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Effect of sowbug on Soil Aggregate Stability in a Desert Region (Case Study: Gareh Bygone Plain, Iran)

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ABSTRACT The appearance of sowbugs (*Hemilepistus shirazi* Schuttz) in the sedimentation basins of the artificial recharge of groundwater (ARG) systems in the Gareh Bygone Plain (GBP) in southern Iran is considered an ecological breakthrough in desertification control. This study was performed at the Kowsar Floodwater Spreading and Aquifer Management Research, Training and Extension Station in GBP, 200 km from the south east of Shiraz, Iran, on the alluvial fan of Bisheh Zard River. Invasion of sowbug to sedimentation of basin due to water increasing persuade us to study about this crustacean. To determine aggregate size distribution, the soil samples were dried, and then the soil was sieved through a set of sieves (8, 4.75, 2.8, 2.0, 1.0, 0.8., 0.3 and <0.3 mm) and the aggregate size distribution was determined. Results also showed that the mean aggregate stability percentage for control (without sowbug) was 26.14% and for burrowed materials (with sowbug) was 78.00%. The aggregate stability percentage of burrowed materials was 3 folds more than that of control. The mean weight diameter for burrowed materials of sowbug was 1.86 g against 0.44g for control. Domestication of this useful organism, a souvenir of the ARG systems is an environmentally sound and a financially viable method of lengthening the economic life of the artificial recharge of groundwater system.

Key words: *Desert management, Floodwater spreading, Soil stability, Terrestrial isopod*

1 IINTRODUCTION

Groundwater consists about 70% of the water consumed in Iran during periods with normal precipitation and a higher percentage during droughts (Kowsar, 2013). Over-exploitation of groundwater in recent droughts has left our agricultural sector in the imminent danger of collapse. However, desertification control through floodwater spreading, particularly for the artificial recharge of groundwater (ARG) on a very large scale, may delay this ultimate crisis, mainly due to reclamation of the drastically disturbed land and recharging the badly depleted aquifers. Implementation of

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the ARG causes sedimentation of the nutritious suspended load, which are abundant in floodwater, thus soil building in the deserts underlain with potential aquifers (Kowsar, 2005; Kowsar, 2011).

It is well- known that various macro fauna inhabit the soil and modify some of its properties (Pankhurst and Lynch, 1994). Tunneling, mounding and pedoturbation are some of the most observable activities which have attracted the attention of soil scientists. Ants, beetles, termites, cicadas and crayfish are a few of the fauna whose activities, which somehow resemble those of the sowbug, have been studied (Tiedeman, 2013). Measurements of aggregate stability have received considerable attention during the last 50 years. It is generally agreed that soil structure stability depends mainly on forces that bind microaggregates (Tisdall and Oades, 1982) into macroaggregate. Macroaggregation depends primarily on temporary binding agents and is believed to be sensitive to changes in soil organic matter content induced by soil management (Williams, 1971; Channey and swift, 1986; Besalatpour *et al.*, 2013).

Earthworms, known to increase aggregate size and stability (Ziegler and Zech, 1992). In recent years, Margonelli (2014) studied termite mounds and its structure carefully and published it in National Geographic in August 2014. The latter investigator discovered indicator plants for the geological formations where specific species of termites were active. Luken and Kalisz (1984) reported that three cicada species (*Magicicada cassini, M. sependesim, and M. septendecula*) that live underground for a period of either 13 or 17 years, burrow to a depth of 36 cm. Stone (1993) found that a crayfish (*Procambarus rogersi* Hobbs.) excavates galleries four to 10 cm in diameter, and longer than 1.5 m, chiefly in the upper 30 cm of soil, but with vertical shafts deeper than one m. Ketterings *et al.* (1997) investigated the impacts of earthworms on soil aggregate stability in a legume cover crop agro-ecosystem. They suggested that earthworm's activity can increase soil structure stability. Although all of the burrows made by the above mentioned animals could function as flow path for water and solutes, this point was not an objective of these investigations. An aggregate is a group of primar particles that cohere to each other more strongly than to other surrounding soil particles. Aggregate stability on the other hand is measure of aggregate resisting disruptive force (Kamper and Rosenau, 1986). Aggregate size distribution after dry sieving can be expressed as a single empirical unit called mean weight diameter (MWD) which is an important characteristic because, firstly, resistance to wind and water erosion and secondly, it give an idea of the distribution of the large pores after tillage. Aggregate stability of soil is a key factor of soil resistivity to mechanical stresses, such as the impacts of rainfall and surface runoff, and therefore to water and wind erosion, which might be prevented by mulching the soil surface. The measurement of soil aggregate stability becomes important, because it can give general information about soil condition (Canasveras *et al.*, 2010). The aggregate stability is the ability of the bonds of the aggregates to resist when exposed to stresses causing their disintegration. Information on soil aggregate stability can also improve programs, adapted to the specific soil type and crop demands (Chenu and Plante, 2006).

The objective of this study is to evaluate the role of sowbug in the formation of aggregates of different sizes and soil aggregate stability changes in the floodwater spreading systems in Gareh Bygone Plain in Fars Province.

2 DESCRIPTION OF THE SOWBUG

Sowbug is a crustacean, 10-15 mm long and five mm wide. It is blackish gray and has seven pairs of legs (Figure 1). According to last classification of crustacean (Barnes, 1987.

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Martin and Davis, 2001) and terrestrial Isopods (Schmidt, 2003), this organism has been classified as follows:

Category Metazoa
Phylum Arthropoda
Subphylum Crustacea
Class Malacostraca Latreille, 1806
Order Isopoda Latreille 1803
Suborder Oniscidae Latreille 1803
Genus Hemilepistus
Species *Hemilepistus shirazi* Schuttz

sowbugs live in damp places, forage on vegetation, and digest the soil organic matter. Their burrows, seven mm in diameter and up to 185 cm deep, serve to aerate and drain the soil profile. The same genus or one of its close relatives burrows down to 100 cm in Gonabad, Northeast of Iran (Rahimi, 1993).

A species of *Hemilepistus* has been shown to excavate up to 1.5 t ha^{-1} in its active period of about three months in Central Asia. The excavated soil had more organic matter and a better structure, thus was more resistant to erosion than the original soil from which it was extracted (Salehrastin, 1978).

This viviparous organism lives for about one year. The white brood pouch under the abdomen of the female swells in March. The eggs form larvae in the pouch, and 60-70 sowbugs, very similar to their parents, are released from the pouch in May. They are very active in the spring and fall. They come out of their burrows in the cool air of early morning and late afternoon. It seems that digging deep into the soil is to reach a humid surrounding. There are semi-spherical spaces at the end of their burrows, five to 10 cm in diameter (Rahbar *et al.*, 2015). They form semi-cylindrical, rods of soil, two mm long and one mm in diameter (burrowed materials), with their mandibules, and place them to one side of the opening of their burrows (Figure 2). These rods are seemingly more resistant to slaking than the freshly laid sediment from which they are formed. As some remains of the sowbug are found in scorpion burrows, it is believed that *Hemilepistus shirazi* Schuttz is eaten by this arachnid.

Figure 1 A dorsal view of a female *Hemilepistus shirazi* Schuttz (Rahbar *et al.*, 2015)

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Figure 2 Parallelepiped-shaped burrowed materials of sowbug

3 MATERIALS AND METHODS

3.1 Study area description

The study was performed at the Kowsar Floodwater Spreading and Aquifer Management Research, Training and Extension Station, and lies between the latitudes 28°35` and 28°40` N and the longitudes 53°53` and 53°57` E on debris cone in the Gareh Bygone Plain (GBP) that is a small island of drifting sands and moving dunes of Iran (Kowsar, 1991). The field study is about 200 km to the Southeast of Shiraz, Iran (Figure 3). The soil texture of the site is loamy sand [coarse-loamy over loamy skeletal, carbonatic, (hyper) thermic, Typic Haplocalcids]. Eight ARG systems, covering a total area of 1365 ha, were installed during the 1983-1988 period (Kowsar, 1998., Kowsar, 2005).

The walls of sowbug burrows are quite durable. Apparently, the sowbug wet and cement their burrows with the body fluids. An extremely thin coating of a grayish material lines the burrows in very fine sand that collapse otherwise.

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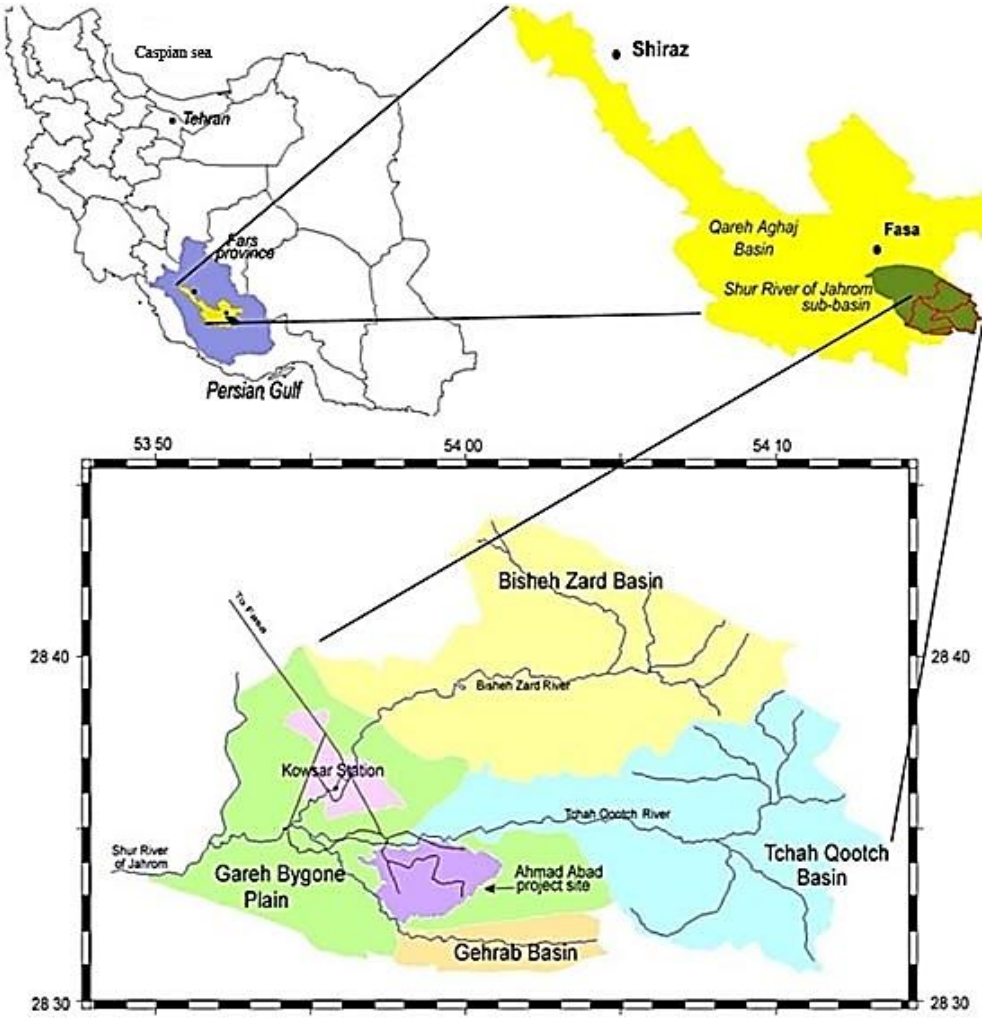

Figure 3 The location of study area in Fars Province, Iran

3.2 Experiment design

One of the floodwater spreading systems that have six plots was selected (Figure 4). Twenty four samples (2 kg) of burrowed materials were taken from near the burrows of sowbug which is about 250 ha of the site. As control, about 2 kg of the rod shaped soil surface were taken from adjusted plots without the burrows and sowbugs. After air dry of soil samples sent them to soil physicallaboratory of Farsresearch center for agriculture and natural resources. The most common method used for aggregate stability measurement is wet sieving. Aggregate stability measured using a wet-sieving apparatus (Eijklkamp, Netherlands).The method of wet-sieving is adapted from Kemper and Rosenau (1986). Aggregate stability is expressed as the percentage of aggregates remaining larger than 0.25 mm. Correction for sand particles larger than 0.25 mm must be than as these particles cannot be broken down further to pass through the sieve (Nimmo and Perkins, 2002; Teh and Jamal, 2006).

Aggregate stability of soil samples was computedbyEq. 1 (Teh and Talib, 2006).

$$AS\% = \frac{W-S}{4-S} \times 100 \quad (1)$$

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Figure 4 Location of the 2nd sedimentation basin of Bisheh Zard 1

Where AS is aggregate stability, Wis the weight of oven dried- aggregates and S is the weight of sand particle.

To determine aggregate size distribution and mean weight diameter (MWD) the soil samples were dried, and then 1500 g of the soils were passed through a set of sieves (8, 4.75, 2.8, 2.0, 1.0, 0.8, 0.3, and<0.3 mm).

The weight of aggregates remaining on each sieve was used to determine aggregate size distribution. Aggregate size distribution after dry sieving can be expressed as an empirical unit called MWD. This was calculated using the Eq. 2 (Teh and Talib, 2006).

$$MWD = \sum_{i-1}^{n} Xi\, Wi (2)$$

where MWD is mean weight diameter, Xi is the mean diameter and Wi is the proportion of the total sample weight.

3.3 Statistical analyses

Statistical analyses were performed using SAS and SPSS 19 softwares. At first normality of data verified through Kolmogrov and Smirnov test and datahomogeneity of variance was evaluated by Leven test. Analysis of variance (ANOVA) in a completely randomized design was used to determine the effect of treatments for each measured variable. As there were only two treatments, the burrowed materials and the freshly-laid sediment (control) the paired t-test was used to detect the significance effect of the sowbug activities on study variables (P<0.01).

4 RESULTS AND DISCUSSION

The results of aggregate size distribution and aggregate stability of burrowed materials and soil control are shown in Tables 1 and 2 and Figure 5. Analysis variance results on soil aggregate stability of sowbug burrowed materials and soil samples (control, without sowbug activity) shows that there was significantly higher (P<0.01). Table 1 and Figure 5 illustrate the mean aggregate stability percentage for study treatments. The mean aggregate stability of control treatment (without sowbug) was 26.14% and ofburrowed materials (with sowbug) was8.00%. The aggregate stability percentage of burrowed materials was threefolds more than the control.

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In Table 2, the MWD for burrowed materials of sowbug was obtained1.86 g and 0.44 g for the control and it wasmore than four folds in comparison with control.

Larger values of MWD denote a higher proportion of larger aggregates in soil sample. The index of MWD is developed to give greater weightening to larger aggregates than that for smaller aggregates. This reflects the fact that larger aggregates often indicate favorable soil structure for agriculture. Aggregate size distribution can also be expressed as the percentage of aggregates that are greater than 2 mm.Soil aggregation is a fundamental property of soils and is a primary control of soil aeration. It determines the hydrological properties of soil such as water-holding capacity and the storage of organic carbon.The stability of soil aggregates is also important because it influences how these properties change with time, and the susceptibility of soils to erosion by both wind and water which can lead to a loss of soil nutrients (Rawlins *et al.*, 2013).

Table 1 Comparison between the control and burrowed materials

Group	N	Means	Significant level
Control (without sowbug)	8	26.14 ± 4.19[b]	<0.01
Burrowed materials (with sowbug)	24	78.00 ± 5.56 [a]	

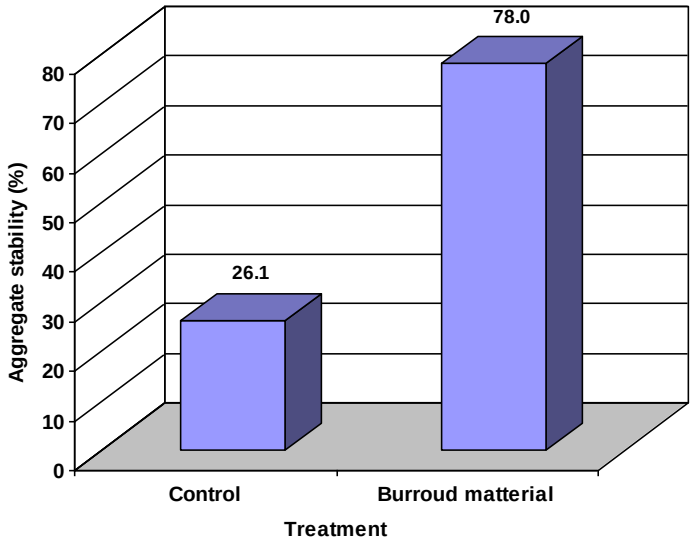

Figure 5 Aggregate stability percentage for control and burrowed materials (BM)

Table 2 The mean weight diameter (MWD) of controland burrowed materials (BM) treatments

Size (mm)	8.0	4.75	2.80	2.0	1.0	0.80	0.30	<0.30	MWD
BM Weight (g)	0	0.30	5.53	95.0	145.5	4.75	1.89	2.0	1.86
Control Weight (g)	0	0	0	0.23	6.63	49.82	106	98.92	0.49

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Some large soil invertebrates have significant effects on soil structural properties, the most important being earthworms, termites and ants. They built organo-mineral structure of different stability such as galleries, casts, fungous-comb chambers and mound (Lavell *et al.*, 1997). Activity of the sowbug is beneficial for improvement of soil physical conditions and thus, plant growth. Burrowing by the sowbug improves air and water penetration into the soil. The burrowed materials and castings resist erosion more than the freshly-laid sediment from which they are formed (Jass and Klausmeier, 2000; Schmidt and Leistikow, 2005). The mechanisms by which sowbug increased soil aggregate stability are not well understood. Much of the research to date has focused on casts. Burrow materials stability is dependent in part on the quality of the ingested organic matter; quality of C (carbon) in the casts may be a factor affecting their stability. Farid, *et al.* (2014) state that organic matter has the highest direct and positive effect on soil aggregate stability in the north west of Iran and it causes increasing stability of soil aggregate. Soil organic matter and texture (clay content) are the main a biotic binding agents in the formation and stabilization of aggregates and play key roles in controlling soil structure stability through their influence on water absorptivity and repellency as well as on the strength of bonds between particles, while soil microbes (bacteria and fungi) and plant roots have been reported as key biotic aggregating agents (Duchicela*et al.*, 2013). Because sowbug eat residue of plants they can increase the contents soil organic carbon and their role can be similar to earthworms, termites and ants.

5 CONCLUSION

sowbugs are incredible organisms that sustain floodwater spreading systems in the south of Iran in Gareh Bygone Plain, and they are important biological factors in soil ecosystem. The influence of sowbug on soil aggregate stability is very important for maintenance of soil fertility and quality. The results of this research stated that sowbugs hadsignificant and positive effects on soil aggregate stability, and showed that this terrestrial organism can make a soil with better quality. Nevertheless further research regarding the impact of sowbug on soil quality is required. In addition, it will be important to explore the effects of sowbug in chemical properties of soil.

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تأثیر خرخاکی بر پایداری خاک دانه‌های خاک یک منطقه بیابانی (مطالعه موردی: دشت گربایگان فسا، ایران)

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چکیده حضور خرخاکی‌ها در حوضچه‌های تغذیه مصنوعی شبکه‌های پخش سیلاب گربایگان فسا در جنوب شرقی ایران به‌عنوان راهی برای مهار بیابان‌زایی در نظر گرفته می‌شود. خرخاکی یکی از موجودات خاکزی مفید است که سبب نفوذ بیش‌تر آب به خاک و سبب بهبود ویژگی‌های فیزیکی خاک شده است. از خاک‌هایی که از فعالیت خرخاکی‌ها به‌دست آمده و هم‌چنین نقاط شاهد (مکان‌های بدون فعالیت خرخاکی) نمونه‌هایی برداشت شد. بعد از هوا خشک شدن نمونه‌های برداشت شده پایداری خاک دانه‌ها و هم‌چنین توزیع اندازه‌ای آن‌ها برآورد شد. برای تعیین نحوه توزیع اندازه خاکدانه‌ها نیز از سری الک‌های آزمایشگاهی (۸، ۴/۷۵، ۲/۸، ۲، ۱، ۰/۸، ۰/۳ و کم‌تر از ۰/۳میلی‌متر) استفاده شد. نتایج نشان داد متوسط پایداری خاک دانه‌های خاک برای شاهد ۲۶/۱۴ درصد و برای خاک‌های تیمار شده با موجودات خرخاکی ۷۸ درصد بود. به‌نحوی‌که پایداری خاک دانه‌های مربوط به خاک‌های با فعالیت خرخاکی ۳ برابر شاهد به‌دست آمد. میانگین وزنی قطر خاکدانه‌ها برای خاک‌های حاصل از فعالیت خرخاکی ۱/۸۶ گرم و برای شاهد ۰/۴۴گرم بود. این موجود زنده سخت‌پوست به عنوان ره‌آورد پخش سیلاب، سازگار با محیط‌زیست و از لحاظ اقتصادی، اجتماعی قابل قبول و سبب افزایش عمر مفید طرح‌های پخش سیلاب برای تغذیه مصنوعی سفره آب‌های زیرزمینی می‌شود.

کلمات کلیدی: پایداری خاک، پخش سیلاب، جورپایان خاک‌زی، مدیریت بیابان

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