10	1123.50	644.90	978.50
	Cy6	854.20	1751.2	862.70	1156.0
P60	Cy2	1081.40	1051.50	1803.20	1312.10
	Cy4	2310.60	1480.60	1323.40	1704.80
	Cy6	1454.70	1080.60	1090.80	1208.70
P80	Cy2	899.00	1674.60	965.50	1179.70
	Cy4	1540.60	509.90	1528.90	1193.20
	Cy6	984.70	713.50	756.60	818.30
	L. S. D % 5		130.85		75.55
Cycles					**Cycles average**
×	Cy2	985.00	1211.10	1150.20	1115.40
Cultivars	Cy4	1672.80	1038.00	1165.70	1292.20
	Cy6	1097.90	1181.80	903.30	1061.00
	L.S.D % 5		75.55		43.62
Power					**Power average**
×	P40	998.60	1260.60	729.80	996.40
Cultivars	P60	1615.60	1204.20	1405.80	1408.50
	P80	1141.40	966.00	1083.70	1063.70
	L.S.D % 5		75.55		43.62
	Cultivars average	1251.90	1143.60	1073.10	

DISCUSSION

Agro physically, laser induction has occurred via the ability of seeds to absorb and store light energy, to transform it into energy stored in chemical compounds, and to use it subsequently in seed germination and then in plant growth and development [11]. Although the mechanisms of laser stimulation have not been understood entirely, it is found that laser stimulation of plants increases their bioenergetic potential, leading to higher activation at phytochrome, phytohormone and fermentative systems, as stimulation of their biochemical and physiological processes [12,13]. Laser radiation is absorbed into biological tissues and, in accordance with the Einstein-Stark law of photochemical equivalence, for every photon absorbed, a particle, such as an atom, molecule or free radical, is activated by a photochemical reaction. It is a primary cellular reaction, which is followed by a secondary systemic one [14] Mosneaga et al., 2008). The results of the present study indicated that the He-Ne laser generates increases in various germination and growth parameters of the studied flax cultivars in addition to several biochemical and physiological parameters. The impact of laser light is considered as a photobiological phenomenon [15]. The results of the current study demonstrated clearly that not only the parameters of germination seeds were increased greatly, but also the growth and metabolism and development of flax plants were significantly accelerated in response to laser irradiation. The role of laser irradiation is classified as a long-term effect. The present understanding and available literature in the field of plant laser irradiation allowed postulating on potential mechanisms underlying this effect [4]. Helium-neon laser radiation has a wavelength of 632.8 nm that is close to phytochrome red (Pr) absorbing wavelength, facilitating the activation of phytochrome most likely. In turn, enzyme activities modulated by phytochrome maybe consequently augmented and result in accelerating phytochrome-mediated responses accelerating (e.g. the decomposition rate of lower entropy macromolecules). Accordingly, the entropy and internal energy of seeds were enhanced during the germination process [4].

CONCLUSION

Flax seed priming was improved by laser exposure. It seems that the Egyptian and Iraqi cultivars were the most responsive genotypes to laser application in comparison with the Syrian cultivar. Results also showed that among the laser powers studied, Power 60 had a very positive and significant correlation within most of the growth traits and yield components. To improve seed priming of flaxseed, seed should be exposed under the laser cycling beam at 4cycles per minute which showed more consistency to use laser energy. The proposed utilize of laser power extremely simple, low-cost, and highly stable pre sowing seed priming technique.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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