Research Article

Evaluation of Irrigation Frequencies and Seed Priming with Plant Nutrients on Growth and Yield of Sunflower (*Helianthus annuus* L.) Genotypes

Muhammad Nawaz Kandhro[1]*, Zulfiqar Ali Abbasi[1], Aijaz Ahmed Soomro[1], Naimatullah Leghari[2], Muhammad Ibrahim Keerio[3], Ahmed Naqi Shah[1], Ghulam Murtaza Jamro[4], Nadia Mangrio[1] and Shazia Parveen Tunio[5]

[1]Department of Agronomy; [2]Department of Farm Power and Machinery; [3]Department of Crop Physiology; [4]Department of Soil Science, Sindh Agriculture University, Tandojam, Pakistan; [5]Water and Agriculture Waste Management Institute, PARC, Tandojam

Abstract | The role of proper irrigation frequency is very essential to obtain optimum yield potentials. Seed priming by water and different nutrients enhances the germination, establishment of seedling, growth and ultimately yield of crop. The experiment was conducted at Students' Experimental Farm, Sindh Agriculture University, Tandojam during autumn 2017 and 2018 for two consecutive years. Split plot design was used and the treatments were replicated thrice. The experimental units were consisted of three factors: irrigation frequencies (two, three, four and five); seed priming (no priming, Priming of seed with canal water, 1.0% Urea and 0.2% Zinc sulphate); and two genotypes of sunflower (HO-1) and (Hysun-33). The analysis of data indicated that irrigation frequencies, seed priming and their interaction affected significantly ($P \leq 0.05$) on growth and yields of traits of sunflower genotypes. In case of irrigation frequencies, enhanced seed yield (2256 kg ha^{-1}) was recorded in five irrigations followed by four irrigations having non-significant differences with each other. Genotype, HO-1 was found superior over Hysun-33 by producing greatest seed yield (1894 kg ha^{-1}). The seed priming with 0.2% $ZnSO_4$ resulted in highest (2010 kg ha^{-1}) seed yield seconded by seed priming with 1.0% Urea (1966 kg ha^{-1}) The interaction of seed priming with 0.2% $ZnSO_4$ × five irrigations gave highest seed yield (2459 kg ha^{-1}) followed by the interaction of seed priming with 0.2% $ZnSO_4$ × four irrigations (2453 kg ha^{-1}) Hence, findings of this study suggested that optimum growth and yield of sunflower could be obtained by applying four irrigations and priming seeds with 0.2% $ZnSO_4$ preferring genotype HO-1 under agro-climatic conditions of Tandojam, Pakistan.

Received | June 19, 2020; **Accepted** | November 17, 2020; **Published** | February 08, 2021
***Correspondence** | Muhammad Nawaz Kandhro, Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan; **Email:** kandhromn@gmail.com
Citation | Kandhro, M.N., Z.A. Abbasi, A.A. Soomro, N. Leghari, M.I. Keerio, A.N. Shah and G.M. Jamro, N. Mangrio and S.P. Tunio. 2021. Evaluation of irrigation frequencies and seed priming with plant nutrients on growth and yield of sunflower (*Helianthus annuus* L.) genotypes. *Pakistan Journal of Agricultural Research,* 34(1): 58-69.
DOI | http://dx.doi.org/10.17582/journal.pjar/2021/34.1.58.69
Keywords | Irrigation frequencies, Seed priming, Sunflower, Genotypes, Growth, Yield

Introduction

Sunflower (*Helianthus annuus* L.) is an essential oilseed crop of world as well as considered ideal crop under agro-climatic conditions and cropping system of Pakistan (Hassan and Kaleem, 2014). It has been identified as world's most significant and commonly cultivated oil crop (Wills and Burke, 2006). Sunflower is the member of Asteraceae family having seven chromosomes. The artists inspired by its sun-like inflorescence (Badouin *et al*., 2017). In the 19th century's first half sunflower was recognized in

Russia as a major oil crop (Mangin *et al*., 2017). At the global level, it is known as the fourth vegetable oil source after rapeseed, palm and soybean. It comes second after rapeseed in Europe and after cottonseed in Pakistan (Siddiqui and Oad, 2015). During 2018 world's area under cultivation for sunflower was 26 million hectares, with its total production of 45 million metric tons (FAO, 2018). Edible oil has been reported as one of the considerable supplies of daily usage (Amjad, 2014). The country is facing acute deficiency in edible oil production. Pakistan imports 88% oil for edible purposes, whereas at the country level only 12% is being produced. The import expenses for edible oil during 2016-17 were Rs 320.893 billion (GoP, 2018). Pakistan ranks 3rd largest country in the world in importing edible oil (Soomro, 2015). It is an important oilseed crop however its lowest yield is one of the main constraints in Pakistan (Sheidaie *et al*., 2013). Sunflower with its low cholesterol is a significant source of edible oil all over the world. It is highly rich in oil 47%. Oil of sunflower is like oil of olive. Its oil is valuable for purpose of cooking, with rich in linoleic acid and essential fatty acid. Oil of sunflower is famous as production of artificial butter due to its color keeping quality (Iqtidar and Jan, 2010). Sunflower oil consumption reduces cholesterol level in the blood, which is responsible for the incidence of coronary heart disease (Ka1aiyarasan and Vaiyapuri, 2007). The oil of sunflower is moderately pleasant, and it covers A, D, E and K vitamin. Oil of this crop is most important due to lack of cholesterol and high content of unsaturated fatty acids, the benefits of oil are well known for human health. The sunflower seeds are very important confectionery source (Buriro *et al*., 2015). Its seed meal is rich with protein, which is used for livestock feed, Seed of sunflower are also source of nutritional feed for poultry (Khalil and Jan, 2010). The dried stems of sunflower are used in houses for fuel purpose. Fiber from the stem be used for making paper, purple black dye is obtained from the seed and yellow dye is obtained from the flowers (Tengong *et al*., 2010).

The priming of seeds is one of the important processes in which germination percentage and uniformity of seedling in various crops could be enhanced (Halmer, 2003). In this process, seeds under controlled conditions are kept in limited water in which some germination processes can occur. After that, seeds are dried for short time before sowing (Kouchebagh *et al*., 2014). The process involves advancing the seed to an equal stage of the germination process, to enable fast and uniform emergence when planted (Dawa1 *et al*., 2017). Farming community can easily adopt many methods of seed priming for alleviating different stress levels. At the same time, they can produce quality seeds and use them further for the next crop cycle without costs of seed purchase (Chatterjee *et al*., 2018). The seed priming caused seed vigour improvement in sunflower. The priming of seeds has been found to improve plant growth (Moeinzadeh *et al*., 2010). Priming with $ZnSO_4$ can improve emergence of crop, seedling establishment and metabolism of seed (Farooq *et al*., 2012).

Increasing water use efficiency is one of the most important ways to increase crop production, save water and protect the environment (Lina and Gautam, 2015). The productivity of sunflower is strongly regulated by water availability (Kazemeini *et al*., 2009). It is the needs of the hour to adopt available managing techniques and skills for increasing irrigation efficiencies (Khan, 2005). In order to produce more crops with less water requirement, strategies need to be considered of water management practices. Studies have confirmed that yield decrease substantially when plant at vegetative growth was not properly irrigated. The proper management of irrigation could lead to enhanced production and better irrigation water efficiency (Eman *et al*., 2015). Bakht *et al*. (2010) disclosed that the maximum yield of sunflower was gained from four irrigations in comparison with other irrigation frequencies. The hybrids, SF-187 produced more yields than the Parsun-1 hybrid. Sunflower head diameter increased when crop was irrigated at large quantity (Flagella *et al*., 2002). In the light of above mentioned facts, the present study was designed to evaluation the effect of irrigation frequencies and seed priming on growth and yield of sunflower.

Materials and Methods

Experimental details and soil selection

An experiment was arranged at Students' Experimental Farm of Sindh Agriculture University, Tandojam, Pakistan during autumn 2017 and 2018. The area of experimental soil was clay loam, which conferring to USDA classification belongs to Order *Aridisols* and Sub-group *Typic camborthids*. Experimental unit size was 6 m x 5 m (30 m^2). Soil was plowed thoroughly and properly leveled. The seedbed was prepared three times by cultivating with a tractormounted cultivator. The NPK fertilizers were applied before sowing with amount of 100-50-50 kg ha^{-1}. The fertilizers were used in form of Urea, SSP and SOP. Phosphate and potash fertilizers were applied at the time of land preparation. Urea was supplemented in three schedules; first at the time of sowing, second at the time of 1^{st} irrigation and third at the time of flowering. Split plot arrangements were used for four irrigation frequencies (Two, Three, Four and Five), Seed priming four (control, canal water, 1.0% Urea and 0.2% Zinc sulphate) and two genotypes of sunflower **(**HO-1, Hysun-33). Irrigation frequencies were assigned to main-plot while sub-plot was fixed to genotypes and seed priming sources were allocated to sub-sub-plot. There were three replications. The canal water or nutrients solution for priming of seeds was done in a container of plastic at field for three hours after that seeds were immediately sown on the field on same day. For 1.0% Urea solution making, 1 kg fertilizer of Urea was dissolved in 100 liters of water while preparing concentration of 0.2% zinc, were dissolved 200 g of $ZnSO_4$ in 100 liters of water. The experiment of 1^{st} year, was done on August 05, 2017 while August 07, 2018. For 2^{nd} year on same day sowing was done of primed seed through single coulter hand drill. After 15 days of sowing maintain proper plant to plant distance thinning of plants was done. Inter culturing was done to make porous soil for strong roots of crop plant, control over weeds and pests before irrigation first. Whereas, second and third inter culturing were done before 2^{nd} and 3^{rd} irrigation, correspondingly. Irrigation in all plots was applied as per treatments. Different practices of cultural performed regular were throughout the experiment.

The area of the experimental soil was analyzed before sowing and after harvesting (Table 1). Soil samples at a depth of 0-20 cm were taken from five locations of the total experimental area before planting of the crop with the help of soil auger. The samples of soil were air-dried, ground, sieved (2.5 mm) and placed in containers of plastic. The samples were investigated for various physical and chemical properties by the procedures of Rayan *et al.* (2001). Soil texture was measured by Bouyoucos hydrometer method. Electrical conductivity (EC) and soil pH was measured in 1:2 soil water extract using EC and pH meters, correspondingly. The determination of organic matter content was followed by Walkley Black method. Total N was determined by Kjedahl method (Rowell, 1994). However, soil was extracted for determining extractable P and K using (AB-DTPA) Ammonium bicarbonate di-ethylene triamine penta acetic acid.

Table 1: *Average of physico-chemical properties of experimental soil for the year 2017 and 2018.*

Parameters	Values
Soil texture analysis	
Sand %	19
Silt %	43
Clay %	38
Textural class	Silty clay loam
Soil chemical analysis	
EC (dSm^{-1})	2.36
Soil pH	8.70
Organic matter (%)	0.49
Total N %	0.02
Extractable P (mg kg^{-1})	1.30
Extractable K (mg kg^{-1})	209

Observations recorded

Data on seed germination m^{-2} was noted by counting the emerged seedlings after 10 days of sowing through per square meter iron frame. Leaf area index (%) was measured at peak vegetative growth from randomly selected five plants by using the formula: Area of leaf $plant^{-1}$ (cm^2) ÷ Area of ground $plant^{-1}$ (cm^2). Plant height (cm) was measured in centimeter through measuring tape from ground to main stem terminal end of plant. The data regarding diameter of head was noticed from five tagged plants with measuring tape at maturity. Weight of seeds $head^{-1}$ (g) was determined from five tagged plants by weighing seeds on digital balance. Seed yield (kg ha^{-1}) was recorded by: Seed yields $plot^{-1}$ (kg) × 10000 m^2 ÷ Net plot area (m^2). However, harvest index (%) was calculated as: Seed yield (kg ha^{-1}) ÷ Biological yield (kg ha^{-1}) × 100.

Statistical analysis

The collected data was subjected to ANOVA technique using Statistix version 8.1 software (Statistix, 2006). The least significant difference test (LSD) was used at alpha 0.05 for comparing differences of treatments.

Weather data

The weather data of experimental site for both years (2017 and 2018) was obtained from Meteorological Station, Tandojam. The data including average temperature (°C). Rainfall (mm) and humidity (%) on monthly basis for August, September, October and November was noted and presented in Figure 1.

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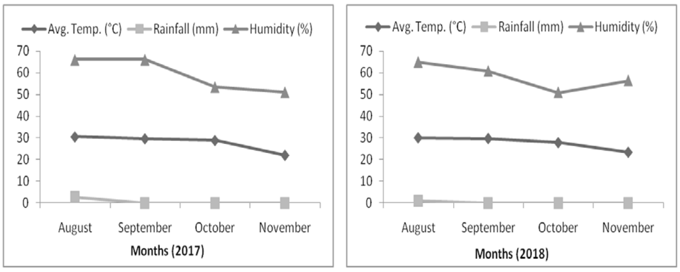

Figure 1: *Weather data of Tandojam during sunflower growing season for 2017 and 2018.*

Results and Discussion

Seed germination (m^{-2})

Germination of seed is the prerequisite for obtaining an optimum number of seedlings which ultimately produces higher seed yield. The statistical analysis of data showed that priming of seed caused significant ($P \leq 0.05$) effect on seed germination while non-significant ($P \geq 0.05$) effect was noted for irrigations, genotypes, irrigation × genotypes, irrigation × seeds priming, genotypes × priming of seeds, and irrigation × genotypes × seeds priming. The results (Table 2) indicated that priming of seed with 0.2% $ZnSO_4$ gave markedly ($P \leq 0.05$) maximum seed germination followed by priming of seed with 1.0% urea whereas, minimum germination of seeds m^{-2} was noted in No priming. The results are supported by the conclusions of Moeinzadeh *et al.* (2010) who suggested that improvement in seed germination, seed vigour and growth of sunflower plants was caused by priming of seeds. The better seed germination under zinc priming may be due to the synthesis of different Auxin in seeds (Rashid and Memon, 2001). In another study Toklu (2015) reported that priming with water and $ZnSO_4$ increased rate of germination and germination percentage. Furthermore, the results of Sharma and Parmar (2017) support the outcomes of our study that highest germination of green pea was obtained due to priming with 1% $ZnSO_4$.

Leaf area index (%)

The statistical analysis of data revealed that sunflower leaf area index (%) was substantially ($P \leq 0.05$) impacted by irrigation, genotypes, priming of seed, and interactions of genotypes × priming of seed, irrigation × genotypes, irrigation × priming of seed and irrigation × genotypes × priming of seeds. The results (Table 3) illustrated that in irrigation frequencies maximum leaf areas index (%) was noticed in five irrigations seconded by four irrigations. Among genotypes, HO-1 produced maximum leaf area index (%) while lowest leaf area index (%) was noted in Hysun-33. In case of priming, the highest leaf area index (%) was registered in seeds primed with 0.2% $ZnSO_4$ followed by seeds primed with 1.0% urea. In case of irrigation × genotypes interaction, the maximum leaf area index (%) was recorded in five irrigations with genotype HO-1 followed by combination of four irrigations with same genotype. The interface of five irrigations × priming 0.2% $ZnSO_4$ resulted in the enhanced area index (%) seconded by same irrigation in interaction of seeds primed with 1.0% urea. Genotype HO-1 × 0.2% $ZnSO_4$ produced highest leaf area index (%) followed by interaction of 1.0% Urea in same genotype. In case of interaction of irrigation × genotype × priming of seed, the maximum leaf area index (%) was found in five irrigations five at seed priming with 0.2% $ZnSO_4$ and genotype HO-1 followed by four irrigation with interaction of priming of seed 0.2% $ZnSO_4$ on same genotype. The results are also corroborated by Ghani *et al.* (2013) who suggested irrigation frequencies exhibited significant impact on leaf area of sunflower. Sunflower leaf area was notably affected by irrigation frequencies (Rady, 2017). Buriro *et al.* (2015) stated that yield contributing traits were affected by irrigation regimes and observed crop productivity also affected by low water. Proper irrigation improved yield contributing traits and leaf area of sunflower. Darwesh *et al.* (2016) indicated that the responses of sunflower leaf area (%) increased gradually with increasing irrigation frequencies. The improved leaf area index with $ZnSO_4$ may be credited to active role of zinc for many enzymes like alcohol dehydrogenises and carbonic anhydrates (Rehman *et al.*, 2015). Similarly, Demir and Mavi (2004) disclosed that irrigation affected significantly on growth and yield components of water melon.

Plant height (cm)

The data illustrated that sunflower plant height was affected considerably ($P \leq 0.05$) by irrigation frequencies, genotypes, priming of seed, and interactions of irrigation × genotypes, irrigation × priming of seeds, genotypes × priming of seeds and irrigation × genotypes × priming of seeds. The results (Table 4) showed that substantially ($P \leq 0.05$) tallest plants were produced by five irrigations followed by four irrigations. The priming of seeds with 0.2% $ZnSO_4$ recorded maximum height of plants seconded by seeds primed with 1.0% urea. The HO-1 genotype was found superior in plant height over Hysun-33. The data illustrated that interaction of genotype HO-1×five

Table 2: *Seed germination m^{-2} of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients.*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	5.3	5.3	5.3	5.3	5.3
	Seed priming: canal water	5.7	5.7	5.7	5.7	5.7
	Seed priming: 1.0% Urea	6.0	6.0	6.0	6.0	6.0
	Seed priming: 0.2% $ZnSO_4$	6.3	6.3	6.3	6.3	6.3
	Mean	5.8	5.8	5.8	5.8	5.8
Hysun-33	No priming	5.3	5.3	5.3	5.3	5.3
	Seed priming: canal water	5.7	5.7	5.7	5.7	5.7
	Seed priming: 1.0% Urea	6.0	6.0	6.0	6.0	6.0
	Seed priming: 0.2% $ZnSO_4$	6.3	6.3	6.3	6.3	6.3
	Mean	5.8	5.8	5.8	5.8	5.8
Averages	No priming	5.3	5.3	5.3	5.3	5.3 D
	Seed priming: canal water	5.7	5.7	5.7	5.7	5.7 C
	Seed priming: 1.0% Urea	6.0	6.0	6.0	6.0	6.0 B
	Seed priming: 0.2% $ZnSO_4$	6.3	6.3	6.3	6.3	6.3 A
	Mean	5.8	5.8	5.8	5.8	-
Variables		**P-value**			**$LSD_{0.05}$**	
Irrigation (I)		0.4547			-	
Genotypes (V)		0.1113			-	
Priming (P)		0.0000			0.2807	
I x V		0.9852			-	
I x P		1.0000			-	
V x P		0.9892			-	
I x V x P		1.0000			-	

Table 3: *Leaf area index (%) of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients.*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	9.8 kl	12.6 hi	13.9 ef	14.6 c-f	12.7 C
	Seed priming: canal water	10.6 jk	12.8 g-i	16.6 b	16.3 b	14.1 B
	Seed priming: 1.0% Urea	10.7 jk	14.8 c-e	16.8 b	17.9 a	15.0 A
	Seed priming: 0.2% $ZnSO_4$	10.9 j	15.0 cd	16.7 b	18.7 a	15.3 A
	Mean	10.5 D	13.8 C	16.0 B	16.9 A	14.3 *A*
Hysun-33	No priming	8.9 l	12.0 hi	11.9 i	12.8 g-i	11.4 C
	Seed priming: canal water	9.1 l	12.6 hi	12.8 g-i	13.7 fg	12.0 B
	Seed priming: 1.0% Urea	9.6 l	12.7 hi	14.1 d-f	14.8 c-e	12.8 A
	Seed priming: 0.2% $ZnSO_4$	9.9 kl	12.8 g-i	12.9 gh	15.1 c	12.7 A
	Mean	9.4 D	12.5 C	12.9 B	14.1 A	12.2 *B*
Averages	No priming	9.4 g	12.3 e	12.9 e	13.7 d	12.1 C
	Seed priming: canal water	9.8 fg	12.7 e	14.7 c	15.0 bc	13.1 B
	Seed priming: 1.0% Urea	10.2 f	13.8 d	15.5 b	16.4 a	13.9 A
	Seed priming: 0.2% $ZnSO_4$	10.4 f	13.9 d	14.8 bc	16.9 a	14.0 A
	Mean	9.9 D	13.2 C	14.5 B	15.5 A	-
Variables		**P-value**			**$LSD_{0.05}$**	
Irrigation (I)		0.0000			0.3364	
Genotypes (V)		0.0000			0.2379	
Priming (P)		0.0000			0.3364	
I x V		0.0001			0.4758	
I x P		0.0001			0.6729	
V x P		0.0014			0.4758	
I x V x P		0.0000			0.3364	

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Table 4: *Plant height (cm) of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients.*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	165.4 k-m	170.5 g-l	181.3 d-f	183.3 de	175.2 C
	Seed priming: canal water	167.7 i-m	172.9 f-k	213.5 ab	215.9 ab	192.5 B
	Seed priming: 1.0% Urea	172.4 f-l	176.5 d-j	215.7 ab	216.3 ab	195.2 AB
	Seed priming: 0.2% $ZnSO_4$	175.9 d-j	185.1 d	217.0 a	220.9 a	199.7 A
	Mean	170.4 D	176.2 C	206.9 A	209.1 A	190.7 *A*
Hysun-33	No priming	160.2 m	166.6 j-m	169.9 h-l	173.4 f-k	167.5 D
	Seed priming: canal water	162.4 lm	167.9 i-m	175.5 e-j	176.5 d-i	170.6 CD
	Seed priming: 1.0% Urea	164.1 k-m	168.5 i-m	178.1 d-h	178.2 d-g	172.3 C
	Seed priming: 0.2% $ZnSO_4$	166.7 j-m	170.9 d-i	179.3 d-h	180.5 d-f	174.4 C
	Mean	163.4 E	168.5 D	175.7 C	177.2 C	171.2 *B*
Averages	No priming	162.8 g	168.6 e-g	175.6 cd	178.4 c	171.3 C
	Seed priming: canal water	165.1 fg	170.4 c-e	194.3 ab	197.1 a	181.7 B
	Seed priming: 1.0% Urea	168.3 e-g	172.5 d-f	195.8 a	198.7 a	183.0 AB
	Seed priming: 0.2% $ZnSO_4$	171.3 d-f	178.0 c	197.5 a	198.4 a	186.3 A
	Mean	166.9 C	172.4 B	190.8 A	193.1 A	-
Variables		**P-value**			**$LSD_{0.05}$**	
Irrigation (I)		0.0000			3.2855	
Genotypes (V)		0.0000			2.3232	
Priming (P)		0.0000			3.2855	
I x V		0.0000			4.6464	
I x P		0.0029			6.5710	
V x P		0.0001			4.6464	
I x V x P		0.0209			9.2929	

Table 5: *Head diameter (cm) of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients.*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	21.0	23.0	24.0	23.5	22.9 C
	Seed priming: canal water	21.5	24.8	25.7	26.0	24.5 B
	Seed priming: 1.0% Urea	21.9	26.0	27.0	27.0	25.5 A
	Seed priming: 0.2% $ZnSO_4$	22.1	25.7	26.9	27.5	25.6 A
	Mean	21.6 D	24.9 B	25.9 A	26.0 A	24.6 *A*
Hysun-33	No priming	20.0	21.0	22.0	22.1	21.3 E
	Seed priming: canal water	20.5	21.3	22.3	22.5	21.6DE
	Seed priming: 1.0% Urea	20.8	22.6	23.1	23.3	22.5 CD
	Seed priming: 0.2% $ZnSO_4$	25.2	23.2	24.7	24.0	24.3 B
	Mean	21.6 D	22.0 D	23.0 C	23.0 C	22.4 *B*
Averages	No priming	20.5	22.0	23.0	22.8	22.1 D
	Seed priming: canal water	21.0	23.0	24.0	24.3	23.1 C
	Seed priming: 1.0% Urea	21.4	24.3	25.0	25.2	24.0 B
	Seed priming: 0.2% $ZnSO_4$	23.7	24.4	25.8	25.7	24.9 A
	Mean	21.6 C	23.4 B	24.5 A	24.5 A	-
Variables		**P-value**			**$LSD_{0.05}$**	
Irrigation (I)		0.0000			3.2855	
Genotypes (V)		0.0000			2.3232	
Priming (P)		0.0000			3.2855	
I x V		0.0000			4.6464	
I x P		0.0029			6.5710	
V x P		0.0001			4.6464	
I x V x P		0.0209			9.2929	

irrigation frequencies produced improved height of plants followed by HO-1 × four irrigations. The best height of plants was observed in the interaction of seed priming with 0.2% $ZnSO_4$ with five irrigations followed by interaction of priming with 1.0% urea on same irrigations. The genotype HO-1 produced highest plant height in priming of seed with 0.2% $ZnSO_4$ followed by priming with 1.0% urea on same genotype. Five irrigation × HO-1 × priming of seed with 0.2% $ZnSO_4$ showed finest height of plant followed by same genotype with four irrigations and interaction of same priming. Rehman *et al.* (2015) found that advanced plant height in $ZnSO_4$ primed seeds may be credited to active role of zinc for different enzymes and hormones like alcohol dehydrogenises and RNA polymerase. The results agree with Kalroo *et al.* (2013) and Khan (2005) who disclosed that irrigation frequencies caused significant effect on plants height and rates of development. Similarly, our opposite results were reported by Amjed *et al.* (2013) who indicated that sunflower hybrid (Hysun-38) showed superiority in plan height in contrast to other cultivars. Darwesh *et al.* (2016) revealed that the irrigation scheduling significantly affected on plant height of sunflower.

Head diameter (cm)

Diameter of head is an essential and basic requirement of seed yield in sunflower crop. The potential of crop yield depends upon head size. It is clear from the data that sunflower head diameter was significantly ($P \leq 0.05$) affected by irrigation, genotypes, priming of seeds, irrigation × genotypes and genotypes × priming of seeds whereas, non-significantly ($P \geq 0.05$) by irrigation × seed priming and irrigations × genotypes × priming of seeds. The results (Table 5) indicated that five irrigations gave maximum head diameter followed by four irrigations having non-significant difference with each other. The highest head diameter was recorded in HO-1 genotype, followed by Hysun-33 with lowest head diameter. The highest diameter of head was observed in priming of seed with 0.2% $ZnSO_4$ followed by 1.0% urea priming. As regards to irrigation × genotypes, the best diameter of head was recorded in the interaction of genotype HO-1 × five irrigation frequencies followed by HO-1 × four irrigation frequencies. The maximum head diameter was recorded in HO-1 genotype with interaction of 0.2% $ZnSO_4$ followed by HO-1 genotype with interaction of same irrigation. These results are supported by conclusions of Moeinzadeh *et al.* (2010) who suggested that priming of seeds caused improvement in sunflower head diameter. Similarly, results of another study showed that priming of seeds demonstrated significant effect on sunflower head diameter (Jafri *et al.*, 2015). Flagella *et al.* (2002) reported that diameter of sunflower head was enlarged with increased number of irrigation. The outcomes are further conformed by Fazel and Lack (2011) who determined that irrigation frequencies caused substantial influence on diameter of sunflower head. Darwesh *et al.* (2016) revealed that the irrigation scheduling had significantly affected on sunflower head diameter.

Weight of seeds head^{-1} (g)

The analysis of variance indicated a substantial ($P \leq 0.05$) influence of irrigation, genotypes, seed priming, and genotypes × seed priming on weight of seeds head^{-1} (g). However, non-substantial ($P \geq 0.05$) effect was revealed for irrigation × genotypes, irrigation × seed priming and irrigation × genotypes × priming of seeds. The results (Table 6) illustrated that highest weight of seeds head^{-1} was noted in five irrigations followed by four irrigations. Among genotypes, HO-1 produced maximum weight of seeds while lowest weight of seeds head^{-1} was observed in Hysun-33. The priming with 0.2% $ZnSO_4$ produced highest weight of seeds head^{-1} seconded by priming with 1.0% Urea. The interaction of HO-1 x priming of seed with 0.2% $ZnSO_4$, produced highest seed weight head^{-1} followed by same genotype in priming with 1.0% Urea. The results are also corroborated by Ghani *et al.* (2013) who suggested that seed priming exhibited significant impact on seed weight of sunflower. Sunflower yield was notably affected by irrigation frequencies Rady (2017). Buriro *et al.* (2015) stated that irrigation frequencies improved yield traits of sunflower. The findings of Darwesh *et al.* (2016) indicated the positive responses of sunflower in terms of seed weight by increasing irrigation frequencies. Demir and Mavi (2004) suggested that frequencies of irrigation significantly affected on yield contributing components of tested crop.

Seed yield (kg ha^{-1})

Seed yield is a major decision making tool used in agricultural crop which refers to output produced per unit area. The statistical analysis of data revealed that a significant ($P \leq 0.05$) effect on seed yield was caused by irrigation, genotypes, priming of seed, irrigation × priming of seed, and genotypes × priming of seed

Table 6: *Weight of seeds head^{-1} (g) of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients.*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	43.3	53.0	53.7	55.4	51.4 CD
	Seed priming: canal water	45.0	58.3	69.5	72.4	61.3 B
	Seed priming: 1.0% Urea	47.3	62.3	77.7	79.3	66.7 AB
	Seed priming: 0.2% $ZnSO_4$	51.7	66.0	80.5	81.0	69.8 A
	Mean	46.8	59.9	70.4	72.0	62.3 *A*
Hysun-33	No priming	39.3	46.0	51.2	46.7	45.8 D
	Seed priming: canal water	40.7	47.3	55.3	55.5	49.7 CD
	Seed priming: 1.0% Urea	42.3	50.6	58.0	60.7	52.9 C
	Seed priming: 0.2% $ZnSO_4$	48.3	62.9	67.1	79.6	64.5 AB
	Mean	42.7	51.7	57.9	60.6	53.2 *B*
Averages	No priming	41.3	49.8	50.7	52.5	48.6 D
	Seed priming: canal water	42.8	56.9	59.8	62.4	55.5 C
	Seed priming: 1.0% Urea	44.8	61.5	65.0	67.9	59.8 B
	Seed priming: 0.2% $ZnSO_4$	50.0	72.8	72.0	73.8	67.1 A
	Mean	44.8 C	60.3 B	61.9 A	64.1 A	-
Variables		**P-value**			**$LSD_{0.05}$**	
Irrigation (I)		0.0002			3.9807	
Genotypes (V)		0.0015			2.8148	
Priming (P)		0.0000			3.9807	
I x V		0.2411			-	
I x P		0.2411			-	
V x P		0.0569			5.6296	
I x V x P		0.1487			-	

Table 7: *Seed yield (kg ha^{-1}) of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients.*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	1500	1526	1801	1853	1670 D
	Seed priming: canal water	1463	1531	2321	2338	1913 BC
	Seed priming: 1.0% Urea	1495	1529	2414	2427	1966 B
	Seed priming: 0.2% $ZnSO_4$	1525	1662	2458	2478	2031 A
	Mean	1495	1562	2248	2274	1894 A
Hysun-33	No priming	1401	1421	1638	1713	1543 F
	Seed priming: canal water	1431	1474	2290	2323	1879 D
	Seed priming: 1.0% Urea	1460	1481	2388	2400	1932 CD
	Seed priming: 0.2% $ZnSO_4$	1501	1571	2417	2441	1982 B
	Mean	1448	1487	2183	2219	1834 *B*
Averages	No priming	1447 g	1474 fg	1780 d	1791 c	1623 D
	Seed priming: canal water	1450 g	1503 f	2319 bc	2332 bc	1901 C
	Seed priming: 1.0% Urea	1477 fg	1505 f	2439 ab	2443 ab	1966 B
	Seed priming: 0.2% $ZnSO_4$	1513 f	1616 e	2453 ab	2459 a	2010 A
	Mean	1472 C	1524 B	2247 A	2256 A	-
Variables		P-value			$LSD_{0.05}$	
Irrigation (I)		0.0000			23.853	
Genotypes (V)		0.0007			16.867	
Priming (P)		0.0000			23.853	
I x V		0.3968			-	
I x P		0.0000			47.706	
V x P		0.0061			33.733	
I x V x P		0.5246			-	

Table 8: *Harvest index (%) of sunflower genotypes under the influence of irrigation frequencies and seed priming with plant nutrients*

Sub-plot (Genotypes)	Sub-sub plot (Sources of seed priming)	Main-plot (Frequencies of irrigation)				Mean
		Two irrigations	Three irrigations	Four irrigations	Five irrigations	
HO-1	No priming	19.3	21.5	19.7	23.5	21.0
	Seed priming: canal water	20.0	21.8	23.5	23.9	22.3
	Seed priming: 1.0% Urea	20.1	21.7	23.7	23.9	22.3
	Seed priming: 0.2% $ZnSO_4$	21.9	21.9	24.3	24.1	23.1
	Mean	20.3	21.7	22.8	23.8	22.2 *A*
Hysun-33	No priming	18.9	19.4	19.6	21.7	19.9
	Seed priming: canal water	19.3	20.9	22.1	21.7	21.0
	Seed priming: 1.0% Urea	19.2	22.1	22.2	22.2	21.4
	Seed priming: 0.2% $ZnSO_4$	20.0	23.0	23.0	23.4	22.4
	Mean	19.4	21.4	21.7	22.3	21.2 *B*
Averages	No priming	19.1	20.5	19.6	22.6	20.4 C
	Seed priming: canal water	19.7	21.4	22.8	22.8	21.7 B
	Seed priming: 1.0% Urea	19.6	21.9	23.0	23.1	21.9 AB
	Seed priming: 0.2% $ZnSO_4$	21.0	22.5	23.6	23.8	22.7 A
	Mean	19.8 C	21.5 B	22.3 AB	23.1 A	-
Variables		**P-value**			**$LSD_{0.05}$**	
Irrigation (I)		0.0680			1.1652	
Genotypes (V)		0.0562			0.8239	
Priming (P)		0.0006			1.1652	
I x V		0.8092			-	
I x P		0.5513			-	
V x P		0.9267			-	
I x V x P		0.8901			-	

whereas, non-significant ($P \geq 0.05$) by irrigation × genotypes and irrigation × genotypes × priming of seed. The results (Table 7) illustrated that enhanced seed yield (kg ha^{-1}) was noted in five irrigations followed by four irrigations. HO-1, genotype produced greatest yield while, lowest yield (kg ha^{-1}) was observed in Hysun-33. The priming of seeds with 0.2% $ZnSO_4$ resulted in highest seed yield (kg ha^{-1}) followed by priming with 1.0% urea The significantly higher seed yield (kg ha^{-1}) was observed in seed priming with 0.2% $ZnSO_4$ × five irrigations seconded by seed priming with 0.2% $ZnSO_4$ × four irrigations. The HO-1 genotype × priming of seed with 0.2% $ZnSO_4$ produced highest seed yields (kg ha^{-1}) which was followed by same genotype in priming of seeds with 1.0% Urea. The results are corroborated by Bakht *et al.* (2010) who suggested seed priming exhibited significant impact on sunflower seed yield. Sunflower yield notably was affected by irrigation frequencies (Fazel and Lack, 2011). Buriro *et al.* (2015) stated that yield contributing traits were positively improved by irrigation managements, and proper irrigation frequencies. Similarly, Siddiqui and Oad (2015) indicated that responses of sunflower seed yield progressively increased with increasing frequencies of irrigations. Our findings are in agreement with Seghatoleslami *et al.* (2012) who concluded that irrigation significantly affected on yield components of crop under study. The results of Sharma and Parmar (2017) also support the outcomes of our study that seed yield of green pea increased at maximum level due to priming with 1% $ZnSO_4$.

Harvest index (%)

The analysis of variance suggested that sunflower harvest index was considerably ($P \leq 0.05$) affected by irrigation, genotypes and priming of seeds while non-substantially ($P \geq 0.05$) by irrigation × priming, irrigation × genotypes, genotypes × priming and irrigation × genotypes × seeds priming. The data (Table 8) demonstrated that highest harvest index was recorded in five irrigations followed by four irrigations. In genotypes, HO-1 proved better by producing maximum harvest index in contrast to Hysun-33. The priming with 0.2% $ZnSO_4$ resulted in considerably ($P \leq 0.05$) highest harvest index followed by priming with 1.0% urea. The findings of this study are in accordance with Moeinzadeh *et al.* (2010) who displayed that seed priming exhibited boost in harvest index %. Appreciable impact on sunflower harvest index % was also reported by Jafri *et al*. (2015). Ghani *et al*. (2013) concluded that positive impact of diverse periods of irrigation was recorded on sunflower harvest index %. Our findings are also corroborated by Khaliq and Cheema (2015) who suggested that irrigation application caused significant influence on harvest index %.

Conclusions and Recommendations

It is concluded that irrigation frequencies and seed priming sources caused substantial effect on growth and yields traits of sunflower genotypes. Four irrigations were found appropriate for obtaining optimal seed yield. The priming of seeds with 0.2% $ZnSO_4$ provided highest results for most of the studied traits particularly seed yield. The genotype HO-1 (OP) surpassed Hysun-33 (Hybrid) in all growth and yield attributes particularly seed yield. Hence, sunflower genotype HO-1 may preferably be sown under agro-climatic conditions of Tandojam and be primed with 0.2% $ZnSO_4$ and irrigated four times for achieving enhanced seed yield of sunflower crop.

Acknowledgments

This original research article is prepared from the PhD thesis submitted at Sindh Agriculture University Tandojam.

Novelty Statement

Priming of seeds with ZnSO4 improved growth and yield of sunflower and saved irrigation water.

Author's Contribution

MNK planned experiment and prepared manuscript. ZAA conducted experiment and collected data. AAS played role as guide. NL provided research material. MIK edited manuscript. ANS interpreted results. GMJ analysed data.

Conflict of interest

The authors have declared no conflict of interest.

References

Amjad, M., 2014. Oilseeds crop of Pakistan. Pakistan Agricultural Research Council Islamabad. pp. 1-40.

Amjed, R., R. Ali and I.R. Noorka. 2013. Differential growth and development response of sunflower hybrid in contrasting irrigation regimes. Am. J. Sci., 13(4): 157-163.

Badouin, H., J. Gouzy and N.B. Langlade. 2017. The sunflower genome provides insights into oil metabolism, flowering and asteroid evaluation. Int. J. Sci., 546: 148-152.

Bakht, J., M. Shafi, M. Yousaf, R. Din and M.A. Khan. 2010. Effect of irrigation on physiology and yield of sunflower hybrids. Pak. J. Bot., 42(2): 1317-1326.

Buriro, M., A.S. Sanjrani, Q.I. Chachar, N.A. Chachar, S.D. Chachar, B. Buriro, A.W. Gandahi and T. Mangan. 2015. Effect of water stress on growth and yield of sunflower. Int. J. Agric. Technol., 2(1): 260- 270.

Chatterjee. N., D. Sarkar, A. Sankar, S. Pal, H.B. Singh, R.K. Singh and J.S. Bohra. 2018. On-farm seed priming interventions in agronomic crops. Acta Agric. Slovenica., 111(3): 1-12. https://doi.org/10.14720/aas.2018.111.3.19

Darwesh, R.K., A.M.M. EL-Mansoury and M.A. El-Shamy. 2016. Effect of irrigation scheduling on sunflower/forage cowpea intercropping pattern, growth, yield and its components. J. Soil Sci. Agric. Eng., 7(2): 135-146. https://doi.org/10.21608/jssae.2016.39355

Dawa1. S., F.U. Khan, Neelofar, F.A. Khan, P. Tundup and T. Angdu. 2017. Effect of different priming methods on growth and flowering of different flowers of Kashmir valley. India Int. J. Curr. Microbiol. App. Sci., 6(12): 3333-3344. https://doi.org/10.20546/ijcmas.2017.612.388

Demir, I and K. Mavi, 2004. The effect of priming on seedling emergence of differentially matured watermelon (*Citrullus lanatus*) seeds. Sci. Hortic., 102: 467-473. https://doi.org/10.1016/j.scienta.2004.04.012

Eman, R.A., E.B. Schultz, Hussein, S. Adam and A.M. Haile. 2015. Crop water productivity for sunflower under different irrigation regimes and plant spacing in Gezira Scheme, Sudan. J. Agric. Environ. Int. Dev., 109(2): 221-233.

FAO, 2018. World Agriculure: Twords 2017-18. Yield of sunflower., Retrieved 2018 Feb.

Farooq M., A. Wahid and K.H.M. Siddique. 2012. Micronutrient application through seed treatments. A review. Soil Sci. Plant Nutr., 12: 125–142. https://doi.org/10.4067/S0718-

95162012000100011

Fazel, M.A., and S.H. Lack. 2011. The effects of irrigation off at different growth stages, planting patterns and plant population on grain yield and dry matter remobilization of grain corn. World Appl. Sci. J., 15(4): 463-473.

Flagella, Z., T. Rotunno, R. Tarantino, R.D. Caterina and A.D. Caro. 2002. Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regimes. Eur. J. Agron., 17: 221-230. https://doi.org/10.1016/S1161-0301(02)00012-6

Ghani, A., M. Hussain and M.S. Qureshi. 2013. Effect of different Irrigation Regimens on the Growth and Yield of Sunflower. Intern, J. Agric. Biol., 2(4): 334-335.

GoP, 2018. Economic survey of Pakistan. 2017-18. Government of Pakistan Ministry of food, Agriculture and livestock division, Economic affairs wing, Islamabad. pp-19-20.

Halmer, P., 2003. Methods to improve seed performance. In: Benech-Arnold RL, Sanchez RA (eds) Seed Physiology, Applications to Agriculture. Food Product Press, New York, pp. 40-48.

Hassan, F.U. and S. Kaleem. 2014. Influence of seasonal disparity on NPK uptake in sunflower. J. Anim. Plant Sci., 24(1): 190-196.

Iqtidar, A.K. and A. Jan. 2010. Cropping technology textbook of agriculture. Third edition, National book foundation Islamabad., pp. 247-248.

Jafri. N., M. Mazid and F. Mohammad. 2015. Responses of seed priming with gibberellic acid on yield and oil quality of sunflower *(Helianthus annuus* L.). Indian J. Agric. Res., 49(3): 235-240. https://doi.org/10.5958/0976-058X.2015.00036.0

Ka1aiyarasan, C. and V. Vaiyapuri. 2007. Effect of integrated nutrient management practices on growth and yield attributes and quality characters of sunflower (*Helianthus annuus* L.). Int. J. Trop. Agric., 35: 15-18.

Kalroo, M.W., H.A. Samoon, B.L. Meghwar, A.M. Laghari, M.S. Depar, A.S. Chandio and A.K. Pathan. 2013. Response of sunflower to varying levels of mineral fertilizers and irrigation scheduling. Life. Sci. Int. J., pp. 1-13.

Kazemeini, S.A., M. Edalat and A. Shekoofa. 2009. Interaction effects of deficit irrigation and row spacing on sunflower (*Helianthus annuus* L.) growth, seed yield and oil yield. Afr. J. Agric. Res., 4(11): 1165-1170.

Khaliq, A. and Z.A. Cheema. 2015. Effect of irrigation regimes on some agronomic traits and yield of different sunflower (*Helianthus annuus* L.) hybrids. Int. J. Agric. Biol., 7(6): 920–924.

Khalil. I.A.K., and A. Jan. 2010. Cropping technology, Textbook of agriculture. Third edition, National book foundation Islamabad., pp. 247-248.

Khan, S.R.A., 2005. Increasing irrigation efficiency. Farming Outlook., (1):23-26.

Kouchebagh, S.B., F. Farahvah, B. Mirshekari, H.A. Kazemi and F.R. Khoei. 2014. Seed priming techniques may improve grain and oil yields of sunflower (*Helintus annuus* L.). J. Anim. Plant Sci., 24(6): 1863-1868.

Lina, D.S., and G. Gautam. 2015. Effect of plant geometry and sulphur levels on growth, yield and oil content of sunflower (*Hellinthus annuus* L.). J. Life Sci., 12(4): 911-913.

Mangin, B., F. Bonnafous, N. Blanchet, E.B. Mestries, L. Cottret, S. Munos and N.B. Llanglade. 2017. Genomic prediction of sunflower oil content. F. Plant Sci., 8: 1633-1638. https://doi.org/10.3389/fpls.2017.01633

Moeinzadeh, A., F.S. Zadehl, M.A. zadeh and F.H. Tajabadi. 2010. Biopriming of sunflower (*Helianthus annuus* L.) seed with *Pseudomonas fluorescens* for improvement of seed invigoration and seedling growth. Agric. J. Crop Sci., 4(7): 564-570.

Rady, M.M., 2017. Predicting the role of irrigation on sunflower yield grown under salin conditions. Proceeding of international conference: Environmentally sound technology in water resources management. pp. 30-35.

Rashid, A. and K.S. Memon. 2001. Soil science. National book foundation Islambabad, pp. 372-379.

Rayan, J., G. Estefan and A. Rashid. 2001. Soil and plant analysis laboratory manual. International center for agricultural research in the dry areas (ICARDA), Aleppo, Syria. pp. 172.

Rehman, A., M. Farooq, R. Ahmad and S.M.A. Basra. 2015. Seed priming with zinc improves the germination and early seedling growth of wheat. Seed Sci. Tech., 43(2): 262-268. https://doi.org/10.15258/sst.2015.43.2.15

Rowell, D.L., 1994. Soil science methods and applications. D. L. Rowell. (ed.). Longman

Group, U.K.

Seghatoleslami, M.J., R. Bradaran, E. Ansarinia and S.G. Mousavi. 2012. Effect of irrigation and nitrogen level on yield, yield components and some morphological traits of sunflower. Pak. J. Bot., 44(5): 1551-1555.

Sharma, M., and D.K. Parmar. 2017. Effect of seed priming with zinc sulfate on yield and quality parameters of rainfed maize-pea sequence under mid hill conditions of Himachal Pradesh. J. Pharm. Phytochem., 7(1): 1401-1407. https://doi.org/10.20546/ijcmas.2018.701.352

Sheidaie, S., M. Divsalar, B. Oskouei, H. Sadeghi and E. Rezvani. 2013. Seed hydropriming application to alleviation of water stress during germination in sunflower hybrids. Int. J. Agric. Crop Sci., 5(2): 155-159.

Siddiqui, M.H. and F.C. Oad. 2015. Sunflower growth and yield under varying irrigation frequencies and sowing methods. Ind. J. Biol. Sci., 12(3): 436-440.

Soomro, A.G., A.H. Memon, M.A. Gadehi, R.M. Memon, S.D. Junejo, S. Talpurand M.A. Memon. 2015. Growth and yield of sunflower in response to planting geometry and nitrogen foliar application at various crop stages. Am. Eur. J. Agric. Environ. Sci., 15(1): 140-146.

Statistix, 2006. Statistix 8.1 user guide, version 1.0. Analytical Software, PO Box 12185, Tallahassee FL 32317 USA. Copyright 2006 by Analytical Software.

Tengong, S., P. Sinkeng, M.H. Linglee and Y. Tsehung. 2010. Equilibrium studies for the removal of dye by sunflower seed husk. Int. J. Physical Sci., 5(8): 1270-1276.

Toklu, F., 2015. Effects of different priming treatments on seed germination properties, yield components and grain yield of lentil (*Lens culinaris*). Not. Bot. Hortic. Agrobo., 43(1): 153-158. https://doi.org/10.15835/nbha4319832

Wills, D.M. and J.M. Burke. 2006. Chloroplast DNA variation confirms a single origin of domestication sunflower (*Helianthus annuus* L.). J. Heredity, 87(4): 403-408. https://doi.org/10.1093/jhered/esl001