The Effects of Sowbug (*Hemilepistus shirazi* Schuttz) on Some Physico-Chemical Properties of Soil in a Desert Region

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Abstract: Desertification control through Flood Water Spreading (FWS) mainly for the Artificial Recharge of Groundwater (ARG) is comprehensive study that is being implemented since Jan. 1963 in the Gareh Bygone Plain (GBP) in Southern of Iran. Total 8 ARG system with a total area of 1365 ha were constructed during the 1983-1987 period on the debris cone and alluvial fan formed by the Bisheh Zard river an ephemeral stream that supplies floodwater to the GBP from none to 8 times a year. 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 crustacean which drills 7-8 mm holes down to 1.8 m in the freshly laid sediment and sand, facilitates preferential flow of water towards the aquifers. Particle size distribution, saturation percentage, pH, Electrical Conductivity (EC) and concentration of major cations and anions, Cation Exchangeable Capacity (CEC) and trace elements were determined using the standard procedures. The burrowed material was highly concentrated in macro- and micro-elements. pH was lowered by 1.4 units in the same material. Saturation percentage of water has been increased 2-folds comparison with control. In this reason, sowbug can be in a desert region in the research station. The amount of total nitrogen in burrowed materials has changed 13-folds in comparison with control. The burrowed material was highly concentrated in organic carbon in comparison with control (7-folds) and show a significant difference in 1% level. The concentration of iron, zinc, manganese and copper due to sowbug activities have increased (3.13, 3.8, 4.9 and 12.7-folds, respectively) and show a significant difference in 1% level. Results show that the physico-chemical properties of burrowed materials are more fertile in comparison with control. Moreover by bringing up, the excavated material sowbugs affect the surface soil composition in a long time.

Key words: Sowbug, desertification control, soil, physico-chemical properties, satwration percentage, Iran

INTRODUCTION

Malthusian dilemma shall be realized in about 100 years if the current trends of land degradation, conversion of prime farmlands to non-agricultural uses and population growth continue unchanged. Desertification control through floodwater spreading, particularly for the ARG on a very large scale, however may delay this ultimate crisis. In the meantime, scientific breakthroughs in birth control and food production may hopefully reverse this predicament. Implementation of the ARG methods in the deserts underlain with potential aquifers not only replenishes the underground reservoirs but also rehabilitates the drastically disturbed lands through sedimentation of nutritious suspended load that abounds in floodwater onto them (Kowsar, 1998). This at least in the land of Iran is mainly due to the extreme

erosivity of the Miocene marls, siltstones and sandstones that cover most of the flood producing basins. These particles that are the nemeses of hydraulic engineers, particularly dam builders are a boon to conservationists as they utilize them to rehabilitate the eroded land and to transform the coarse-textured, infertile soils into productive fields.

Soil building in sedimentation basins, the integral part of the ARG systems has converted 1365 ha of a moving sand menance into a fertile land in the GBP in Southern Iran (Kowsar, 1991, 1998). One of the main theoretical constraints of this successful project was the inevitable impermeability of the ARG systems due to deposition of the suspended load onto the sedimentation basins and recharge ponds and the downward migration of fine clay particles, specifically those of chlorite, palygorskite and smectite through the soil profile (Mohammadnia and

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Kowsar, 1998). As sub-soiling is harmful to the tree roots planted in the basins and its effects are usually short lived, terminating with the next flood we had to resort to biological means. We knew that decomposition of *Eucalyptus camaldulensis* Dehnh. roots, planted in the basins would form channels that facilitate preferential flow towards the watertable. However, surface sealing by a very hard crust with an ever-increasing thickness would hinder the smooth flow of water toward the rooting zone. Therefore, drilling of numerous biopores in the crusts was the method of choice.

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 that 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.

Baxter and Hole (1967) investigated the ant (*Formica cinerea montana* Emery) activities in Grant county, Wisconsin. Salem and Hole (1968) studied the ant (*Formica exsectoides* Forel) mounds in Lafayette county, Wiscosin. Wiken *et al.* (1976) reported on the ant (*Formica fusca* L.) activities in Northeast of Mt.

Talow in British Columbia and Levan and Stone (1983) researched soil modification by *Formica fusca* L. in centeral New York. These investigators found ant tunnels at depths ranging from 120-150 cm. Soil mixing by scarab beetles (*Peltotrupes youngi*) was studied by Kalisz and Stone (1984) in the Ocala national forest in Florida. Although, they measured burrows as deep as 3.6 m, these researchers speculated that *P. youngi* may burrow down to 5 m.

Mermut *et al.* (1984) and Jones (1989) studied termite mounds in Kenya and Tanzania, respectively. The latter investigator discovered indicator plants for the geological formations where specific species of termites were active. Luken and Kalisz 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. As their density may reach as high as 1,700,000 ha^{-1}, they should have quite an impact on soil infiltrability. Stone (1993) found that a crayfish (*Procambarus rogersi* Hobbs.) excavates galleries 4-10 cm in diameter and longer than 1.5 m, chiefly in the upper 30 cm of soil but with vertical shafts deeper than 1 m.

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. The appearance of many circular biopores

next to quailbush [*Atriplex lentiformis* (Torr.) Wats.] in the spring of 1992, 10 years into the project was a glad tiding for us. Close examination revealed mild infestation of these bushes by a sowbug species (*Hemilepistus shirazi* Schuttz). Preliminary sounding of the burrows indicated the presence of a vertical shaft, 30-40 cm deep in each one. The rapid infiltration of floodwater into the hard crust formed by the dried fine sediment and perforated by the sowbug encouraged us to investigate different aspects of this very useful gift of Nature. This is the first in a series of reports that presents a brief description of the animal, the architecture of its burrows, infiltrability enhancement of the perforated crust and some physico-chemical properties of the extracted materials deposited on one side of each burrow.

Description of the sowbug: This organism is a crustacean, 10-15 mm long and 5 mm wide. It is blackish gray and has 7 pairs of legs (Fig. 1). Unlike pillbug, it is not capable of rolling up into a ball. This organism has been classified as follows (Robert, 1980):

Gategory: Metazoa
Phylum: Arthropoda
Subphylum: Mandibulate
Class: Crustacea
Order: Isopoda
Suborder: Oniscoidae
Genus: Hemilepistus

Sowbugs live in damp places, forage on vegetation and digest the soil organic matter. Their burrows, 7 mm in diameter and up to 80 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, NE Iran (Rahimi, 1993). The Northward extension of *Hemilepistus*

Fig. 1: A dorsal view of a female *Hemilepistus shirazi* Schuttz

Fig. 2: Parallelepiped-shaped burrowed material

sp., reaches Central Asia where they may be found up to
$100 \ m^{-2}$ burrowing down to 80 cm and excavating up to
1.5 ton ha^{-1} of soil in their active period of about
3 months. The excavated soil has more organic matter and
a better structure thus is more resistant to erosion than
the original soil form which it was extracted (Saleh Rastin,
1978). This viviparous organism lives for about 1 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, 5-10 cm in diameter. They form
semi-cylinderical, rods of soil, 2 mm long and 1 mm in
diameter with their mandibule and place them to one
side of the opening of their burrows (Fig. 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 that *Hemilepistus shirazi* Schuttz is eaten
by this arachnid.

MATERIALS AND METHODS

This study was performed at the Kowsar floodwater
spreading and aquifer management research, training and
extension station in the gareh bygone plain, 200 km to the
SE of Shiraz, Iran on the debris cone of the Bisheh Zard
river (Fig. 3). The major soil of the site is loamy sand
(coarse-loamy over loamy skeletal, carbonatic (hyper)
thermic and typic haplocalcids). A 8 ARG systems,
covering a total area of 1365 ha were installed during the
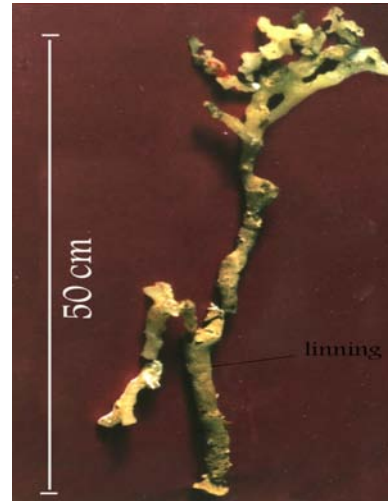1983-1988 period. More details may be found elsewhere

Fig. 3: Paraffin wax cast of a sowbug burrow. The
opening is on the top

(Kowsar, 1991, 1998). Configuration of the burrows was
studied by making their paraffin casts. Measured volumes
of molten paraffin wax were poured into the burrows
through a long stemmed glass funnel. The casts were
removed from the soil profile by digging diligently around
them making sure that the broken pieces were placed in
proper order then photographing them (Fig. 4). It should
be mentioned that the lateral penetration of the molten
wax into the wall of the burrows made the cast diameter
4-5 times their true measurement of 7 mm.

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.

There are 8 floodwater spreading system about
1368 ha in extent in the GBP. To characterize some of the
physico-chemical properties of the sowbug burrowed
materials, the BZ1 system was selected. The system on
which this research was conducted was the first in a
series of 8 systems constructed in Gareh Bygone plain
since 1983. This system has 6 sedimentation basin (Fig. 5).
I chose the second sedimentation basin of this system as
the sowbugs were very active there.

About 2 kg of the rod-shaped soil (burrowed
material) were collected from 70 sowbug infested plots
(10-20 g adjacent to each) opening. These samples were
thoroughly mixed. The same amount of surface soil
(freshly laid sediment) was also taken from the adjacent
plot without the burrows as the control. This sample was
thoroughly mixed too. Particle size distribution (sand, silt
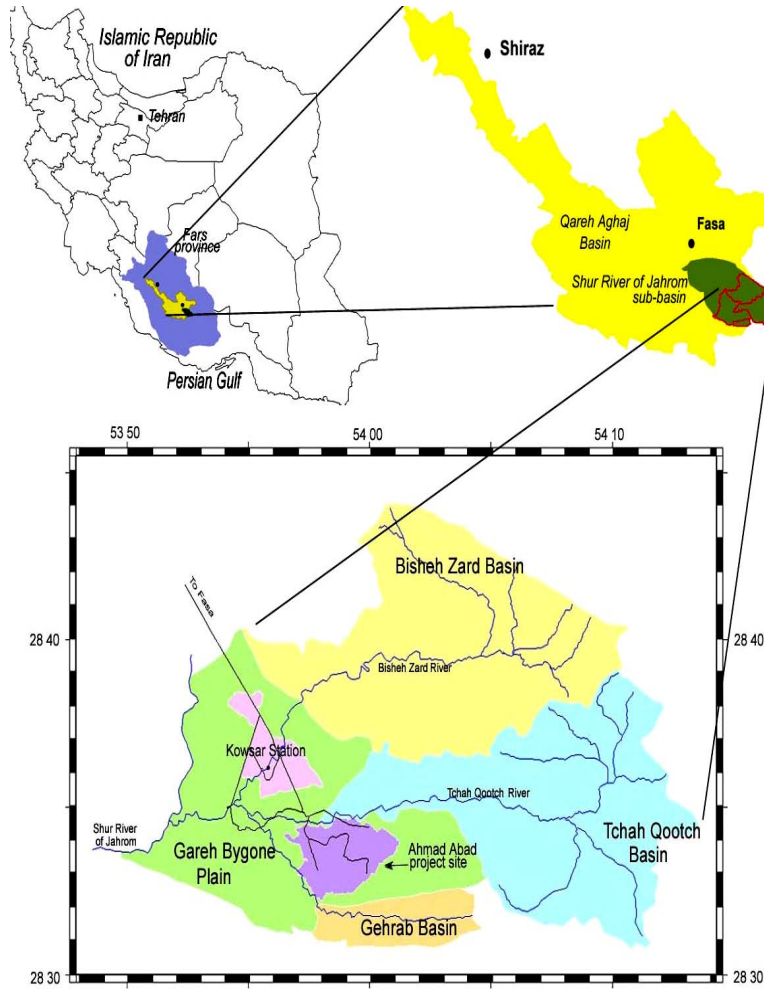and clay), saturation percentage, EC, pH, bicarbonate,

Fig. 4: The map of site study
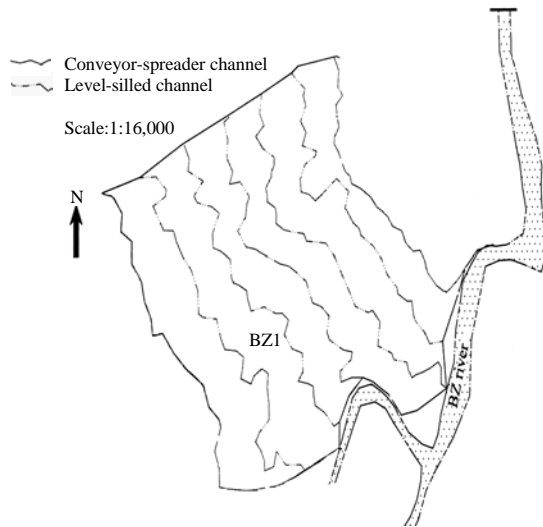
Fig. 5: The BZ1 floodwater spreading system

carbonate, Cation Exchange Capacity (CEC), organic carbon, potassium, phosphorus, total nitrogen, iron, copper, magnesium, zinc and the dissolved cation and anion were determined using the standard procedures.

RESULTS AND DISCUSSION

Chi-square (χ^2) test was used to compare the physico-chemical properties of the burrowed materials and the freshly laid sediment (control): Chi-square (χ^2) test obtained as following:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

Where:
O_i = Sowbug
E_i = Without sowbug (Check)

Table 1: Chi-square distribution and significant level table for sowbug Burrowed materials

Variables	χ^2	Sig.	
Sand (%)	37.79	0.000	**
Silt (%)	399.55	0.000	**
Clay (%)	61.28	0.000	**
Water satu. per.	209.56	0.000	**
pH	1.81	0.874	NS
EC	70.07	0.000	**
O.C. (%)	404.30	0.000	**
Ava. K	112169.23	0.000	**
Ava. P	738.06	0.000	**
T.N. (%)	37.34	0.000	**
CCE (%)	1.26	0.939	NS
Fe	92.91	0.000	**
Zn	29.92	0.000	**
Cu	925.80	0.000	**
Mn	5757.53	0.000	**
K^+	90.18	0.000	**
Na^+	678.75	0.000	**
Mg^{2+}	1146.59	0.000	**
Ca^{2+}	632.83	0.000	**
Cl^-	1540.95	0.000	**
SO_4^{2-}	263.25	0.000	**
HCo_3^-	786.31	0.000	**
CO_{32}^-	1.20	0.945	NS
CEC	34.73	0.000	**

$\chi^2(0.05, 5) = 11.07$; $\chi^2(0.01, 5) = 15.09$

$$\chi^2 = 111.446**$$

$$\chi^2(5, 10) = 18.307$$

$$\chi^2(1, 10) = 23.209$$

According to obtained amount and degrees of freedom (K-1), the value of χ^2 was calculated and compared with the Chi-square distribution table (Table 1). Because the amount of calculated is much more than obtained amount from Table 1 (37.09>15.79). Therefore, we can confidently claime that most of element exception carbonate calcium and pH is greater than freshly laid concentration (control) and show a significant different in 1% level.

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 of the sowbug activities.

The SPSS 1.6 and Excell Softwares were used for the analysis of the data (Table 2 and 3). Establishment of a forest in a sandy desert is one of the most important effects of floodwater spreading as it has fixed the moving sand, eliminated the dust and created a better environment for the wildlife in the Gareh Bygone plain. Desertification control through floodwater spreading and planting trees and shrubs has changed this

Table 2: Selected characteristics of the rod-shaped soil excavated by the sowbugs and the surface soil of the sedimentation basins and the Paired t-test

Selected characteristics	(Freshly-laid sediment)	Burrowed materials	Significance level	CV
Sand (%)	79.98±5.7[a]	60.00±5.00[a]	**	7.69
Silt (%)	12.00±4.2[b]	29.00±11.6[a]	*	14.20
Clay (%)	8.17±3.40[a]	11.24±6.9[a]	NS	16.00
Saturation percentage	33.52±2.70[b]	66.10±63[a]	**	9.92
pH	8.3±0.27[a]	6.74±0.4[b]	**	4.53
EC ds/m	2.60±0.27[a]	0.43±0.27[a]	**	5.30
O.M.	0.95±0.92[b]	6.63±1.80[a]	**	13.70
Calcium carbonate	40.89±2.82[a]	42.10±2.40[b]	*	6.53
Available K	101.20±0.88[b]	1397±8.80[a]	*	18.30
Available P	12.75±3.77[b]	52.50±17.8[b]	*	13.00
Total nitrogen	0.047±6.002[b]	0.61±0.04[a]	**	10.30
Fe	2.31±0.88[b]	7.25±1.92[a]	**	21.00
Zn	0.49±0.19[b]	1.84±0.53[a]	**	14.00
Cu	0.49±0.19[b]	1.87±0.53[a]	**	14.00
Mn	13.53±6.11[b]	66.50±18[a]	**	12.40
Dissolved Po.	1.93±1.70[a]	6.53±5.9[a]	NS	10.30
Dissolved sodium	0.63±0.50[b]	10.02± 4.6[a]	**	16.50
Dissolved Mag.	2.22±0.67[b]	21.80±8.8[a]	**	15.00
Dissolved calcium	2.17±0.20[a]	16.78±12.44[b]	*	14.30
Dissolved chlorine	2.7±1.17[b]	25±8.37[a]	**	14.20
Dissolved sulphate	1.15±0.52[b]	7.35±3.68[a]	*	16.20
Dissolved Bica.	2.65±1.18[b]	22.05±12.6[a]	*	17.50
Dissolved Car.	0.65±0.9[a]	0.00[a]	NS	19.50
CEC	8.15±0.315[b]	13.98±0.108[a]	**	5.37

SP = Saturation Percentage; OM = Organic Matter; Gyp = Gypsum

drastically disturbed land. Invasion of the terrestrial sowbug was mainly due to the provision of forage and water for this environmentally benign creature. This crustacean has been seen in Sarvestan, Lar and Abadeh in the Province of Fars. Sowbug is herbivorous in the processes of building its nest, it mixes the subsoil and the topsoil.

The number of sowbug changes in different seasons. Their population is estimated at about 10,00,000 in 1 ha. Their population is higher in October and March in the Gareh Bygone plain as compared with other months. The number of burrow is about 20000 ha^{-1} and there are about 50-60 sowbugs in each burrow. Sowbug makes humus from the litter and residues of plants by its mouth parts. Because of sowbugs use litter and plant residue, they have an important role in the biological cycle. Soil forming trend accelerates by sowbug in artificial recharge system that is a big distinction. Studies show that terrestrial living things are very important in soil physico-chemical changes. Table 1-3 show that the burrowed materials texture has changed from loamy sand to a sandy loam and this texture is more suitable for the plant growth.

Statistical analyses show a significant difference at the 1% level for numerous soil characteristics as compared with those of the control. Most trees and shrubs need a loamy texture for good growth. It seems that the preference of the sowbugs for the finer material and a more productive soil having a lower percentage of sand and a percentage of silt, thus a higher water holding

Table 3: Statistical parameters and the Paired t-test results for the paired samples statistics between the means of the treated and control

Selected charactristics	Mean	N	SD	SEM	t-values	Sig. (2-tailed)
Pair 1						
Sand1	58.6333	6	4.12197	1.68279	-10.263	0.000**
Sand2	80.8167	6	4.70932	1.92257		
Pair 2						
Silt1	32.0000	6	10.13903	4.13924	4.236	0.008**
Silt2	11.4167	6	3.98016	1.62489		
Pair 3						
Clay1	9.3667	6	6.05893	2.47355	0.405	0.702[NS]
Clay2	7.9667	6	3.00311	1.22601		
Pair 4						
WaterS1	67.1367	6	4.76118	1.94374	21.069	0.000**
WaterS2	33.2733	6	2.33330	0.95256		
Pair 5						
Ph1	6.7983	6	0.32744	0.13368	-6.946	0.001**
Ph2	8.3183	6	0.23752	0.09697		
Pair 6						
EC1	3.8450	6	0.34732	0.14179	19.390	0.000**
EC2	0.8383	6	0.18071	0.07378		
Pair 7						
OC1	6.8750	6	1.49925	0.61207	11.910	0.000**
OC2	0.6100	6	0.21872	0.08929		
Pair 8						
avk1	1,605.333	6	317.00263	129.41578	11.642	0.000**
avk2	123.3333	6	23.65305	9.65632		
Pair 9						
avp1	52.0000	6	14.18450	5.79080	8.222	0.000**
avp2	12.8333	6	2.99444	1.22247		
Pair 10						
TN1	0.6640	6	0.07436	0.03036	22.266	0.000**
TN2	0.0593	6	0.01019	0.00416		
Pair 11						
CCE1	43.1733	6	1.95267	0.79717	4.794	0.005**
CCE2	40.5733	6	2.41153	0.98450		
Pair 12						
Fe1	7.6900	6	1.70627	0.69658	6.554	0.001**
Fe2	2.5233	6	0.76894	0.31392		
Pair 13						
Zn1	1.8717	6	0.41840	0.17081	7.279	0.001**
Zn2	0.4817	6	0.15420	0.06295		
Pair 14						
Cu1	13.2067	6	30.86093	12.59892	1.023	0.353[NS]
Cu2	1.1817	6	2.08122	0.84965		
Pair 15						
Mn1	76.3917	6	3.35208	1.36848	44.745	0.000**
Mn2	5.6667	6	1.49268	0.60939		
Pair 16						
K1	7.8433	6	5.93286	2.42208	3.173	0.025*
K2	2.2967	6	1.74343	0.71175		
Pair 17						
Na1	7.1433	6	4.94578	2.01910	3.456	0.018*
Na2	0.5833	6	0.39923	0.16299		
Pair 18						
Mg1	23.3183	6	7.92152	3.23395	6.903	0.001**
Mg2	2.4500	6	0.70922	0.28954		
Pair 19						
Ca1	13.3000	6	11.19500	4.57034	2.433	0.051*
Ca2	2.1667	6	0.20656	0.08433		
Pair 20						
Cl1	25.5167	6	6.50613	2.65611	7.886	0.001**
Cl2	3.0750	6	1.08524	0.44305		
Pair 21						
So41	8.1333	6	3.45582	1.41083	5.121	0.004**
So42	1.2833	6	0.50761	0.20723		
Pair 22						
Hco31	19.8367	6	12.75323	5.20648	3.598	0.016*
Hco32	2.6667	6	1.32010	0.53893		

Table 3: Continued

Selected charactristics	Mean	N	SD	SEM	t-values	Sig. (2-tailed)
Pair 23						
Co31	0.0000	6	0.00000	0.00000	-	-
Co32	0.2000	6	0.00000	0.00000		
Pair 24						
CEC1	14.4450	6	0.54051	0.22066	22.110	0.000**
CEC2	7.8017	6	0.54920	0.22421		

capacity has lured them to the sedimentation basins. It is no wonder that plants grow better within the sedimentation basins as compared to the area outside of them. The burrowed material texture has changed from loamy sand to sandy loam. Saturation percentage of water has increased 3-fold as compared with the control (significant difference at the 1% level: Table 1-3). It may be the reason why the sowbug has invaded the research station. The phosphorus content of the burrowed material increased by about 4.5-fold as compared with that of the control and shows a significant difference at the 5% level (Table 2 and 3). Soil electrical conductivity increased significantly as compared with that of the control. This increase was due to the sowbug consumption of the leaves of *Atriplex lentiformis*, which resulted in salt accumulation in its excreta. As the sowbug feeds on the litter residues, soil organic carbon has increased about 6-fold and show a significant difference at the 1% level compared with that of the control. It may also probably be due to a decrease in the soil pH.

The burrowed materials were highly concentrated in organic carbon in comparison with control (7-fold) and show a significant difference in 1% level (Table 2 and 3). Soil organic matter plays a crucial role in the function of terrestrial ecosystem and is closely liked with a wide range of ecosystem services. The total nitrogen content has increased about 13-fold due to the sowbug activity as compared with that of the control and shows a significant difference at the 1% level. This can be very important because nitrogen is the main protein component and it is needed for the normal growth of plants.

Arid regions are poor in nitrogen. Adding nitrogen fertilizes to this soil is one way to compensate the loss of soil nitrogen. The excessive use of nitrogen fertilizers in both developed and developing countries causes unpleasant environmental problems groundwater pollution. However, N accumulation by the sowbug is the recycling of a precious resource. The lower pH (1.6 unit) and higher saturation percentage of the treated soil is due to its higher organic matter conten and show a significant difference in 1% level.

A decrease in soil pH and an increase in organic matter, phosphorus and nitrogen cause lead to an increase in micronutrients. Soils of arid and semi-arid regions are poor in these constituents. As such decrease

hardly possible in farm fields and it incurs at high costs therefore this function of the sowbug is also remarkable. This decrease in the pH is worthwhile because the soils of arid regions are usually poor in micronutrients.

Micro-nutrients such as iron, zinc, manganese and copper have increased due to the activity of sowbugs and show a significant difference at the 1% level as compared with the control. Concentrations of iron, zinc, manganese and copper have increased 3.13, 3.8, 4.9 and 12.7-fold, respectively.

Micro-nutrients are very important in the biological processes; they are involved in enzymes reaction and they are essential for photosynthesis process. Concentrations of soluble cations (K^+, Na^+, Mg^{2+} and Ca^{2+}) and soluble anions (Cl^-, SO_4^{2-}, CO_3^{2-} and HCO_3^-) have increased in burrowed materials as compared with those of the control and show the significant difference at the 1% level. This is mainly due to the calcareous shell of this crustacean. Calcium carbonate content in burrowed material shows a significant difference at the 1% level as compared with that of the control. Calcium carbonate is important in soil as it helps aggregation of soil particles. Aggregation enhances soil surface resistance to erosion and it also increases infiltration rate. Rersearchers believe that the very high contents of Ca and Mg, 5 and 10-fold, respectively is due to the addition of sowbug carcasses to the burrowed soils. Physico-chemical properties of burrowed materials are more fertile in comparison with control.

Cation Exchangeable Capacity (CEC) of the burrowed materials has increased and shows a significant difference at the 1% level as compared with that of the control. An overall improvement in the soil physico-chemical properties of the soil enhances its productivity. This matter has been reported for other terrestrial organism, especially earthworms and termites. Results show that the physico-chemical properties of burrowed materials are more fertile in comparison with control.

CONCLUSION

Extending the economic life of the artificial recharge of groundwater systems is a challenge to the planners and implementers of these facilities. The surface geology of most of the flood-producing watersheds makes their

runoff highly turbid; therefore very large sedimentation basins have to be incorporated into the design. However, the presence of very fine particles, particularly clay minerals such as chlorite, palygorskite and smectite cause rapid clogging of these basins and infiltration ponds. Although, root channels enhance percolation, infiltrability of the basins and ponds is highly decreased by crust formation. 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. The sowbugs activity also improves the chemical properties of soil and makes it more fertile. They increase soil organic carbon content that plays a central role in the productivity of the soil and environmental quality. The higher soil organic carbon in the burrowed material as compared with those of the original soil a nd the freshly laid sediment, represents a potential for carbon sequestration when viewed as a long-term management system. They also increase micro-nutrient contents in the soil that is so important for arid and semi-arid region. Invasion of the sowbug to the ARG systems in the Gareh Bygone Plain in 1993 changed the picture. These crustaceans which sometimes make up to 10 burrow m^{-2} with depths down to 185 cm have increased infiltration rates up to 4-fold. As they feed on quailbush, it seems prudent to introduce this browse plant into the systems even for the sole purpose of attracting the sowbugs. Needless to say this plant can support four sheep, the year round if planted at a density of 625 bushes ha^{-1}, quite a feat for a sandy desert. Domestication of this organism, a souvenir of the ARG systems seems technically practicable, environmentally sound, economically feasible and socially acceptable.

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