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FIRE EFFECT ON POPULATION OF SOIL-INHABITING NEMATODES IN CLOUDS FOREST, SHAHRUD, IRAN

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ABSTRACT

Nematodes are so abundant and omnipresent in ecosystems, hence they serve as elegant indicators of environmental disruption, including fire. The effect of fire on nematode population was studied in the soil of Clouds Forest, Shahrud, Iran. For the purpose, 100 soil samples of burned and unburned areas from the depth of 20cm were taken for two times (1 and 13 months after the fire) randomly. Nematodes were collected using sieves, and according to centrifuge method. The results showed the population of nematodes, genera *Acrobeles*, *Discolaimus*, *Mylonchulus*, *Amplimerlinius*, *Aphelenchus*, *Criconemoides*, *Nagelus*, *Helicotylenchus*, *Xiphinema*, *Filenchus*, *Crossonema*, *Rotylenchus*, *Psilenchus* and *Aphelenchoides*, decreased in the soil burned compared with unburned soil at one month after the fire. The most of reducing the population was obtained in plant-associated, predator, omnivore, plant parasite, bacteriovore and fungivore nematodes in burned soil, respectively. The population experienced higher than increase in the 13 months after a fire in predator, plant parasite, bacteriovore, omnivore, plant-associated and fungivore nematodes, respectively ($p \leq 0.05$).

Key words: Forest, Fire, Soil, Nematode, Environment.

Introduction

Fire is an important part of the evolutionary history of most forest ecosystems in the world (Conard *et al*., 2001 and Covington and Moore, 1994). The effects of fire on forest ecosystem are complex, so that fire caused changes in the physical, chemical and biological properties in forest soil (Neary *et al*., 1999). Among these properties the forest biomass has been more sensitive to heat (DeBano *et al*., 1998). The soil fauna play critical role in preserving soil structure and enhancing nutrient cycling (Coleman *et al*., 1984; James, 1988; McSorley, 1993 and Reichle, 1997). Nematodes, mites, rotifers, earthworms and insect larvae are the most important animal groups in the soil (Lupwayi *et al*., 2010). Nematodes are vermiform animals, the most terrestrial, and microscopic, 1-10 mm long (Perry and Zunche, 1997). The phylum of Nematoda is found in different habitats (Bloemers *et al*., 1997) and after insects, the greatest diversity of species of animals (Weisz and Keogh, 1982).

Nematodes constitute one of the most important groups of organisms which inhabit the soil about the roots of plants and which frequently play a vital part in their growth and production. Rarely is any crop free from their attacks, whether in the field, the orchard, the home garden, or the greenhouse. These slender, active, wormlike creatures are found not only in the soil, but also in fresh and salt water wherever organic matter exists, from the arctic to the tropics and from the ocean depths to the tops of high mountains (Thorne, 1961). Nematodes are the most numerous Metazoan on earth. They are either free-living or parasites of plants and animals. Although they occur in almost every habitat (Cobb, 1915), they are essentially aquatic animals. Nematodes depend on moisture for their locomotion and active life and therefore soil moisture, relative humidity and other environmental factors directly affect nematode survival. However, many nematodes can survive in a hydrobiotic state. Soil structure is influential as pore size affects the ease with which nematodes can move through the soil interstices (Perry and Moens, 2006).

Nematodes play a substantial part in all ecosystems, ranging from deserts to the polar areas (Perry and Zunche, 1997). The animals are so abundant and omnipresent in ecosystems, so serve as elegant indicators of environmental disturbance (Bongers, 1990; Ferris *et al*., 2001; Heininger *et al*., 2007; Höss *et al*., 2004; Schratzberger *et al*., 2006 and Yeates, 2003). They have an intricate relationship with the soil ecosystem, as most of them spent at least part of life cycle in the soil. The animals are very diverse in terms of the feeding habits and fed bacteria, fungi, and microscopic animals or may be a parasite of plants, animals and human (Freckman and

> The most of population decrease was obtained in plant-associated, predator, omnivore, plant parasite, bacteriovore and fungivore nematodes in burned soil, respectively.

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Baldwin, 1990; Freckman and Virginia, 1997 and Ingham, 1994).

The groups of Rhabditids and Cephalobids are bacteriovore; Aphelenchids are fungivore; Hoplolaimids, Criconematids, Dolichodorids and Longidorids are plant parasite; Tylenchids are plant-associated; Mononchids are predator and Dorylaimids are omnivore nematodes (Brzeski, 1998; Perry and Moens, 2006 and Thorne, 1961).

Nematodes have successfully adapted to nearly every ecosystem from marine (salt water) to fresh water, to soils, and from the Polar Regions to the tropics, as well as the highest to the lowest of elevations. They are ubiquitous in freshwater, marine, and terrestrial environments, where they often outnumber other animals in both individual and species counts, and are found in locations as diverse as mountains, deserts and oceanic trenches. They are found in every part of the earth's lithosphere. Nematodes have even been found at great depth (0.9-3.6 km) below the surface of the Earth in gold mines in South Africa (Borgonie *et al*., 2011). Their many parasitic forms include pathogens in most plants and animals (including humans) (Hsueh *et al*., 2014). Some nematodes can undergo cryptobiosis. One group of carnivorous fungi, the nematophagous fungi, are predators of soil nematodes. They set enticements for the nematodes in the form of lassos or adhesive structures (Pramer, 1964; Hauser, 1985 and Ahrén *et al*., 1998).

Referable to the feeding habits, nematodes have both negative and positive effects on the soil ecosystem. Negative effects include transmission of some plant pathogens such as viruses, crop loss and reduction of beneficial soil organisms (Nickle, 1991 and Sasser, 1989). However, nematodes also feed on pathogenic organisms, a positive effect. Nematodes are rich sources of foods because they store most of their energy as biomass, which is given back to the soil community upon death (Freckman and Baldwin, 1990).

Several studies have been done on the effect of forest fire on the soil microbial population structure (Baath *et al*., 1995; DeBano *et al*., 1998; Fonturbel *et al*., 1995 and Matlak, 2001). In the most of the studies, heat of fire reduced the properties population of these beings and changed the rest of the feeding habits population (McSorley, 1993 and Rutigliano *et al*., 2007). In recent years, several fires were occurring in the forest regions of Iran (Fig. 1), so to study the effect of fire on soil organisms were considered to maintain optimal conditions of the forest and its management. Effects of fire on soil microorganisms such as nematodes, taking into consideration the type of feeding habits, is significant the stability and performance of all components of forest ecosystems. So, was studied population of nematodes, based feeding habits, in the burned and unburned soil of Clouds Forest, Shahrud, Iran. As the knowledge of nematodes increases, the data can be applied in the management of natural and agricultural ecosystems.

Fig. 1: A: A view of Clouds Forest, B: Forest fire, C, D: Forest conditions at the times of sampling.

Material and Methods

Study area

The study area is located in the Clouds Forest (in Persian: Abr), northeastern Iran. This area has a temperate climate, with mild, cold winters and mild, hot summers. The annual average rainfall is 438 mm, almost exclusively all falling in autumn and winter (October-March). The average maximum daily temperature in the hot season is 38^{0}C (in August), and it is -10^{0}C in winter (in January). The topography is mountainous, with several steep slopes, and has a peak of 1,400 m amsl. Vegetation at the site is in the main composed of yew (*Taxus baccata* L.), alder (*Alnus subcordata* C. A. May), ash (*Fraxinus angustifolia* Vahl), and zelkova (*Zelkova carpinifolia* (Pall.) Dippel). In September 2010, fire damaged an area of approximately 50 ha. To the same conditions in the study area, a site of border of burned and unburned soil was chosen to study with vegetation and altitude as the same condition. The geographical location of the site was 55^{0}04'43'' E and 36^{0}47'49'' N. In each of burned and unburned soil was selected 10 contiguous blocks, 5×5 m for the study (Fig. 2).

Sampling

At two times (1 and 13 months after the fire) in October 2010 and 2012, was sampled of soil from burnt and unburnt blocks. Each block was randomly sampled from 20 cm depth of soil. Sample replicates, each weighing 250g, were collected seasonally in individual bags. In total, 100 soil samples were collected. Samples were transported to the laboratory to extract and identify

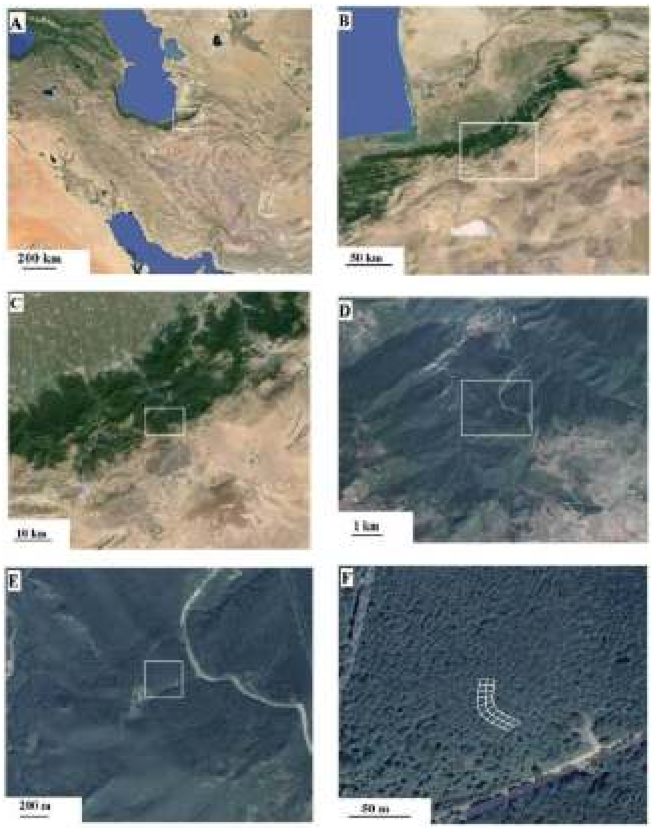

Fig. 2: Location map of the study area (A-F). A: Iran, B: Northeastern Iran, C: Shahrud region, D: Clouds Forest, E: Fire occurrence area, F: Sampling blocks.

nematodes. Soil samples were kept in cold storage at 4°C until being processed.

Laboratory investigation

Nematodes were extracted from 200g of fresh soil samples using sieves (10, 45, 60, 100 and 400 mesh), and according to centrifuge or flotation of the sugar solution (1.18 g/cm^3) method (Jenkins, 1964), then were preserved in formalin 40% (De Grisse, 1969). Nematodes from each sample were identified to order and family using a compound stereomicroscope and were classified based on morphological characteristics into the trophic groups according to known feeding habitats (Brzeski, 1998; Perry and Moens, 2006; Siddiqi, 2000 and Thorne, 1961). The nematode population was determined in groups of feeding habits: bacteriovore, fungivore, predator, omnivore, plant associated and plant parasite per kg of soil.

Statistical method

Analysis of the data was performed based on a randomized complete block design based on nematode population in each group of feeding habits. All data were submitted to a statistical analysis of variance (ANOVA) using the SAS model with Duncan's multiple-range test, and were applied to assess differences between separate means. Differences at the level of $p \leq 0.05$ were considered statistically significant.

Results and Discussion

Nematodes were separated of six groups of feeding habits bacteriovore, fungivore, predator, omnivore, plant-associated and plant parasite; and have been identified, including groups of Criconematids, Dolichodorids, Hoplolaimids and Longidorids as plant parasite, Tylenchids as plant-associated, Aphelenchids as fungivore, Rhabditids and Cephalobids as bacteriovore, Mononchids as predator, and Dorylaimids as omnivore. The results confirmed our expectation that nematode populations of all groups of feeding habits were highest in the control blocks and lowest in the burned blocks in both times of sampling (Fig. 3 and 4). The results showed the population of nematodes, genera *Acrobeles*, *Discolaimus*, *Mylonchulus*, *Amplimerlinius*, *Aphelenchus*, *Criconemoides*, *Nagelus*, *Helicotylenchus*, *Xiphinema*, *Filenchus*, *Crossonema*, *Rotylenchus*, *Psilenchus* and *Aphelenchoides*, decreased in the soil burned compared

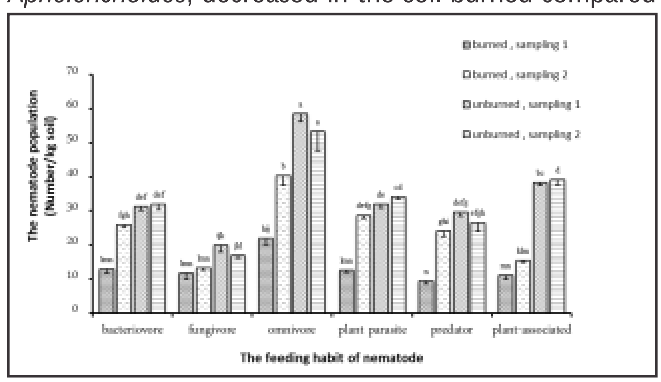

Fig. 3. The nematode population (Number / kg soil) on the feeding habits in burned and unburned areas at the times of sampling after the fire (sampling 1: 1 month after the fire, sampling 2: 13 months after the fire).

Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

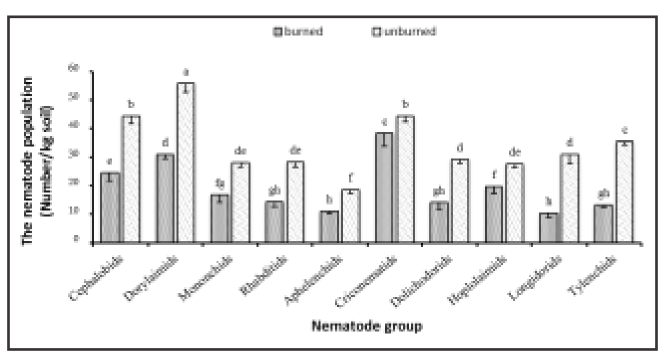

Fig. 4: The nematode population (Number / kg soil) on the groups of nematodes in burned and unburned areas.

Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

with unburned soil at one month after the fire (Fig. 5). The population of nematodes fell in the soil burned than unburned at the times of sampling (1 and 13 months) after the fire. The most of population reduction in soil one month after the fire was observed in plant-associated, predator, omnivore, plant parasite, bacteriovore, and fungivore nematodes, respectively (Fig. 6). In the 13 months after the fire, the highest and the lowest reduction of nematode population were obtained in plant-associated and predator nematodes, respectively (Fig. 6). The highest and lowest percentage of reduction, both sampling times, about plant parasite nematodes was observed in Longidorids and Criconematids, respectively (Fig. 7).

The most to the least of the increase of nematode population (%) on the feeding habits in the year between the two sampling after the fire obtained in predator, plant parasite, bacteriovore, omnivore, plant-associated, and fungivore nematodes, respectively; so that all feeding habits were significantly different from each other ($p \leq 0.05$) (Fig. 8).

In this case, the greatest increase in population was observed in Dolichodorids (plant parasite), and the lowest in Aphelenchids (fungivore) (Fig. 9).

Research has demonstrated the immediate effect of fire on soil microorganisms is a reduction of their biomass. In fact, the peak temperatures often considerably exceed those required for killing most living beings (DeBano *et al*., 1998). In extreme cases, the topsoil can undergo complete sterilization. Adverse effects on soil biota can be due also to some organic pollutants produced by the burning processes (Kim *et al*., 2003).

The fire resulted in a lower trophic diversity, lower generic diversity, and lower generic richness in burned forest soils than in unburned forest soils. In other words, the fire was able to change the balance of the feeding habits diversity in the biomass of forest topsoil (Pen-

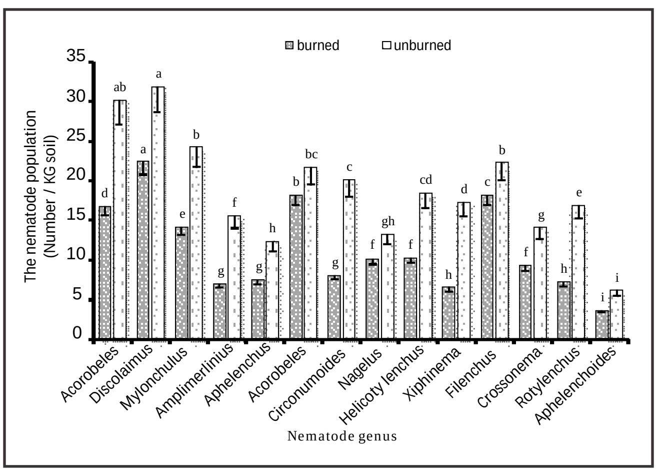

Fig. 5. The nematode population (Number / kg soil) on the genera of nematodes in burned and unburned areas.
Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

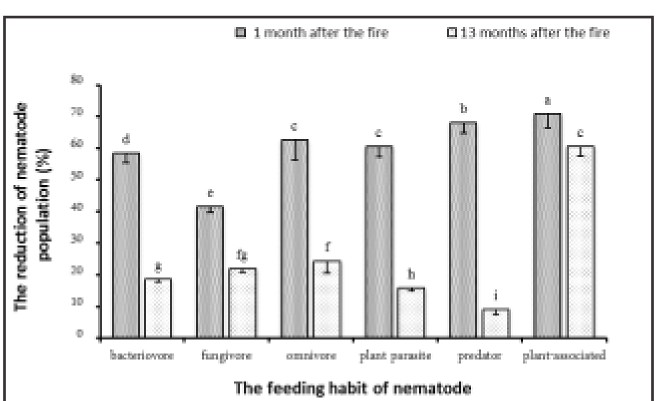

Fig. 6. The reduction of nematode population (%) on the feeding habits in the times of sampling after the fire.
Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

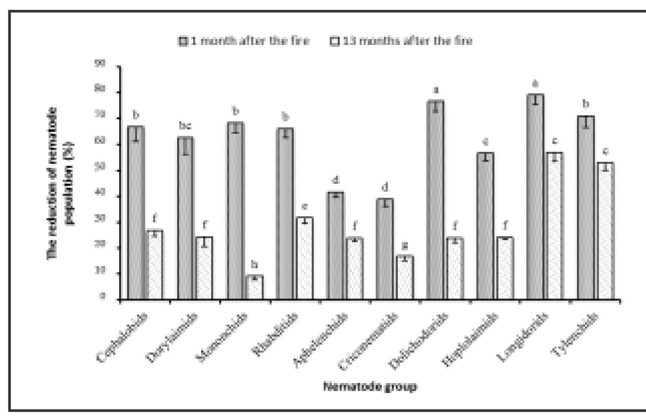

Fig. 7: The reduction of nematode population (%) on the groups of nematodes in the times of sampling after the fire.
Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

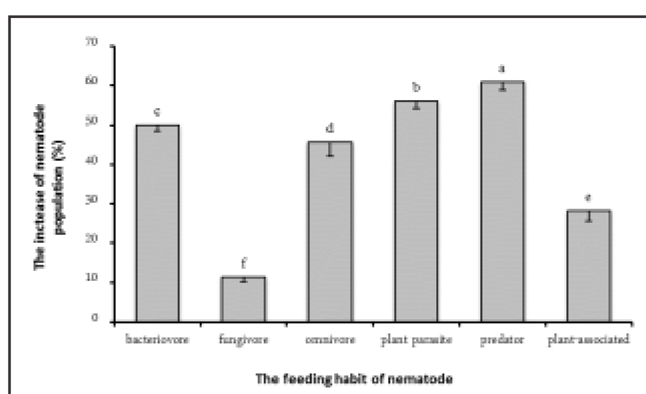

Fig. 8: The increase of nematode population (%) on the feeding habits in the year between the two sampling after the fire.
Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

Mouratov *et al*., 2012). In this study, the maximum of the population in the unburned soil related to the omnivore, plant-associated, plant parasite, bacteriovore, predator and fungivore nematodes, respectively; whereas these conditions have altered so that the maximum amount of nematode population has been obtained in burned soil, one month after the fire, on the feeding habits of omnivore, plant parasite, bacteriovore, fungivore, plant-associated, and predator respectively (Fig. 3).

Some researchers have shown that bacteriovore nematodes (Cephalobids: *Acrobeloides* spp. and *Cephalobus* spp.) were more abundant in burned forest soils than in soils of the unburned forest. This probably responded to the higher microbial biomass that developed because of greater available nutrients and organic carbon in post-fire soils (Rutigliano *et al*., 2007). In Clouds Forest, from unburned soil, the highest population of nematode was obtained in Dorylaimids (omnivore) then Cephalobids (bacteriovore) and Criconematids (plant parasite) (Fig. 4). However, the highest reduction of nematode population (%) on the groups of nematodes in the times of sampling after the fire was obtained on Dolichodorids and Longidorids from plant-parasitic nematodes and Cephalobids and Rhabditids from bacteriovore nematodes, and Mononchids and from predator nematodes (Fig. 7).

Ross *et al.* (1997) have reported the increase in plant-associated nematodes parallels the plant growth-related increase in soil invertase activity. The status of the plant-associated nematodes were found in the clouds Forest

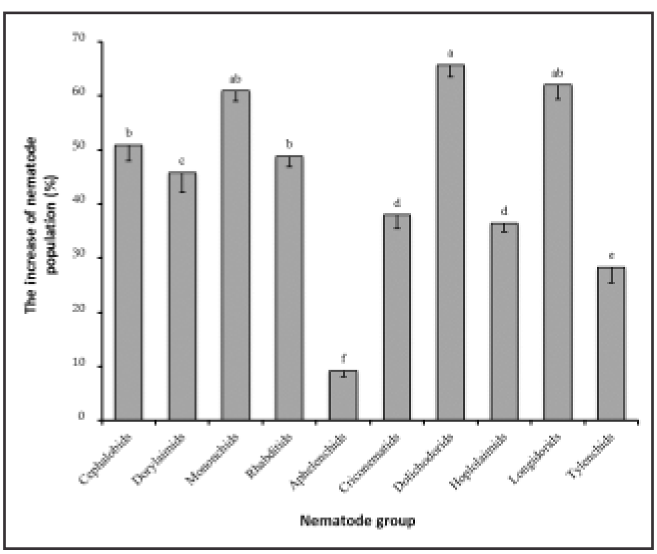

Fig. 9: The increase of nematode population (%) on the groups of nematodes in the year between the two sampling after the fire.

Comparisons were carried out using Duncan test (α=0.05); means that do not share the same letter are significantly different (p=0.05).

(Fig. 8). In the other words, the lowest of the increase of nematode population were about to fungivore and plant-associated. Plant parasitic nematodes are dependent on the health of the plant. A sudden change in the health of the plant, such as the occurrence of forest fires, without new growth, could possibly cause plant parasitic nematodes to decrease in abundance. It was found while both burning and mowing affects the health of the plant, plots that are cleared of litter tend to regenerate more quickly (Freckman and Baldwin, 1990). An overabundance of litter caused by mowing could also introduce too many toxins into the soil and decrease nematode population (Yeates *et al*., 1997).

In the burned soil was found that after 13 months of clouds forest fire, predator and plant parasite nematodes population were increased significantly compared with the previous year (the first sampling time). In this study, the greatest increase in population, two sampling intervals, after the predator nematodes and plant parasitic nematodes was observed in bacteriovore nematodes (Fig. 8).

Fonturbel *et al*. (1995) observed that total microflora and single microbial groups, such as heterotrophic bacteria, filamentous fungi, and algae, did not suffer any long-term effect when moderate intensity wildfires occurred in pinus forests periodically submitted to controlled fires. However, in the study, the fungivore nematodes had the lowest percentage of population reduction after the fire compared with other feeding habits groups (Fig. 6).

It seems that predator and omnivore nematodes were very susceptible to fire. Bongers and Ferris (1999) found that predators and omnivores nematodes were sensitive to ecological disturbances such as forest fire. The experimental results showed that the highest of the percentage of population reduction, a month after the fire, related to plant-associated nematodes; and predator and omnivore nematodes were followed (Fig. 6).

McSorley (1993) reported that numbers of bacteriovores and omnivores increased within 6 weeks after a fire. He also reported a decrease in fungivores nematodes, but no change in abundances of plant parasite nematodes. Some of the short-term effects of fire reported by McSorley (1993) extended through 2 years post-burn. Bacteriovores numbers remained higher in burned areas, with more intact trees than in unburned forest soils. However, numbers of fungivores in burned forest soils did not differ from those in unburned forest soils. Thus, the deleterious effect of fire on those fungivores was either short-term or did not occur as a result of the fire. In conclusion, wildfire in conifer forests in a Mediterranean climatic region had several long term effects on soil-nematode communities. These effects appeared to be mediated through changes in food resources of different nematode groups. The most significant differences were marked increases in the abundances of 2 genera of bacteriovores nematodes (*Cephalobus* spp. and *Acrobeloides* spp.) and reduced numbers of omnivore nematodes.

In the study, within one year after the first sampling, were observed percentage of population increase in all feeding habits groups nematodes. The increase was higher in predator and plant parasitic nematodes, and was lower in fungivore and bacteriovore nematodes (Fig. 8).

These results suggest, although the population of predator and plant parasitic nematodes is rapidly reduced after the fire (sampling one month after the fire) (Fig. 6), but after a year, the population of predator and plant parasite nematodes has increased, gradually increasing vegetation and microorganism population in burned soil (Fig. 8).

From Mediterranean region, in a pine forest, found that within six weeks after controlled burning, total numbers of omnivore nematodes were increased, while that of plant parasite was the same. These effects seem to occur through changes in food sources of nematodes. The fungivore nematodes declined after burning while bacteriovore, initially the most abundant bacteriovore, increased (McSorley, 1993). Censusing soil nematodes at 99 burnt and unburnt forested sites, Matlack (2001) concluded that, in the long run, fire does not significantly affect the nematode community either in the number of individuals or diversity.

Bloemers *et al*. (1997) found that forest disturbance had an effect on nematode species diversity, possibly due to the large change in the nematode food supply.

Research has shown fire affects fungi more than bacteria (Baath *et al*., 1995 and Vasquez *et al*., 1993); therefore the higher numbers of bacteriovores nematodes in burned forest soils.

Since the lowest population decline was related to fungivores nematodes in the results, it is apparent that the fire had either no significant effect on soil fungi and fungivores nematodes or had only a short-term effect that lasted for less than one year. While plant-associated and predator nematodes were more reduction of population in soils of the burned forest. These groups may have colonized roots that were still alive, but that was stressed by the loss of nutrients from the fire-killed canopy.

The results of some studies have shown significant differences in the abundance of fungivore nematode papulation in burned and unburned forest. Hence, some researchers believe that the fire is at least a short-term effect on populations of fungi and fungivore nematodes in the soil so that the effect gradually being resolved within a year. While predator nematodes and some plant parasitic nematodes in unburned soil (compared with burnt soil) were more abundant, and had a slight population decrease (Bááth *et al*., 1995 and Vasquez *et al*., 1993).

Bloemers *et al*. (1997) suggested that a positive relationship exists between the amount of substrate for plant growth and an abundance of parsers such as bacteria and fungi.

A research has shown a gradual increase is predictable in soil that has been bacteriovore and fungivore populations of nematodes (Pen-Mouratov *et al*., 2012).

Bloemers *et al*. (1997) suggested there could be a positive correlation between the amount of litter and abundance of primary decomposers. Pen-Mouratov *et al*. (2012) could then expect bacteriovore and fungivore nematodes to increase in mowed prairie plots that were also recently burned. Bloemers *et al*. (1997) found the inverse of this to be true as well: in tropical soils, the proportion of bacteriovore nematodes decreased as organic inputs to soil decreased. None of the treatments increased nematode abundance over the control group.

Further studies on the relationship of soil and nematodes in burned forests can be measure soil moisture, pH and organic matter content, as well as the identification of nematode species. Since the survival and activity of soil moisture depend nematodes, this could be a long-term relationship between humidity and nematode population considered in the discussion of forest fires.

Conclusions

As expected fire as a disruptive environmental factor decreased population of nematodes in forest topsoil. The most of population decrease was obtained in plant-associated, predator, omnivore, plant parasite, bacteriovore and fungivore nematodes in burned soil, respectively. The population had higher than increase in the 13 months after the fire in predator, plant parasite, bacteriovore, omnivore, plant-associated and fungivore nematodes, respectively. The highest and lowest percentage of reduction, both sampling times, about plant parasite nematodes was observed in Longidorids and Criconematids. The greatest increase in population was observed in Dolichodorids (plant parasite), and the lowest in Aphelenchids (fungivore).

मेघ वन, शाहरूद, ईरान में मृदा-निवासी सूत्रकृमिकों की आबादी पर आग का प्रभाव

हमीद रजा अबदूस एवं अयातुल्लाह सईदीजेदाह

सारांश

सूत्रकृमि पारितंत्रों में बहुत प्रचुर और सर्वव्यापी हैं, अतः ये आग सहित पर्यावरणीय गड़बड़ी के परिष्कृत के रूप में कार्य करते है। मेघ वन, शाहरूद ईरान की मृदा में सूत्रकृमि आबादी पर आग के प्रभाव का अध्ययन किया गया। इस प्रयोजन के लिए बेतरतीब रूप से दो बार (आग के बाद 1 और 13 माह पर) 20 से.मी. की गहराई से जले और बिना जले क्षेत्रों के 100 मृदा नमुने लिए गए। छलनी का उपयोग करके और अपकेंद्रित्र विधि के अनुसार सूत्रकृमि एकत्र किए गए। परिणामों ने आग के एक माह बाद बिना जली मृदा की तुलना में जली मृदा में सूत्रकृमियों, वंश *एक्रोबीलीस, डिस्कोलिमस, माइलोनकूलस, एम्पलिमीर्लिनियस, एफीलींकस, क्रिकोनीमॉइडीस, नेजीलस, हीलिकॉटलींकस, जाइफिनीमा, फाइलेंकस, क्रोसोनीमा, रॉटीलींकस, सिलींकस* और *एफीलींकॉइडीस* की आबादी में कमी को दर्शाया है। अधिकांश ह्वासमान आबादी जली मृदा में क्रमशः पादप सम्बद्ध, परभक्षी, सर्वभक्षी, पादप परजीवी, जीवाणुभोजी, कवकभोजी सूत्रकृमियों में पाई गई। क्रमशः परभक्षी, पादप परजीवी, जीवाणु भोजी, सर्वभक्षी, पादप सम्बद्ध और कवकभोजी सूत्रकृमियों में आग के बाद 13 महीने में वृद्धि की अपेक्षा आबादी उच्च अनुभव की गई ($P \leq 0.05$)।

References

Ahrén D., Ursing B.M., Tunlid A. (1998). Phylogeny of nematode-trapping fungi based on 18S rDNA sequences. *FEMS Microbiology Letters*, 158(2): 179–184.

Bááth E., Frostegárd A., Pennanen T. and Fritze H. (1995). Microbial community structure and pH response in relation to soil organic-matter quality in wood-ash fertilized, clear-cut or burned coniferous forest soils. *Soil Biology and Biochemistry*, 27: 229-240.

Bloemers G.F., Hodda M., Lambshead P.J.D., Lawton J.H. and Wanless F.R. (1997). The effects of forest disturbance on diversity of tropical soil nematodes. *Oecologia*, 111: 575-582.

Bongers T. (1990). The maturity index: an ecological measure of environmental disturbance based on nematode species composition. *Oecologia*, 83: 14–19.

Bongers T. and Ferris H. (1999). Nematode community structure as a bioindicator in environmental monitoring. *Trends in Ecology and Evolution*, 14: 224-228.

Borgonie G., Garcia-Moyano A., Litthauer D., Bert W., Bester A., van Heerden E., Möller C., Erasmus M. and Onstott T.C. (2011). Nematoda from the terrestrial deep subsurface of South Africa. *Nature*, 474(7349): 79–82.

Brzeski M.W. (1998). *Nematodes of Tylenchina in Poland and Temprate Europe*. Warszawa, Poland, Muzeum I Instytutu Zoologii Polska Academia Nauk, 397 pp.

Cobb N.A. (1915). *Nematodes and their relationships.* Yearbook of the Department of Agriculture for 1914, Washington, DC, pp. 457-490.

Coleman D.C., Anderson R.V., Cole C.V., McClellan J.F., Woods L.E., Trofymow J.A. and Elliott E.T. (1984). *Roles of protozoa and nematodes in nutrient cycling*. In: Giddens, J.E.; Todd, R.L. (Editors), *Microbial-plant interactions*. pp.17-28. American Society Agronomy, Madison, U.S.A. 68 pp.

Conard S.G., Hartzell T., Hilbruner M.W. and Zimmerman G.T. (2001). Changing fuel management strategies the challenge of meeting new information and analysis needs. *Inter. J. Wildland Fire*, 10: 267-275.

Connor H.E. and Edgar E. (1987). Name changes in the indigenous New Zealand flora 1960-1986 and Nomina Nova IV, 1983-1986, *New Zealand J. Botany*, 25: 115-170.

Covington W.W. and Moore M.M. (1994). Southwestern ponderosa forest structure - changes since Euro-American settlement. *The J. Forestry*, 92: 39-47.

De Bano L.F., Neary D.G. and Ffolliott P.F. (1998). *Fire effects on ecosystems*. Wiley, New York, 333 pp.

De Grisse A. (1969). Redescription ou modification de quelques techniques dans L'etude des nematodes phytoparasitaires. *Mededelingen Rijksfaculteit der Landbouwwetenschappen Gent*, 34: 351-369.

Ferris H., Bongers T. and De Goede R.G.M. (2001). A framework for soil food web diagnostics: extension of the nematode faunal analysis concept. *Applied Soil Ecology*, 18: 13–29.

Fonturbel M.T., Vega J.A., Bara S. and Bernardez I. (1995). Influence of rescribed burning of pine stands in NW Spain on soil microorganisms. *The European J. Soil Biology*, 31: 13-20.

Freckman D.W. and Baldwin J.G. (1990). *Soil Biology Guide*. Pp. 155-200 in Daniel L. Dindal (Ed). John Wiley & Sons, New York, 341 pp.

Freckman D.W. and Virginia R.A. (1997). Low-Diversity Antarctic soil nematode communities: Distribution and response to disturbance. *Ecology*, 78(2): 363-369.

Hauser J.T. (1985). Nematode-trapping fungi. *Carnivorous Plant Newsletter*, 14(1): 8–11.

Heininger P., Höss S., Claus E., Pelzer J. and Traunspurger W. (2007). Nematode communities in contaminated river sediments. *Environmental Pollution*, 146: 64–76.

Höss S., Traunspurger W., Severin G.W., Juttner I., Pfister G. and Schramm K.W. (2004). Influence of 4-nonylphenol on the structure of nematode communities in freshwater microcosms. *Environmental Toxicology and Chemistry*, 23: 1268–1275.

Hsueh Y.P., Leighton D.H.W. and Sternberg P.W. (2014). *Nematode Communication*. In: Biocommunication of animals (Witzany G ed). Springer, p. 383-407.

Ingham R.E. (1994). Nematode Interactions. *Ecology*, 75(7): 2146 2147.

James SW. (1988). The postfire environment and earthworm populations in tall grass prairie. *Ecology*, 69: 476-483.

Jenkins W.R. (1964). A rapid centrifugal flotation technique for separating nematodes from soil. *Plant Disease Reporter*, 48: 692.

Kim E.J., Oh J.E. and Chang Y.S. (2003). Effects of forest fire on the level and distribution of PCDD/Fs and PAHs in soil. *Science of the Total Environment*, 311:177–189.

Lupwayi N., Hamel C. and Tollefson T. (2010). Soil biology of the *Canadian prairies*, *Agricultural Soils of the Prairies*, 3: 16-24.

Matlack G.R. (2001). Factors determining the distribution of soil nematodes in a commercial forest landscape. *Forest Ecology and Management*, 146: 129–143.

McSorley R. (1993). Short-term effects of fire on the nematode community in a pine forest. *Pedobiologia*, 37: 39-48.

Neary D.G., Klopatek C.C., DeBano L.F. and Ffolliott P.F. (1999). Fire effects on belowground sustainability: a review and synthesis. *Forest Ecology and Management*, 122: 51-71.

Nickle W.R. (1991). *Manual of Agricultural Nematology*. Marcel Oekker. Inc. New York, 103 pp.

Pen-Mouratov S., Ginzburg O., Whitford W.G. and Steinberger Y. (2012). Forest fire modifies soil free-living nematode communities in the biriya woodland of Northern Israel. *Zoological Studies*, 51(7): 1018-1026.

Perry R.N. and Moens M. (2006). *Plant Nematology*. Printed and bound in the UK by Biddles Ltd, King's Lynn, 447 pp.

Perry R.N. and Zunche U. (1997). *Nematodes: harmful and beneficial organisms*. In Fauna in soil ecosystems: recycling processes, nutrient fluxes, and agricultural production (G. Benckiser Ed.), (pp 85-124). New York: Marcel Dekker, Inc, 400 pp.

Pramer C. (1964). Nematode-trapping fungi. *Science*, 144(3617): 382–388.

Reichle D.E. (1997). *The role of Soil invertebrates in nutrient cycling, Soil organisms as Components of ecosystems.* (V. Lohm, and T. Person Ed.), Swedish Natural Science Research Council, Stockholm, 252 pp.

Ross D.J., Speir T.W., Tate K.R. and Feltham C.W. (1997). Burning in a New Zealand snow-tussock grassland: effects on soil microbial biomass and N and P availability, *New Zealand J. Ecology*, 21: 63-71.

Rutigliano F.A., DeMarco A., D'Ascoli R., Castaldi S., Gentile A. and De Santo A.V. (2007). Impact of fire on fungal abundance and microbial efficiency in C assimilation and mineralization in a Mediterranean marquis soil. *Biology and Fertility of Soils*, 44: 377-381.

Sasser J.N. (1989). *Plant parasitic nematodes: The farmers' hidden enemy*. Department of plant pathology, North Carolina State University, 116 pp.

Schratzberger M., Bolam S., Whomersley P. and Warr K. (2006). Differential response of nematode colonist communities to the intertidal placement of dredged material. *J. Experimental Marine Biology and Ecology*, 334: 244–255.

Siddiqi M.R. (2000). *Tylenchida, Parasites of Plants and Insects*. CABI Publishing, St. Albans, Wallingford, UK, 833 pp.

Thorne G. (1961). *Principles of Nematology*. McGraw-Hill Book Company, Inc. New York, Toronto, London, 553 pp.

Vasquez F.J., Acea M.J. and Carballas T. (1993). Soil microbial populations after wildfire. *FEMS Microbiology Ecology*, 13: 93- 104.

Weisz P.B. and Keogh R.N. (1982). *The Science of Biology*. Fifth Edition, McGraw-Hill College, 1010 pp.

Yeates G.W. (2003). Nematodes as soil indicators: functional and biodiversity aspects. *Biology and Fertility of Soils*, 37: 199–210.