University of Birjand

Water Harvesting Research Vol. 4, No. 1, Spring & Summer 2021, Original Paper p. 76-82

10.22077/JWHR.2021.4324.1043

The Effects of Gravelly Filters on Soil Moisture in rainwater Catchment Systems

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Received: 23 August 2021/ **Revised**: 24 December 2021/ **Accepted**: 26 December 2021

Abstract

Rainwater harvesting system is one of the approaches to an adaptation to climate change and global warming. Rainwater harvesting has been resulted in diversification of water resources and will lead to increase water security. Optimum utilization of rainfall in arid and semi-arid plains ranging in sloping surfaces is very important. In areas where rainfall distribution during the season is not commensurate with the water needs of trees and plants, the water harvesting system and sand filters installed at the end of the system can lead to water infiltration into the rhizosphere of plant roots. The aim of this project is to investigate the performance levels of insulation, semi-insulating, and natural (With or without gravelly filters) range land to expansion of water supply around the seedlings dry almond in Isfahan province. To do this, 48 plots with dimensions of 7 * 4 meter with three treatments of insulation coating, semi-insulation, and natural cover with gravel filters and without gravel, filters were constructed at the end of rainwater level systems in three replications on the slope with a slope of 18%. At the bottom of each plot, a soil profile with dimensions of 1 * 1 * 1 meter was created to dig a seedling-planting hole with the aim of increasing the soil moisture. At this stage, materials such as rotten manure and straw, as well as nylon coating were used to increase water penetration and more moisture retention in the soil. In order to investigate the effect of the mentioned factors in increasing soil moisture, almond seedlings were planted in the system and simultaneous data on plant growth and soil moisture were recorded at two depths of 30 and 50 cm. Changes in pit moisture were measured at specific time intervals and finally statistically analyzed. Statistical analysis showed that among the treatments used, the treatment of adding 25% by volume of soil of seedling planting hole with rotten manure plus straw and straw and nylon with insulation cover and gravelly filter had the maximum volumetric moisture at a depth of 50 cm.

Keywords: Water harvesting System, Soil moisture, Gravelly filters, Dry land garden.

1- Introduction

Climate change and a growing demand for water for agricultural and urban development are increasing the pressure on water resources (Ammar et al., 2016). One of the prominent climatic features of arid and semi-arid regions of the world, especially Iran, is the scarcity and inappropriate distribution of rainfall throughout the year, and it is such that the problem of water shortage in these regions is always evident (Madani et al., 2016). Since rainfall in these areas, is very low, therefore it does not meet the water needs of plants (Dogan, 2012). Ponds, pans, dams, terracing and percolation tanks are the most common types of rainwater harvesting techniques in arid and semi-arid regions (Ziadat, 2012). Ancient evidence of the use of rainwater harvesting (RWH) techniques has been found in many countries around the world, including Jordan, Palestine, Syria, Tunisia, and Iraq (Al-Adamat et al., 2012). The use of rainwater collection methods in these areas will lead to the provision of accessible water equivalent to the water needs of plants; it will also lead to economic production, and will help provide livelihood for villagers (Cosgrove and Loucks, 2015). Success in water extraction projects depends not only on the design of rainwater catchment systems by experienced experts but also on the economic and social issues of residents of arid and dehydrated areas (Lasage and Verburg, 2015). The farmer implementing water extraction projects, contributes significantly to the benefit of the community living in these areas (Campisano et al., 2017). At present, extensive research has been done on the extraction of rainwater and the increase of soil moisture storage in different parts of the world using different levels, including insulated and semi-insulated surfaces, which differ in the type of use of extracted water (Yosef, and Asmamaw, 2015). In this regard, we can refer to insulation surfaces such as bitumen, paraffin or nylon coating and other methods such as collecting pebbles and vegetation from catchment surfaces (Kazantzidis, 2015). Important factors that play a significant role in increasing the maintenance of soil moisture reserves include the combined use of insulation surfaces to produce more runoff on the one hand and the use of vegetation or sand filters on the other hand to penetrate the extracted runoff which improves soil moisture conditions (Dorigo et al., 2017). The basic hypothesis in this project is the feasibility of soil moisture storage by using different treatments in soil profiles to establish the development of sloping orchards and using catchment surface systems. For this purpose, a study was conducted in Isfahan province at the Zayandehrood Dam National Station. In this research, we have tried to analyze the rainfall in different systems of rainwater catchment surfaces (insulated, semi-insulated or rolled surface and natural cover) and the use of different moisture storage treatments (soil treatments and gravel filters) in seedling planting holes to increase the moisture reserve for the establishment of productive plants. The main purpose of this project is to compare different methods of collecting precipitation (insulated, rolled and control), pebble filters at the end of systems and different soil treatments at the location of seedling holes in quantitative and qualitative optimization of runoff production in catchment surface systems and increasing soil moisture storage in low rainy months. Finally, this project has been done for the development of dry land sloping gardens.

2- Materials and methods

This project carried out in Zayandehrood National Dam Station (Figure 1).

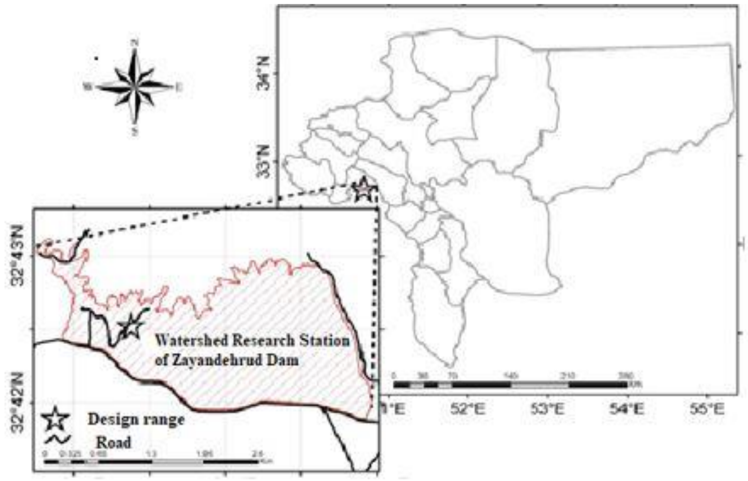

Fig.1- Location of Zayandehrood National Watershed Research Station and experimental plots

48 plots with dimensions of 4 * 7 meter, including insulation surface (covered with nylon UPV), semi-insulated or rolled, and natural cover with and without gravely filters at the bottom of each plot at the beginning of seedling planting hole were created. At the bottom of each level of the catchment surface system, a seedling hole with dimensions of 1 * 1 * 1 meter was created with four soil treatments. Soil treatments including the following were applied for three years. The map illustrating the geographic location of study area and 48 plots, within the manuscript has been shown in Figure (2).

Fig. 2- Position of experimental plots

1-Mixed treatment of cow manure and soil at a ratio of 25% by volume

2-mixture of cow manure and soil at a rate of 25% by volume plus a nylon at the bottom of the seedling planting hole and towards the slope of the valley

3-mixture of cow manure and soil at a rate of 25% by volume plus a nylon at the bottom of the seedling planting hole and about 15 cm at the bottom of the thorn and debris hole in the site

4-control treatment without any operation

After creating different levels and applying soil treatments, almond seedlings were planted. The diameter of the pebble filters at the surface output of the systems was considered 25 cm. On both sides of the almond seedling crown and at a distance of 10 cm, TDR probes were placed at two depths of 30 and 50 cm (Figure 3).

Fig. 3- Measurement of volumetric moisture of treatments by TDR device

The reason for choosing two depths of 30 and 50 cm was to check the soil moisture in the root depth of the almond tree. To investigate moisture changes in the soil profile of seedling holes, moisture from two depths of 30 and 50 cm was measured every 10 days with TDR model 6050X1. According to the daily and monthly rainfall recorded in the climatology station of Zayandehrood National Dam Station, the average monthly rainfall from May to October during three years, which has the greatest impact on seedling growth stages and shows the treatments applied for better store of seedling profile moisture, was recorded. The orchards tested in the area contained almond trees (Shahroud 7 and 12). The statistical design used in this research project was factorial in a completely randomized design and was analyzed with SAS software.

3- Results and Discussion

To review and analyze the results from May to October during three years, which have the greatest impact on the growth stages of seedlings, third year outcome data were shown. The results of analysis of variance of the data obtained from volumetric moisture at two depths of 30 and 50 cm, showed that there was a significant difference at the level of one percent probability between different levels of rainwater catchment systems, soil treatments, depth in soil treatments and depth in filtered and unfiltered systems. There was no significant difference between the depths in the systems in soil treatments (Table 1).

Table 1- Results of analysis variance of different levels of systems with gravely and non-gravely filters, soil treatments and two depths of volumetric moisture content in seedling planting holes

Sources of changes	Average squares degrees of freedom	Volumetric moisture content
Different levels of rainwater catchment systems with and without filters	5	**87.98
Soil treatments	3	**525.35
rainwater catchment systems* Soil treatments	15	**18.85
Depth (volumetric moisture at two depths)	1	**163.85
Depth* rainwater catchment systems	5	**11.65
Depth* Soil treatments	3	**3.22
Depth* Soil treatments* rainwater catchment systems	15	**3.35
Error	96	

** Indicates significance at the 1% probability level * Indicates significance at the 5% probability level

Comparison of means showed that among different systems of rainwater catchment levels (insulated, semi-insulated or rolled and natural cover with pebble filters and without pebble filters) the insulation system with pebble filters 16.92 % by volume was the highest and the system with coating Natural and without gravel filter with 14.51% had the lowest value. Semi-insulated systems with and without gravel filter and natural cover were in the same group (Table 2).

Table 2 - Comparison of the mean percentages of volumetric content between different systems of rainwater catchment levels with and without gravely filters

Rainwater catchment systems with and without gravely filters	Volumetric content (%)
Insulation cover without pebble filters	15.86[c]
Semi-insulated without pebble filters	15.28[d]
Natural cover without pebble filters	14.51[e]
Insulation cover with pebble filters	16.92[a]
Semi-insulated cover with pebble filters	16.48[b]
Natural cover with pebble filters	15.87[c]

Means with the same letters do not have significant differences.

Insulation surfaces such as bitumen, paraffin or nylon coatings and other methods such as pebble collection and vegetation were mentioned from the water harvesting systems used by other researchers (Aladenola and Adeboye, 2010; Ward and Butler, 2012; Jones and Hunt, 2010). Comparison of means showed that between the two depths (30 and 50 cm) studied on both sides of the crown of seedlings, the highest percentage and the lowest of volumetric content in depth of 50 and 30 cm(16.88%, 14.75%) were obtained respectively (Table 3). The role of gravelly filters in water transfer to the root development area is very effective and factors such as depth, texture, soil structure are effective in water retention capacity of this water (Roughani et al., 2011 and Jubaida, 2017).

Table 3 - Comparison mean of the volumetric content between two depths of 30 and 50 cm between different systems of rainwater catchment levels

Depth(cm)	Volumetric humidity (%)
30	14.75b
50	16.88a

Comparison of means showed that between soil treatments (mixed treatment of cow manure and soil at 25% by volume, mixed treatment of cow manure and soil at 25% by volume plus a nylon at the bottom of the seedling planting hole and towards the slope of the valley, treatment of a mixture of cow manure and soil at a rate of 25% by volume plus a nylon at the bottom of the seedling planting hole and about 15 cm at the bottom of the thorn and debris pit in place, and control treatment without any operation in the place of seedling hole), in terms of volumetric content, the treatment of cow manure and soil at 25% by volume plus a nylon at the bottom of the seedling planting hole and about 15 cm at the bottom of the thorn hole and the debris in the site with 18.63% was the highest and the control treatment had the lowest amount of moisture content with an average of 13.46% were obtained. The other two treatments, one and two, were placed between the two values (Table 4). Soil conditioner has played an important role in soil moisture, which has been suggested by various researchers (Seneviratne et al., 2010 and Brocca, et al., 2012).

Table 4 - Comparison mean of volumetric content between soil treatments of different rainwater catchment systems

Soil treatments	Volumetric humidity (%)
mixed treatment of animal manure and soil at 25% by volume	14.87[c]
Animal manure and soil in the ratio of 25% by volume + nylon	16.32[b]
Animal manure and soil in the proportion of 25% by volume + nylon + thorns and debris	18.63[a]
control	13.44[d]

4- Conclusion

The use of different and low cost rainwater catchment systems significantly increases runoff production and soil moisture storage in low rainy seasons and ultimately leads to the development of rainfed gardens and helps the livelihood of villagers.

Due to climate change and lack of rainfall, today, the use of water harvesting systems is increasing in different parts of the world. Iran is one of the countries facing a shortage of rainfall and the use of water harvesting systems has been used since ancient times. Upgrading and streamlining these rainwater storage systems can play an important role in increasing soil moisture content. In this research, by using water harvesting systems and the application of gravely filters and soil treatments, the soil moisture storage was improved. In the low rainy seasons in this region, which starts from May and continues until the end of September, the use of these water harvesting systems improves the soil moisture situation and increases the yield of rainfed orchards with one or two irrigations during this six-month period.

5- Acknowledgement

Special thanks are due to members of the Isfahan agricultural and natural resources research and education center for their assistance. The authors also appreciate anonymous reviewers for their comments improving the manuscript.

6- Conflicts of Interest

No potential conflict of interest was reported by the authors.

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