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Study of *Arthropoda* associated with the windrow composting of municipal solid waste

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Abstract
Many *Arthropoda* are active in degradation of decomposable components of municipal solid waste and can develop their complete life cycle or a part of it in compost pile. The aim of the study was to identify *Arthropoda* living in the compost pile during the composting process. This descriptive study was carried out by sampling a compost pile in the research center of Kashan University of Medical Sciences that lasted 63 days. 11 samples were taken in order to evaluate individuals of Arthropoda present at different stages of compost and also 11 separate samples were taken for the determination of physical and chemical characteristics of compost and transferred to laboratory. During composting process of solid wastes four classes including Insecta (73.44%), Arachnida (24.47%), Chilopoda (1.19%) and *Diplopoda* (0.9%) with respect to immature and adult were identified. Class *Insecta*, order *Diptera* (39.11%) was among the most abundant and diverse groups reported. The results of the present work showed that composting, due to the presence of high quantity of organic matters and food naturally attracts many *Arthropoda* that convert the materials into biomass. Therefore, the proper site selection has a great importance in the location of compost sites.

Keywords: Compost, insecta, Arachnida, Chilopoda, Diplopoda

1. Introduction

Solid waste management especially in populated and metropolitan areas is increasingly difficult and costly [1]. Organic matters comprising a significant portion of domestic, industrial and agricultural wastes can cause serious threats to environment in case of poor management [2]. According to a legislation enacted by The European Union in 2005, organic matters must be managed properly prior to final disposal [3]. Composting is one of the management methods in which organic matters are decomposed by existing microorganisms; pathogens are destroyed and finally a harmless, odorless and stabilized matter is produced [4, 5]. By this method, organic components of the wastes are converted into suitable humus applicable for nourishing and amending of soil instead of disposing them in landfills that is costly [6-8].

Composting process is commonly done in two ways; aerobically and an aerobically. Windrow is one of the most common aerobic methods using for decomposing of organic wastes [9, 10]. Windrow composting proceeds in four stages; mesophilic, thermophilic, cooling and maturation [11]. Key parameters in composting process include pH, temperature, humidity, oxygen and ratio of carbon to nitrogen. These parameters are strongly interdependent; their control is therefore necessary [3, 12]. The recommended parameters are a temperature in the range 37 to 60 ºC, a humidity between 40 and 60%, carbon to nitrogen ratio 20-25 to 1, a pH in the range 6 - 8 and an amount of oxygen of 21% for preserving aerobic conditions, and the whole pile must be returned twice a month by hand or mechanically [4, 13, 14].

Bacteria, fungi, molds, and macroinvertebrates such as some *Arthropoda* live in compost piles [15] and many types of them are active in the decomposition of organic matters at different stages of composting [16]. More than 2000 species of bacteria have been identified in compost studies. The main group of bacteria responsible for composting are thermophilic ones [3]. More than 194 species of mold and fungi have been investigated in composting processes. *Aspergillus fumigatus* is one of the responsible species that is even found sometimes at distances 500 meters downstream in the wind direction [17-19]. Temperature and humidity are two main items for survival, growth and development of bacteria and fungi [20].

Compounds generated at the different decomposition stages of wastes attract a diversity of *Arthropoda*, and most of them complete their life cycles within the compost [15].

Some of the *Arthropoda* including *Musca domestica* are attracted by compost piles due to their odorous nature, but could carry diseases on their legs, their digestive system and the small hairs that cover their bodies [21-23].

Beetles of the Chilopoda are attracted to compost piles due to the presence of decaying fruits and vegetables [24]. Some individuals of *Arthropoda* in addition to feeding, move and tunnel through the piles which help aeration and increase decomposition, which is beneficial for the feeding and breeding of other species in compost piles and somewhat control *Musca domestica* [25, 26]. Presence and survival of *Arthropoda* in compost piles strongly depends on the availability of food sources and suitable environmental conditions [27-29].

According to our knowledge, studies on Arthropoda in relation to compost are scarce. Members of Arthropoda have excessive importance due to their diversity; transporting agents in their digestive system, and on their legs and wings that may cause illness to humans and animals. In Iran, composting facilities have only recently been organized and so there is no sufficient information about the attraction and diversity of vectors considering that each region has its own biodiversity.

This study was carried out to determine the diversity of *Arthropoda* and the role of each species in Windrow composting with respect to climatological conditions. The result of the present study could be a suitable guide for site selection of compost facilities, the use of produced biomass to raise plants for animals and avoid the presence of annoying Arthropoda and related diseases in personnel and peoples living near compost factories and also compost users.

2. Methods

This descriptive study was carried out in order to determine *Arthropoda* in Windrow composting of solid urban wastes. A total of 4500 kg of commingled municipal solid waste were transferred to the research center of Kashan University of medical sciences. Then, compostable components which accounted for 70 percent by weight of the solid were separated and shredded. To avoid probability of groundwater and soil contamination, composting piles was built on a waterproof, paved surface with a slightly sloping (2%) in order to collect leachates.

The shredded wastes were piled in a conical flask with a height, width and length of 1.5, 2.5 and 4.5 meter, respectively. Sample collection lasted 63 days which during the first two weeks, 4 and in the remaining weeks 1 (totally 11) samples were taken. To collect individuals, stratified sampling was considered in which Windrow width was cut from surface to floor in several sections along the length. Then, for each section, by varying the depth within the pile, a replicated trial of 3 types of sampling, one third from the surface, half and one third from the floor, was undertaken. Then, in order to obtain a homogenous sample, all samples were well mixed in a clean plastic bucket and quartered to reduce the sample size. A quarter of the mixed sample was separated and the process was repeated until the desired sample quantity was obtained [30]. 1 kg of compost pile was placed into a sampling glass and transferred to the laboratory of environmental health. Then, All *Arthropoda* were separated and placed into alcohol and identified using microscope. A thermometer was used to monitor the levels in the compost and ambient air temperatures. Humidity was measured by placing a sample in an oven for 24-48 h at 105 ºC. For pH measurement, a solid-liquid extraction was carried out: samples were diluted 1:10 in distilled water, placed in a shaker for 24 h and after vacuum filtration; pH was measured using a pH meter [4]. The Walkley and Black method was used to measure the amount of carbon in compost samples. For nitrogen measurement, the Kjeldahl method was used. To supply for oxygen requirements, the whole pile was turned once a week in the first month and once every two weeks in the second month [31].

3. Results

In the present study, 11 samples were taken and 335 individuals of *Arthropoda* belonging to 4 classes of *Insecta* (73.44%), Arachnoid (24.47%), Chilopoda (1.19%) and Diplopoda (0.9%), 5 orders, 11 families and 5 genera were observed (Tables 1 and 2).

Class *Insecta*: *Insecta* are the most diverse groups identified. Individuals within *Insecta* belonged to three orders: Diptera (39.11%), *Coleoptera* (26.87%) and Heteroptera (7.46%). Among the Diptera order, the Muscidae (33.43%), Drosophilidae (3.88%), Fanniidae (0.9%) and Syrphidae (0.9%) families were identified. Among the *Coleoptera* order, the Staphylinidae (17.01%), Carabidae and Nitidulidae (each one 4.48%) and Dermestidae (7.46%) families were found.

Class *Arachnida: Arachnida* are the second important group of *Arthropoda*. The observed orders were Astigmata (20.89%) and Cryptostigmata (3.58%). Also, Tyroglyphidae (order *Astigmata*) and Euphthiracaridae (order *Cryptostigmata*) families with abundance of 21.34% and 3.66% were recorded, respectively.

Classes *Diplopoda* and Chilopoda: *Diplopoda* and Chilopoda are the third and fourth groups of importance and in the present study their abundance was 1.19% and 0.9%, respectively.

Totally, class *Insecta*, order *Diptera*, family *Muscidae*, genus *Musca* was the most abundant group observed in this study, while genus Orius from the family *Syrphidae* was found to be the less abundant. In this study, with respect to abundance, individuals of *Arthropoda* in ninth stage of sampling (22.7%), eighth (21.8%) and tenth sampling (21.2%) that were in adult, pupa and adult forms, respectively.(Table 1 and Fig .1).

Until the end of the fourth stage of sampling, only the class Diptera was identified. In the sixth stage *Diplopoda* and Chilopoda were recorded. Class *Arachnida* was observed during the fifth to eleventh (except in sixth) stage. The abundance of adults, larvae and pupa of *Arthropoda* were 53.4%, 29.37% and 17.16%, respectively.

In the class *Insecta*, genera *Musca* (*M. domestica)* and *Stomoxys* (*S. calciterans*) were reported in both larvae and pupa forms, while in this class, only order *Coleoptera* family *Staphilinidae*, was found in adult form. It is notable that class *Arachnid*a was only observed in adult form (Table 1).

Temperature of compost in the first, third and eleventh stages of sampling was 38, 65 and 26 ^{0}C, respectively. Furthermore, humidity at the beginning of composting, in the second and the eleventh stages were 67.5, 73% and 38%, respectively. pH of the pile in the first days was 5.5 and gradually increased during the process and at the end became 7.7. Ratio of carbon to nitrogen at the start of the process was 35:1, then gradually decreased and finally reached to 12.5:1(Table 3).

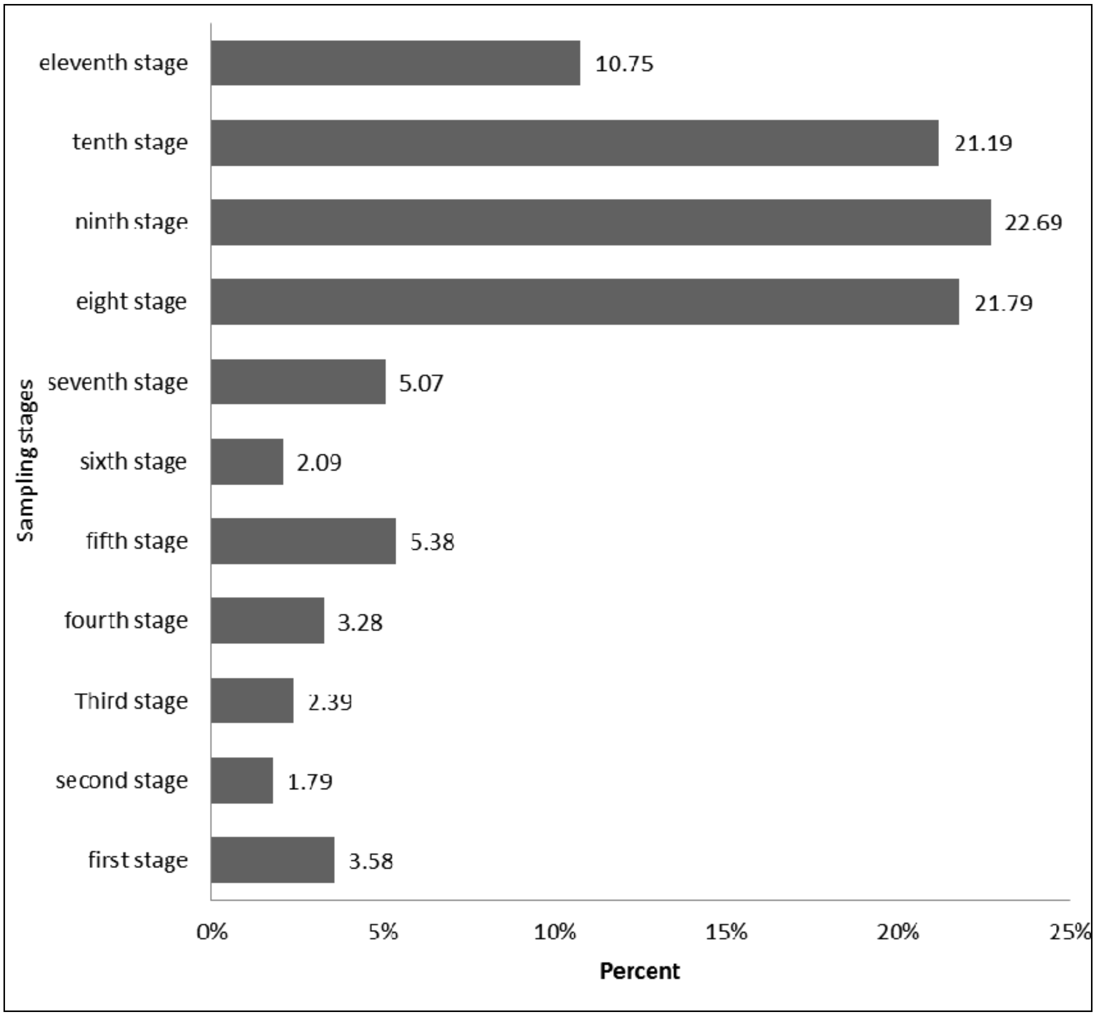

Fig 1: Abundance of *Arthropoda* in compost pile with respect to sampling stages

Table 1: Distribution of *Arthropoda* reported in windrow pile according to sampling stages

Sampling stages	Class	Order	Family	Genus	Life cycle	individuals
one	*Insecta*	*Diptera*	*Muscidae*	*Musca*	larvae	12
second	*Insecta*	*Diptera*	*Muscidae*	*Musca*	larvae	6
third	*Insecta*	*Diptera*	*Muscidae*	*Stomoxys*	larvae	8
fourth	*Insecta*	*Diptera*	*Muscidae*	*Musca*	pupa	6
				Stomoxys	Pupa	5
fifth	*Arachnida*	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus*	Adults	7
	Insecta	*Heteroptera*	Anthocoridae	*orius*	-	8
		Coleoptera	*Dermestidae*	-	larvae	3
sixth	Chilopoda	-	-	-	-	3
	Diplopoda	-	-	-	-	4
seventh	*Arachnoida*	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus*	Adults	17
eight	*Insecta*	*Coleoptera*	*Carabidae*	-	larvae	15
	Arachnida	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus*	Adults	8
		Cryptostigmata	*Euphthiracaridae*	*beetle" or "moss" mites*	Adults	12
	Insecta	*Diptera*	*Muscidae*	*Musca*	larvae	13
				Stomoxys	larvae	8
				-	pupa	17
ninth	*Insecta*	*Coleoptera*	*Staphylinidae*	-	Adults	23
		Heteroptera	*Anthocoridae*	-	-	**5**
	Arachnida	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus*	Adults	13
	Insecta	*Diptera*	*Muscidae*	-	Larvae	13
				-	pupa	17
		Coleoptera	Chilopoda	-	Adults	5
tenth	*Insecta*	*Coleoptera*	*Staphilinidae*	-	Adults	17
		Heteroptera	*Anthocoridae*	-	-	12
	Arachnida	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus)*	Adults	21

	Insecta	*Diptera*	*Drosophilidae*	-	Adults	13
			Syrphidae	-	larvae	3
		Coleoptera	Chilopoda	-	Adults	5
eleventh	*Insecta*	*Coleoptera*	*Staphilinidae*	-	Adults	12
	Arachnida	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus)*	Adults	4
	Insecta	*Diptera*	*Muscidae*	-	pupa	7
			Fannidae	-	larvae	3
		Coleoptera	Chilopoda	-	Adults	5
			Staphylinidae	-	larvae	5

Table 2: Relative abundance (%) of collected *Arthropoda* from windrow pile

Class	Order	Family	Genus	individuals	Relative abundance
Insecta	*Diptera*	*Muscidae*	*Musca*	37	11.04
			Stomoxys	21	6.27
				54	16.12
		Drosophilidae		13	3.88
		Fannidae		3	0.9
		Syrphidae		3	0.9
	Coleoptera	*Staphilinidae*		57	17.01
		Carabidae		15	4.48
		Chilopoda		15	4.48
		Dermestidae		3	0.9
	Heteroptera	*Anthocoridae*	*Orius*	8	2.39
				17	5.07
Arachnida	*Astigmata*	*Tyroglyphidae*	*Mold Mite (Tyrophagus)*	70	20.89
	Cryptostigmata	*Euphthiracaridae*	*beetle" or "moss" mites*	12	3.58
Diplopoda				4	1.19
Chilopoda				3	0.9

Table 3: Physical and chemical parameters of windrow compost with respect to sampling stages.

Sampling stages		**temperature ℃**		**Humidity (%)**	**PH**	**Ratio of carbon to nitrogen**
Stage	hour	Ambient air	pile			
First	14:15	38	38	67.5	5.5	35
Second	9:30	30	48	73	6.85	34
Third	10:50	29	65	55.8	6.2	29
Fourth	8:45	28	60	60	7.4	27.8
Fifth	11:00	25	45	53	7.25	28.6
Sixth	16:00	23	43	41.8	7.65	22
Seventh	8:30	14	40	42	8	20.7
Eight	10:30	19	42	45.77	7.72	18.2
Ninth	10:30	19	39	44.6	8.08	15
Tenth	9:00	13	37	40.1	8.4	13.6
Eleventh	8:20	12	26	38	7.7	12.5

4. Discussion

In this study, four classes of *Insecta*, *Arachnoida*, Chilopoda and *Diplopoda* were reported in Windrow composting. The Individuals of class *Insecta* had the highest abundance (73.44%). In this class, order *Diptera* was in the highest number. In a study about order *Diptera* in Bariloche compost factory in Argentina, families *Syrphidae*, *Muscidae* and *Fanniidae* were found as it is the case in this study [21]. In the present study, the individuals of family Chilopoda were observed, as also previously reported by Bartelt and Hossain in Peru [24]. The odor of decomposition of organic components of urban waste, especially fruits and vegetables attracts family Chilopoda [24]. In the present study, orders of *Diptera* and *Coleoptera* were observed in the pile in a high number. In another study, the same results were observed regarding some urban wastes of Colombia [15]. Individuals of order *Diptera*, have the highest tendency to nurture of organic matters in comparison with other orders. Therefore, their presence in compost pile is logical.

In the present study, 53.26% of the total observed individuals of class *Insecta* were from the order *Diptera*, as also previously observed by Morales and Wolff which obtained 98.5% of individuals from this order [14]. This presence appears normal in these two studies. In this study, the order *Heteroptera* was observed due to the high number of immature insects that the individuals of the order hunt them. Furthermore, individuals from the order Hymenoptera were found surrounding the pile (not in the compost pile) and therefore were not included as the compost pile individuals in this study [15]. Therefore, the presence of hunter insects surrounding the pile is Predictable. In this study, families *Fannidae*, *Muscidae*, *Drosophilidae*, *Syrphidae* belonging to order *Diptera* were identified in the compost pile. However, in Morales & Wolff study, in addition to the observation of families *Fannidae*, *Muscidae*, *Drosophilidae*, *Syrphidae* belonging to order *Diptera*, other families including *Psychodidae*, *Calliphoridae*, Scatopsidae, Ulidiidae, Milichiidae, Sepsidae, Stratiomyidae, Heleomyzidae, Sphaeroceridae, Tephritidae, Phoridae and Curtonotidae were also observed [15]. It seems that in the region were Morales &

Wolff did their study; more types of insects being living maybe due to the special climatological and geographical conditions. Individuals of family *Drosophilidae* were recorded in high number during the decomposition process of waste demonstrating that this kind of substrate is suitable for feeding, egg laying and the development of individuals. A research in Latvia in 2004 [32] and also in another study by Carson *et al*. in Island in 1983 [33], individuals of family *Drosophilidae* were recorded in composting piles that its results is similar to this study.

5. Conclusion
The results of the present work show that composting due to the presence of high quantity of organic matters and food naturally attracts many *Arthropoda* that convert the materials into biomass. In addition, the presence of *Arthropoda* in compost pile is important due to the health aspects, compost can be a feeding and breeding place for vectors that carry and spread diseases. Therefore, the proper site selection is of great importance in the location of compost sites and has a significant role in health during composting.

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7. Conflict of interest statement
The authors have no conflict of interest.

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