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Research Article

The Effect of Soil Solarization Duration on the Abundance and Diversity of Nematodes in Intercropping Fields of Shallot with Chili

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ABSTRACT

Solarization is a technique that increases soil temperature and affects nematode abundance and diversity in agricultural land and can be used as alternative management technique against soil borne pathogens including plant-parasitic nematodes. Intercropping is also known to have strong influences on soil nematodes. This study aims to determine the effects of solarization duration on nematode abundance and diversity in soil of shallot intercropped with chili, and its effect on shallot productivity as the main crop. The study was conducted with randomized complete block design (RCBD) that included three treatments of solarization durations (0, 14, and 30 days) with 5 replications for each treatment. Soil samples were taken before solarization, after solarization and before harvest. Nematodes were extracted from soil samples using the modified whitehead-tray method. The results showed that different solarization durations affected soil temperature, nematode diversity, and abundance. The highest soil temperature resulted from solarization duration of 14 days (42.7 °C). Overall, 22 nematodes genera were found with bacterivores nematode being the dominant trophic group in all solarization treatments. Soil solarization had less impact on the abundance of predator and omnivore trophic groups. The abundance of all nematode genera significantly decreased after 14 days of solarization. The abundance of plant-parasitic nematodes significantly decreased in the 14-day solarization treatment, standing with a decline of fungivore nematodes through soil ecosystem shifts. Meanwhile during harvest, the abundance and diversity of nematodes increased significantly. Moreover, shallot plants showed higher plant height, root weight, root length, gross weight of bulbs and dry weight of bulbs at solarization durations of 14 and 30 days compared to those without solarization. From this study, the 14 days of solarization was the best treatment for nematode management in the shallot productions to provide balanced soil nematodes environment.

Keywords: nematode abundance; shallot; soil solarization; temperature

INTRODUCTION

Soil nematodes are an active dominant soil fauna group in plant rhizosphere (Li *et al*., 2021). Soil nematodes are part of the soil ecosystem and changes in their community are one of the biological tools to evaluate soil management and crop conditions in terrestrial ecosystems

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(Pen-Mouratov *et al*., 2010). Nematode community composition can be used as an indicator of environmental change and ecosystem function in soil. Through the abundance of nematodes in any environment and condition, nematode could be a soil health indicator (Bileva *et al*., 2014). This is based on their feeding behavior that can be grouped into five trophic groups: bacterivores, fungivores, herbivores (plant parasitic nematodes/PPNs), omnivores, and predators (Yeates *et al*., 1993). Which each group have different life strategies that can provide an indication to soil health (Bileva *et al*., 2014). There is a close relationship between nutrient mineralization, bacterivores, and fungivores in the soil (Domene *et al*., 2021). Bacterivores and fungivores showed strong positive correlation to soil organic matter (Quist *et al*., 2019). Meanwhile, omnivores/predators were secondary consumers, eating other small animals and nematodes in the soil (Zhang *et al*., 2021). Omnivorous are more sensitive to environmental change (Zhao & Neher, 2013). Meanwhile, PPNs infestations occurs as endoparasites and ectoparasites which can migrate into the plant's vascular system causing root damage and affecting nutrient absorption and transport mechanisms (Mandal *et al*., 2021).

Soil water availability regulates nematode activity and can increase nematode populations (Landesman *et al*., 2011). Temperature change affect nematodes distribution and nematode generation time (Nisa *et al*., 2021). Nematode activity tends to increase at temperature of 25 ºC, decrease at 30 ºC, and become inactive at 40 ºC (Mulyadi, 2009). Lisnawita *et al*. (2010) stated that temperature greatly affects the biological factors of nematodes, such as the number of new cysts, reproductive factors, survival, paternity, and propagation. Prolonged temperature increases in soil can reduce the infectivity of nematodes due to depletion of reserved energy and result in mortality. In addition, temperature and humidity significantly affect nematode diversity and abundance of highest trophic nematode level decreased above temperature of 21 °C, and 30% humidity and pH changed from alkaline to acidic (Nisa *et al*., 2021). Matute (2013) demonstrated that temperature increases also increased plant transpiration, reduced soil water content, and changed nematode microenvironment. In addition, temperature increases also increased plant root growth and resource supply for respiration, thus affecting soil nematode community. As poikilothermic animal, nematode's metabolic rate, activity level, and behavior are affected by environmental temperature (Munteanu, 2017). It is known that temperature is one factor that affected soil nematode abundance and diversity beside of the soil pH, and moisture (Marsudi, 2019).

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Intercropping practices are also known to have impacts on soil nematodes. In many cases, intercropping could reduce yield losses due to nematodes (Chadfield *et al.,* 2022; Hassan *et al.,* 2023). Nematode numbers of some tropic groups increased through intercropping (Teshita *et al.,* 2024). Hence, nematodes have different responses to different plants (Teshita *et al.,* 2023). Soil solarization is a technique that utilizes solar radiation and aims to increase soil temperature by using clear polyethylene sheets to reach temperatures that are detrimental to soil-borne pests and pathogens (Candido *et al*., 2011). However, effect of soil solarization duration on soil nematode abundance and diversity is less known. Thus, this study aims to investigate solarization duration effects on nematode abundance and diversity in soil of shallot intercropped with chili, and its effect on shallot productivity as the main crop.

MATERIALS AND METHODS

Research Location

The research was conducted from December to March 2022 at Gotakan Village, Panjatan District, Kulon Progo Regency, Yogyakarta. Observations of nematode genera, diversity, and abundance were conducted at the Nematology Laboratory, Department of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada.

Soil and Field Treatment and Solarization Preparation

Soil was plough, formed into 1.2 × 4 m^2 soil beds, and watered. Solarization treatment was done before bud planting by covering beds with polyethylene plastic for 14 and 30 days. After treatment, shallot var. 'Nganjuk' bulbs were planted at distance of 20 cm. Chili plants were planted 2 weeks before the shallots were harvested. Planting beds without solarization treatment were used as the control. Soil temperature, moisture, and pH were measured daily during solarization at 02.00 P.M. These parameters were measured with a soil survey tool (Mediatech Soil Survey Instrument Digital 5 in 1 Backlight) by plugging it into the treated soil for 20 s. The randomized complete block design (RCBD) with five replication was used in the experiment.

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Nematode Soil Extractions

Nematode diversity and abundance were observed from soil samples taken before solarization, after solarization and before harvest. As much as a 200 g of 5 soil samples were randomly sampled from treatment area from 10−20 cm depth and composited. Soil nematode extraction used a modified Whitehead-Tray method (Bezooijen, 2006). A tray prepared with a nylon screen was placed on top of the filter tray and filter paper (unscented tissue) until the surface of the tray was covered. Composited soil from the field (100 mL) was placed on the filter tray and labelled. Then soaked with water until it reached the filter paper surface. The water-soaked soil was left for 48 hours at room temperature. The resulting suspension was precipitated and decanted until its volume reached 50 mL. A total of 5 mL of suspension was taken and transferred to a counting dish. Nematodes were observed under a compound microscope (Olympus CX-22) with magnification of 40×−100×. Identification of nematodes to the genus level was carried out based on morphological characteristics according to Heyns (1971), and Luc *et al*. (2005). Then the identified nematode genera were grouped into bacterial feeders, fungal feeders, predators and herbivores or plant parasitic nematodes.

Data Analysis

Data of soil temperature, nematode abundance and diversity, and shallot production were analyzed using ANOVA. If significant effects of treatment were detected, a Duncan's Multiple Range Test (DMRT) at the 5% level was done. All analysis were conducted using the SPSS.25.Mac program. Regression analysis was used to determine the correlation between solarization duration and soil temperature. Regression model with R^2 which was close to 1 was the most appropriate model used to determine the relationship formula. Regression analysis was performed using the Ms. Excel program.

The diversity of the nematode genus was analyzed using the Shannon-Wienner diversity index (Krebs, 1989), described in Equation (1).

$H' = -\sum (P_i \ln P_i)$ (1)

H' = Shanon diversity index;

Pi = abundance index;

Pi = ni/N,

ni = number of individuals of each nematode genus;

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N = total number of all nematode genera.

RESULTS AND DISCUSSION

Effect of Solarization Duration on Soil Temperature, Moisture, and pH

Observation of soil temperature in different solarization duration treatments showed significantly different results (Table 1). The results showed that the highest temperature was in the solarization duration of 14 days (42.72 ^{o}C), and the temperature decreased in the soil solarized for 30 days (41.08 ^{o}C). Soil moisture was inversely proportional to soil temperature. Moisture in the control treatment (73.47%) was higher than the 14-day and 30-day solarization treatments. Soil acidity (pH) was not significantly different between treatments.

Soil solarization affected soil temperature and soil moisture but had no effect on soil pH. Soil treated with solarization for 14 days (42.72 °C) showed significantly higher temperatures compared to other treatments but showed soil moisture decreased. This may be due to soil turning done in the 14-day solarization duration increased temperature of topsoil layer because it still being brittle increasing solar radiation seeping into soil cracks and raise soil temperature to ones higher than 30-day solar treatment. While in the 30-day solarization duration, soil was compact reducing sunlight reception. Soil temperature increase can be attributed to polyethylene plastic used as mulch could trap heat. Polyethylene plastic limits soil water evaporation causing solar radiation that penetrated plastic mulch can be trapped, absorbed, and converted into heat (Stirling, 2014).

Correlation between solarization duration and soil temperature was described based on the regression analysis in Figure 1 and Table 2. The purpose of regression analysis is to model the expected value of the dependent variable (y) against the independent variable (x). This means that the value of x (solarization duration) can determine the soil temperature (y). Therefore, the solarization duration (x value) can be changed or adjusted to obtain the required temperature (y value). The closest relationship between solarization duration and soil temperature was polynomial with $R^2 = 1$ and with the equation $y = -0.0282x^2 + 1.1633x + 31.955$. Compared to linear and exponential regression forms, which have R^2 values smaller than 1 or close to 0, indicating no relationship. The polynomial regression equation with $R^2 = 1$ indicated there was a relationship between solarization duration and temperature (Table 2).

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The relationship between soil solarization duration and soil temperature was in the form of a polynomial regression (Figure 1). The relationship between solarization duration and soil temperature was modeled as y = soil temperature and x = solarization duration. Soil temperature tended to increase as the solarization duration increased but the increase was non-linear. Soil temperature increased to a certain point and there was a decrease in soil temperature even though the solarization duration increases. In this study, the 14-day solarization temperature reached 42.72 °C and gradually decreased thereafter. The relationship between temperature and solarization duration was polynomial ($R^2 = 1$).

Soil Nematodes Abundance and Diversity at Various Solarization Durations

The abundance and diversity of nematode genera at different solarization durations varied (Table 3). There were 22 nematode genera included parasite nematodes (7 genera), fungivores (2 genera), bacterivores (4 genera), omnivores (3 genera), and predators (6 genera). Different solarization duration treatments also resulted in different nematode abundances. Solarization affected soil nematode abundances. The abundance of nematodes (Figure 2) at a solarization duration of 14 days and 30 days decreased significantly (up to 75% at 14 days of solarization). While in the control treatment, the nematode population before and after solarization treatment were not significantly different. Nematode abundance significantly increased during harvest. Soil solarization was reported to reduce nematode populations by between 37–100% (Candido *et al*., 2008). In this study, increased solarization durations increased soil temperature and decreased soil moisture resulting in decreased nematode populations. These results were in accordance with Liu *et al*. (2022) who found that soil moisture content decreased from 61.27% to 29.13% with increasing temperature and soil nematode abundance decreased under excessive heating. Nematodes are aquatic animals that require soil free water to carry out their biological functions. As temperature increases, soil moisture decreases, thereby reducing nematode populations (Van Den Hoogen *et al*., 2019). Excessive warming increases transpiration, exacerbating soil water loss and heat stress, which impacts on living space and reduces the number of soil nematodes (Yan *et al*., 2018). Munteanu (2017) showed that soil nematodes normally thrive at temperatures between 15−30 ºC and become immobile from 5−15 ºC and 30–40 ºC. High soil temperatures caused nematode mortality. The temperature in the 14 and 30 days solarization treatments exceeded the optimal temperature for nematodes to be mobile causing nematode abundance to decrease in the solarized plots. Nematode populations increased during the middle of the season

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or near harvest. This was influenced by sufficient food or hosts availability that will accelerate the reproduction and development of nematodes. Liswarni *et al*. (2019) stated that nematode life cycle was influenced by environmental factors and food quality and quantity where abundance of these resources led to shorter life cycle, while in less suitable host plants these life cycle became longer.

Nematode abundance before solarization, after solarization and harvesting of each nematode genus was different. Several nematode genera abundance significantly decreased ($p<0.05$) after solarization which include several parasitic nematodes (*Meloidogyne* and *Tylenchorhyncus*), fungivore nematodes (*Aphelenchus* and *Tylenchus*), bacterivore neamtodes (*Cephalobus, Mesorhabditis,* and *Rhabditis*), omnivore nematodes (*Dorylaimus* and *Mesodorylaimus*). Overall, the abundance of all nematode genera increased again at harvest. The abundance of nematodes before solarization in all feeding trophic groups were not significantly different (Figure 3). However, after solarization, the abundance of parasitic and fungivorous nematode trophic groups at solarization durations of 14 days and 30 days decreased significantly from before solarization and then increased at harvest. The abundance of bacterivorous, predatory, and omnivorous nematodes decreased and then increased significantly at harvest.

Different trophic groups responded differently to the increase in temperature caused by soil solarization. Increased temperature led to a reduction in most of the identified nematode genera. Temperature and moisture have direct influence in controlling nematode activity. Temperature is an important factor in the overall movement of nematodes and their ability to expand their distribution range (Luc *et al*., 2005). Nematode communities are usually dominated by bacterivores and plant parasites, with low omnivores and fungivores (Hu *et al*., 2015). These results were consistent with the results of this study at the time before the solarization duration. In this study, soil solarization significantly reduced the abundance of parasitic nematodes (*Meloidogyne* and *Tylenchorhyncus*), fungivores (*Aphelenchus* and *Tylenchus*), bacteriovores (*Cephalobus*, *Mesorhabditis*, and *Rhabditis*) and omnivores (*Dorylaimus* and *Mesodorylaimus*). However, bacterivores were still dominant in the nematode community after solarization. These results were consistent with the study of Liu *et al*. (2022) where the abundance of bacterivores initially decreased due to warming, which indicated that warming had major impact on the abundance of bacterivores, but the dominant position of bacterivores in the nematode community remained unaffected. Parasitic nematodes were a group that was highly sensitive to soil

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solarization. According to Pontes *et al*. (2021), an increase in temperature can prevent eggs from developing and hatching resulting in a decrease in juvenile abundance where in some studies near-zero numbers of *P. vulnus* and *M. xenoplax* were detected in solarized soil after nine days (Shea *et al*., 2022). Shutt *et al*. (2021) showed that four and five weeks of solarization treatment were able to suppress the Meloidogyne population.

Fungivores, although few, decreased in abundance after solarization and increased at harvest. This was consistent with the study of Pires *et al*. (2023), which showed the abundance of fungivorous nematodes when the temperature increases, their numbers decrease, indicating a response to thermal stress in Alpine grassland systems. Certain temperatures reduced the abundance of fungivorous nematodes but as temperatures increase, fungivorous nematodes adapted to warming, and increasing their abundance (Liu *et al*., 2022). Fungivore abundance in agricultural fields at harvest time was higher than before and after solarization, which is related to increased root vegetation as a food source for fungivorous nematodes (Van Capelle *et al*., 2012). Soil solarization had little impact on the abundance of predatory and omnivorous trophic groups, indicating that predatory and omnivorous nematode groups were resistant to high temperatures. According to Wang *et al*. (2018), omnivorous nematodes showed resistance to climate warming as their numbers were only slightly affected by increased temperatures. Previous research found that all nematode groups (bacterivores, fungivores, predators, and plant parasites) associated with *Brassica rapa* were negatively correlated with pH and temperature and tended to be thermophilic and acidophilic (Matute *et al*., 2013).

Soil solarization caused a reduction in the number of all feeding trophies of nematodes but they eventually recover towards harvest. As harvest approaches, the soil had a large diversity of crops that provide a variety of food sources and hosts for soil nematodes. The increase in organic matter in the soil caused the number of bacteria as food for nematodes to increase. These results were in accordance with the research of Renčo *et al*. (2010) which found that bacterivorous nematodes were the most dominant group in agricultural soils. The abundance of bacteria in all agricultural ecosystems was caused by high microbial biomass due to tillage and fertilization (Renčo *et al*., 2020).

Population abundance and genus diversity of nematodes determined the diversity index (Table 3). Soil solarization significantly affected soil nematode diversity. Population abundance and diversity of nematode genus determine the value of diversity index. The highest Shannon

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diversity index was found in the non-solarization treatment (control). Diversity index analysis of soil treated with solarization decreased drastically compared to before solarization treatment.

The level of nematode diversity at the three solarization durations before treatment, after treatment and at harvest was significantly different (Table 4). Krebs (1989) states that, the criteria for the value of the Shanon-Wiener diversity index (H') is if the value of H' < 1 = low diversity, and if the value of H'< 1–3 = moderate diversity, while if the value of H' > 3 = high diversity. The Shannon-Wienner diversity index (H') is used to describe the diversity of species in a community which is an indicator of the evenness and abundance of species present and habitat disturbance. When treated with three different solarization durations, nematode diversity at 14 days solarization duration showed the lowest results (H'= 1.70) than other treatment. This showed that soil solarization affected nematode diversity. The nematode population decreased with an increase in solarization duration. Still, this result was in range of moderate diversity. Soil abiotic factors could also affect the abundance and diversity of nematodes including soil temperature, soil moisture, organic matter, and soil pH (Mutala'liah *et al*., 2017).

All parasitic nematodes associated with shallot roots caused a decrease in shallot productivity due to the root damage. Table 5 showed that the average plant height, root weight, root length, wet weight, and dry weight of shallots were higher in plants grown in solarized soil.

Soil solarization with a duration of 14 and 30 days, generally affected the average height of the plant, root weight, root length, wet weight of the shallot bulbs and dry weight of shallots bulbs which are higher than without solarization. The abundance of soil nematodes affected the growth performance of plants. Previous research showed solarization caused Meloidogyne population to be lower and enhanced plant performance than non-solarization treatment (Shutt *et al*., 2021). In addition, soil solarization can improve and maintain the availability of nutrients in soil that are essential for plant growth and development. Plants thrive at optimal growth temperature. The increase in temperature mainly affected the physiological processes of plants, especially photosynthesis, transpiration, respiration, and yield (Parthasarathi *et al*., 2022). The results of Mauromicale *et al*. (2010) showed that soil solarization could improve soil characteristics that affect plant performance by maintaining the balance of soil nutrients. In addition, soil solarization also increased dissolved nutrients such as calcium, nitrogen, and magnesium (Abd-Elgawad *et al*., 2019) to be more available for plants in solarized soil.

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CONCLUSION

Different solarization duration affected soil temperature, soil moisture, and nematode abundance and diversity. The relationship between of solarization duration and soil temperature was described by the polynomial linear regression model. Overall, in total of 22 genera nematodes were found from three solarization durations. The abundance of all nematode genera decreased significantly at a duration of 14 days of solarization. Bacterivores were the dominant trophic group in all solarization treatment. Soil solarization only had little impact on abundance of predators and omnivores nematodes. The lowest diversity index value was on 14-day solarization treatment with a value of 1.70, which slightly impacted of nematodes diversity. Shallots productivity at 14 days and 30 days solarization duration resulted in a better average productivity compared to without solarization.

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APPENDIX

Table 1. Mean soil temperature, moisture, and pH with different solarization durations

Solarization Treatment	Soil Temperature	Soil Moisture	Soil pH
14 Days	42.72 a	62.05 c	6.96 a
30 Days	41.08 b	65.14 b	6.96 a
Control	31.95 c	73.47 a	6.95 a

Notes: Means followed by the same letters were not significantly different according to Duncan's post-hoc test at 0.05 level of significance.

Table 2. Regression of the relationship between solarization duration and soil temperature

Regression relationship	Formula	R^2
Linier	$y = 0.3083x + 34.197$	0.6174
Polynomial	$y = -0.0282x^2 + 1.1633x + 31.955$	1
Exponensial	$y = 33.924e^{0.0085x}$	0.582

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Table 3. Abundance of soil nematode genera at three solarization durations

	Before solarization			After solarization			Harvest		
	Control	14 days	30 days	Control	14 days	30 days	Control	14 days	30 days
				Parasites					
Rotylenchulus	0.67 a	2.00 a	1.99 a	0.67 a	0.00 a	1.33 a	8.67 a	3.33 b	5.33 ab
Ditylenchus	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	0.67 a	1.99 a	1.99 a
Meloidogyne	6.00 a	5.33 a	8.67 a	6.00 a	0.67 b	0.67 b	10.00 a	5.99 ab	4.67 b
Helicotylenchus	0.67 b	0.00 b	4.00 a	2.00 a	0.00 a	0.00 a	10.67 a	2.67 b	8.67 ab
Pratylenchus	2.67 a	1.33 a	1.33 a	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	0.67 a
Tylenchorhyncus	1.33 a	4.00 a	1.33 a	2.00 a	0.00 b	0.00 b	10.00 a	1.99 b	1.99 b
Aphelenchoides	4.00 a	10.00 a	3.33 a	0.67 a	0.00 a	0.00 a	4.67 a	0.00 b	0.67 a
				Fungivores					
Aphelenchus	6.00 a	3.33 a	8.67 a	12.00 a	0.00 b	1.99 b	8.67 a	0.67 b	3.33 b
Tylenchus	14.67 a	11.33 a	13.33 a	12.67 a	2.00 b	6.00 b	15. 33 a	11.33 a	15.33 a
				Bacterivores					
Cephalobus	9.33 ab	4.67 b	11.33 a	7.99 a	0.67 b	5.33 a	10.67 ab	6.00 b	11.99 b
Eucephalobus	10.00 a	4.67 a	5.33 a	7.33 a	4.67 a	4.00 a	6.00 a	9.33 a	8.00 a
Mesorhabditis	2.00 a	1.33 a	0.67 a	2.67 a	0.00 b	0.00 b	4.00 a	2.67 a	5.33 a
Rhabditis	8.00 a	4.67 a	5.55 a	11.33 a	4.67 b	3.33 b	10.00 a	6.67 a	11.33 a
				Omnivores					
Eudorylaimus	0.00 a	0.00 a	0.00 a	0.67 a	0.00 a	0.00 a	1.99 a	0.67 a	1.99 a
Dorylaimus	12.67 a	16.67 a	18.67 a	18.68 a	6.67 b	4.47 b	14.00 a	16.00 a	16.00 a
Mesodorylaimus	1.99 a	0.67 a	1.33 a	2.67 a	0.00 b	1.33 ab	4.00 a	4.00 a	2.67 a
				Predator					
Aporcelaimellus	4.00 a	0.67 b	0.67 b	1.99 a	1.33 a	0.00 a	4.67 a	0.67 b	1.33 b
Discolaimium	3.33 a	2.67 a	2.00 a	1.99 a	1.33 a	1.33 a	1.99 a	0.00 b	1.33 ab
Mononchus	0.00 a	0.67 a	0.00	0.00 a	0.00 a	0.00 a	0.00 a	0.67 a	2.67 a
Mylonchulus	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	1.99 a	0.00 b	0.00 b
Granonchulus	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a	0.67 a	0.00 a	0.00 a
Tripyla	1.33 a	0.00 a	0.00 a	1.33 a	0.00 a	0.00 a	1.99 a	1.33 a	2.00 b

Notes: Means followed by the same letters were not significantly different according to Duncan's post-hoc test at 0.05 level of significance.

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Table 4. Shanon-Wiener Index of soil nematodes at three different solarization

Solarization Treatment	H' Before solarization	H' After Solarization	H' Harvest
14 Days	2.42	1.70	2.67
30 Days	2.37	2.11	2.67
Control	2.51	2.37	2.75

Table 5. Average growth of shallot plants from three different solarization duration

Solarization Treatment	Plants Height	Roots Weight	Roots Length	Gross Weight	Dry Weight
14 Days	42.32 a	7.97 a	10.55 a	99.75 a	93.19 a
30 Days	40.92 a	6.89 a	8.99 b	97.51 a	88.18 b
Control	35.04 b	5.07 b	7.63 c	77.57 b	70.26 c

Notes: Means followed by the same letters were not significantly different according to Duncan's post-hoc test at 0.05 level of significance.

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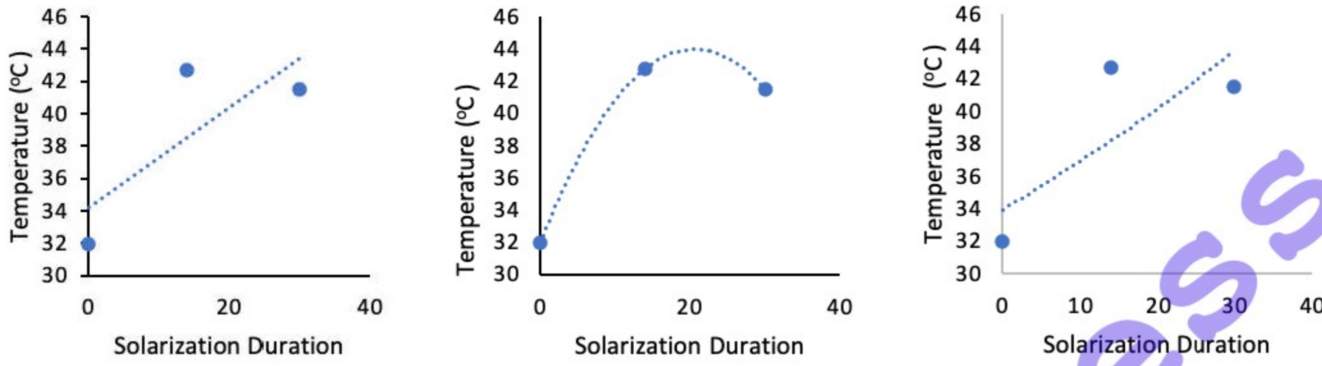

A) **B)** **C)**

Figure 1. Regression between solarization duration and soil temperature. A). Linear, B). polynomial, C). Exponential

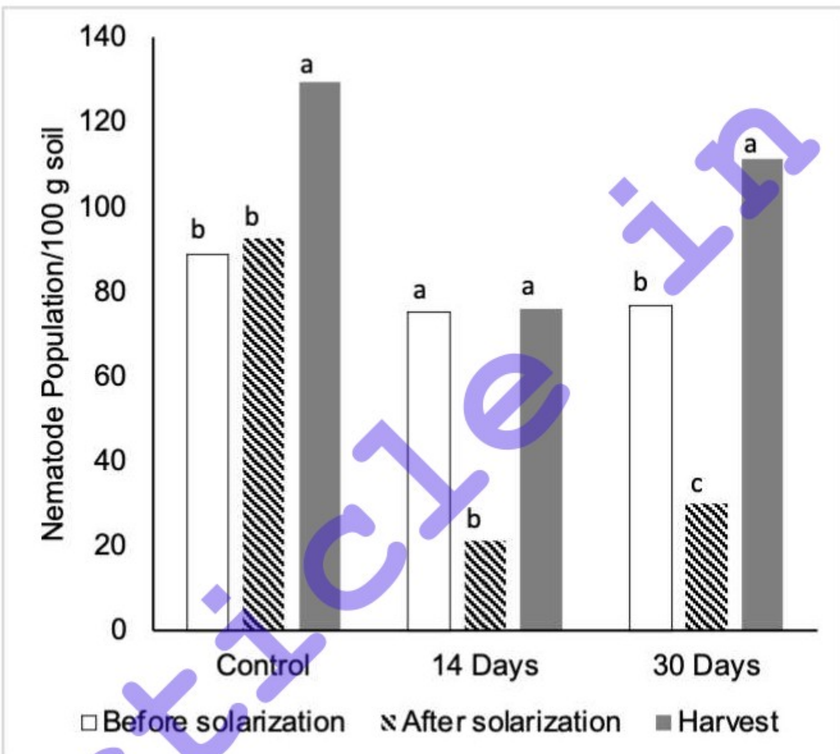

Figure 2. Nematode abundance at three different solarization durations. Bars represent the average of 15 soil samples and different letters on bars indicate significance at $p \leq 0.05$ among different solarization duration treatments.

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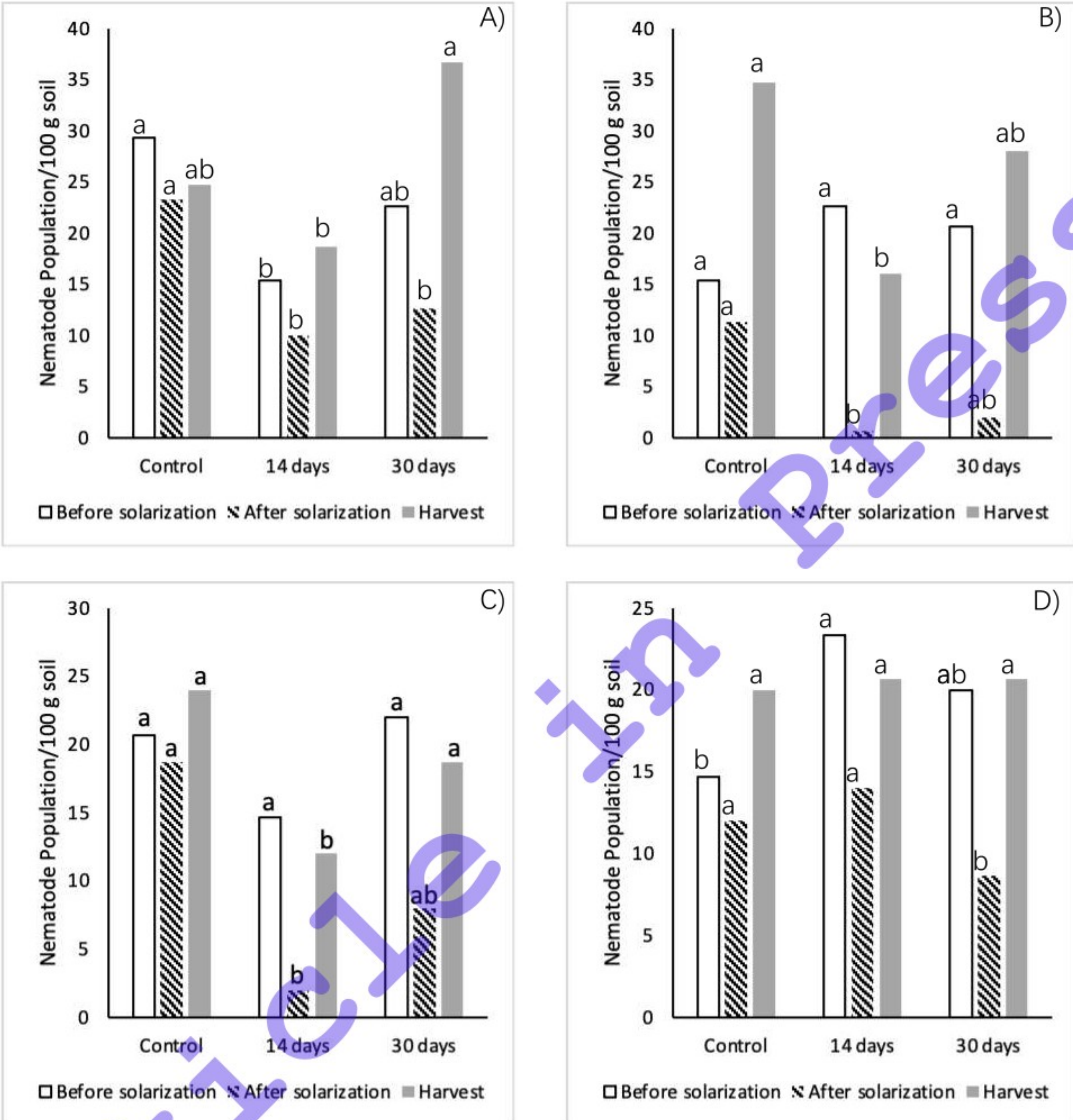

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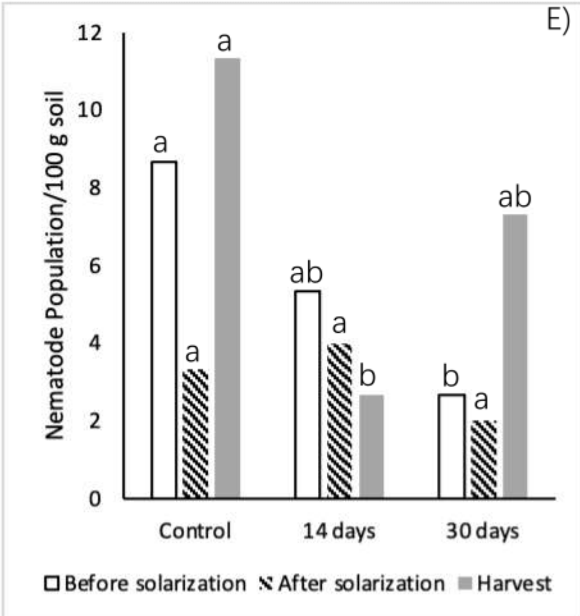

Figure 3. Abundance of nematodes from different trophic groups at three different solarization durations. A) bacterivores, B) parasitic nematodes, C) fungivores, D) omnivores, E) predators. Bars represent the average of 15 soil samples and different letters on bars indicate significance at $p \leq 0.05$ among different solarization duration treatments.

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