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MICRO-CATCHMENT RAIN WATER HARVESTING TECHNOLOGY IN CONSERVATION AGRICULTURE AND PLANT PRODUCTION

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Abstract

Water harvesting techniques provide collecting rainwater to reduce water shortage effects and drought as well as added soil and water conservation benefits in dry areas. In the present study, drought effects and flood disasters on agriculture and rainwater harvesting benefits were examined in Southeastern Anatolia region of Turkey. Results showed that, runoff loss was found higher in the plots of plastic mulch than the plots of stone mulch. Sediment loss was found maximum in the plots of the surface compaction whereas minimum losses were quantified in the stone plots. Best erosion control was observed for micro-catchment surface covered with plastic sheet. As a result, Negarim micro-catchment water harvesting technique was found to be useful and feasible technique in enhancing the plant production and the conservation of natural resources.

Introduction

Rainwater harvesting is based on the principle of collecting and accumulating the rain falling to the earth or storing it in a region for later use. It is one of the most effective water management methods that can be used against water shortage in arid and semi-arid areas. Water harvesting is used for domestic and urban use, as well as for large-scale agricultural activities (Fig. 1). Collecting rainwater, storing it and using it in agricultural activities is a historical water management practice. The history of rainwater harvesting dates back to the Neolithic Age. It is known that cisterns were used to supply water in arid areas in Egypt in 4000 BC. Various rainwater harvesting techniques have been developed for drinking and agricultural activities such as aqueducts, cisterns, roof storage systems. Water harvesting systems have a wide variety of advantages. It combats drought and supports the permanence of vegetation. It provides erosion control, reduces flood and flood damage. It is a historical practice, supports agricultural irrigation and supports agricultural development in rural areas. While providing adaptation against climate change, it provides water conservation for the future. It is a technique that can provide the development of water resources, which includes methods that the poor can apply (Anonymous 2022).

Turkey has a semi-arid climate in the world. Throughout the country, water/agricultural year precipitation has been determined as 550.9mm. While the normal values of precipitation in Turkey were 573.4mm, these values were recorded as 465.5mm in the 2022 water year. It has been determined that precipitation has decreased by 29% compared to normal values in the country (MGM 2023). While precipitation reaches 3000 mm in some regions, it cannot exceed 250 mm in some regions. For this reason, the desired amount of water cannot be supplied to the plant, especially during the periods when water is needed in plant production. In case of current water use, it is stated that two-thirds of the world's population will face water shortage in 2025 (Çakmak *et al.* 1999). Agricultural production in the Southeastern Anatolia Region of Turkey is mostly carried out in dry conditions. Production in dry conditions is based on rain water. In the drought

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assessment study using the Standard Precipitation Index, 40 years of precipitation data from Siverek, 17210, and 17261 Gaziantep stations in the Southeastern Anatolia Region were analyzed, and 1 and 12-month meteorological drought levels were examined. In case of 1 month shift, it has been reported that 52 to 71% of normal, 16 to 48% of severe drought occurs. Very severe drought in the region was determined to be 8% only in Gaziantep station (Özfidaner and Topaloğlu 2020). In the dry years, there are problems in production and the yield decreases. It is known that in terms of topography, landforms and geological structure of the country are quite diverse and consist of sloping lands with high altitude values. Rain water falling on these sloping lands is generally unmanageable and reaches the lands by passing to the surface flow. It causes erosion by carrying the fertile soil on the surface with the surface flow. In these arid agricultural lands with reduced productivity, holding and storing rainwater can provide erosion control while meeting the water needs of the grown plant. Because of these advantages, rainwater harvesting is a suitable technique for sustainable soil management.

Due to the lack of precipitation in the Southeastern Anatolia region in 2021, important agricultural products such as wheat, barley and lentils dried up in the field and could not be harvested in many provinces most of the country's grain needs are met (Fig. 2). It was reported by the Chamber of Agricultural engineers that there was a yield loss of 75 to 90% in the region in 2021 and that the lack of precipitation continued in 2022. The distribution of precipitation according to months is also important in this region, especially in February 2022, while precipitation decreased by 60% in the southeast, the lack of precipitation in April negatively affected grain mortality in grains (Fig. 3). Yield losses exceeding 50% were experienced in cereals and pulses. The fact that the precipitation does not occur during the periods when the plant needs it has increased the risk of agricultural drought in dry agricultural areas. In addition, torrential rains and floods at the end of the dry months, in many parts of the country, also damaged agricultural products. In the Southeastern Anatolia region, the heavy rains following the drought caused fruit drop in fruit bearing trees and vineyards (Fig. 4). Excessive rainfall delayed ripening in some crops. Drought analysis of the provinces in the Southeastern Anatolia Region was made, and monthly total precipitation data from 9 meteorology stations between 1960 and 2016 were evaluated. In the study using the Effective Drought Index (ECI) method, a total of 154 drought events were determined.

Irregularity of precipitation causes cracks in fruits and vegetables and causes groundwater to rise in arid region soils. It causes root rot and fertilization problems in plants. Producers who have problems entering the field after untimely and heavy rains are unable to harvest. The experienced hail rains damaged the leaves, especially in fruit trees. Plant buds are crushed, new shoots are broken and flowers are destroyed and fruit drop is experienced. In addition to the decrease in yield, quality losses are also observed. In the flood disaster that occurred between May and June 2022 in the Southeastern Anatolia region and Kilis province, the agricultural lands of many farmers were severely damaged. According to the 2022 rainy season, the highest decrease in precipitation was observed in the Southeastern Anatolia Region with 57%. Thus in the present study attempts were taken to evaluate effects of micro-catchment water harvesting technique for increasing the growth and yield of tree growth as well as conserving soil and water.

Materials and Methods

Southeastern Anatolia region having a semi-arid climate and climate change is the biggest risk in this region. Long-lasting droughts, forest fires, severe and sudden floods negatively affect the lives of all living things. The lack of precipitation and irregular and unpredictable storms in this region negatively affect agricultural production. These regions, precipitation must be managed in a controlled manner. Rainwater harvesting is an economical and beneficial practice for these regions. Evaporation losses, runoff and accompanying erosion damage in arid areas can be controlled by appropriate rainwater harvesting technique (Oweis *et al.* 2001). In the semi-arid conditions of the Southeastern Anatolia region Şanlıurfa, the 30-year average temperature was 18^{o}C, the precipitation was 344.1mm, and the evaporation was 2047mm. Micro-catchment rainwater collection systems are based on the collection of runoff at small distances in the root zone. Flow water is stored in the areas where it is collected or delivered directly to the plant root zone. These systems are useful application for trees, shrubs or annual plants (Oweis *et al*. 1999). The size of the basin can range from a few square meters to an area of 1 decare. These structures are constructed to direct the runoff towards the lowest point of the plant where the plants are placed. Negarim microcatchments are often beneficially used for fruit trees with high economic value such as pistachio, apricot, olive, pomegranate and almond (Oweis *et al*. 1994). In the present study, runoff and sediment were measured in 45 negarim microcatchments, 15 from each mulch cover. In the trial area, which has semi-arid climatic conditions in the Southeastern Anatolia region, an average of 299 mm of precipitation was received in three water years (2010-2011-2012). In the pistachio orchard with an average slope of 6%, microcatchment water harvesting, natural, clean water was provided for the plant with various mulch applications, sediment and surface flow losses were prevented by mulching and erosion control were also provided in this sloping orchard (Kuzucu 2013). Here the effectiveness of mulch covers for erosion control was compared. Runoff and sediment losses from rainfall were also measured after each rainfall. The rainwater runoff and sediment transported by rainwater between the experimental subjects were measured by collecting them in a collection container with a sheet metal gutter placed at the bottom of the micro-basins. After each rainfall that caused runoff, the lid on the runoff tank was opened and the water height was measured. The water in the tank was mixed and suspended and 2 liter sub-samples were taken and analyzed in the laboratory to calculate sediment losses. In this way, the cover material that realized the best surface runoff and reduced sediment losses among the cover materials used was determined (Fig. 5). Precipitation and temperature falling in the research area monitored by an automatic climate station and evaporation monitored daily from the evaporation tank was measured. Plant height was measured with a meter. Experimental design and experiment area map are presented in Figs 6 and 7.

In the study area, there was low precipitation and high evaporation. Therefore, rainwater harvesting is an extremely important research for this region. This region has struggled with drought for many years. There have been great losses in agricultural production. Especially sloping agricultural lands, soil losses have occurred in addition to yield loss. For all these reasons, this study is of great importance for the region.

Results and Discussion

Plant development was different from each other with the application of microcatchment water harvesting mulch covers. The heights of the trees were measured as 116.7 cm for plastic cover, 95.7 cm for straw cover, 95.1 cm for surface compaction, 70.2 cm for control subjects and 70.1cm for stone cover (Fig. 8). In another study the plastic-covered ridge and gravel-covered furrow subject and the plastic-covered ridge subjects provided more water storage and soil moisture retention than the control subject. Tree height, crown diameter and trunk circumference development increased by 70, 57 and 79%, respectively, compared to the control subject Xiao-Yan *et al*. (2008).

In the present study, the average maximum runoff during 3 water years was determined as 7090 l/plot for plastic cover, and the average minimum runoff was 756 l/plot for stone cover. The average maximum sediment transport was measured at 2870g/plot for surface compaction, and the average minimum sediment loss was measured at 590 g/plot for stone cover (Fig. 9). Xiao-Yan *et al.* (2002) determined that while the surface runoff efficiency was 33% in compacted plots, this

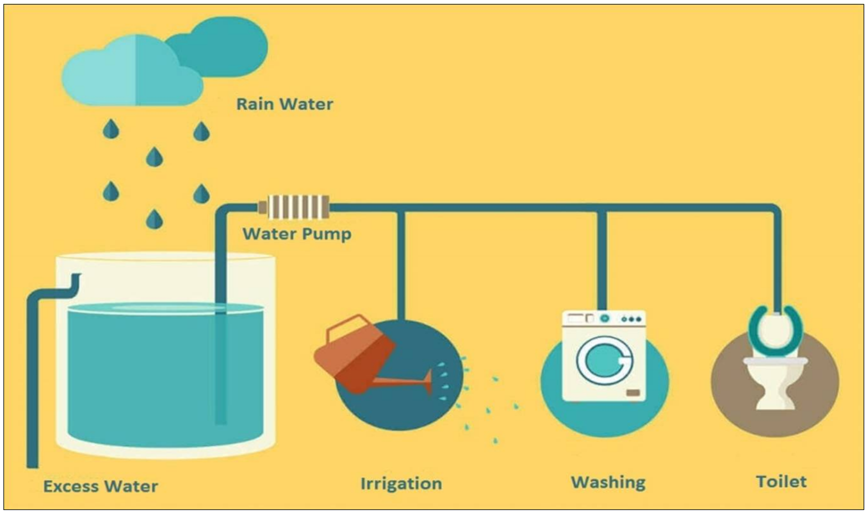
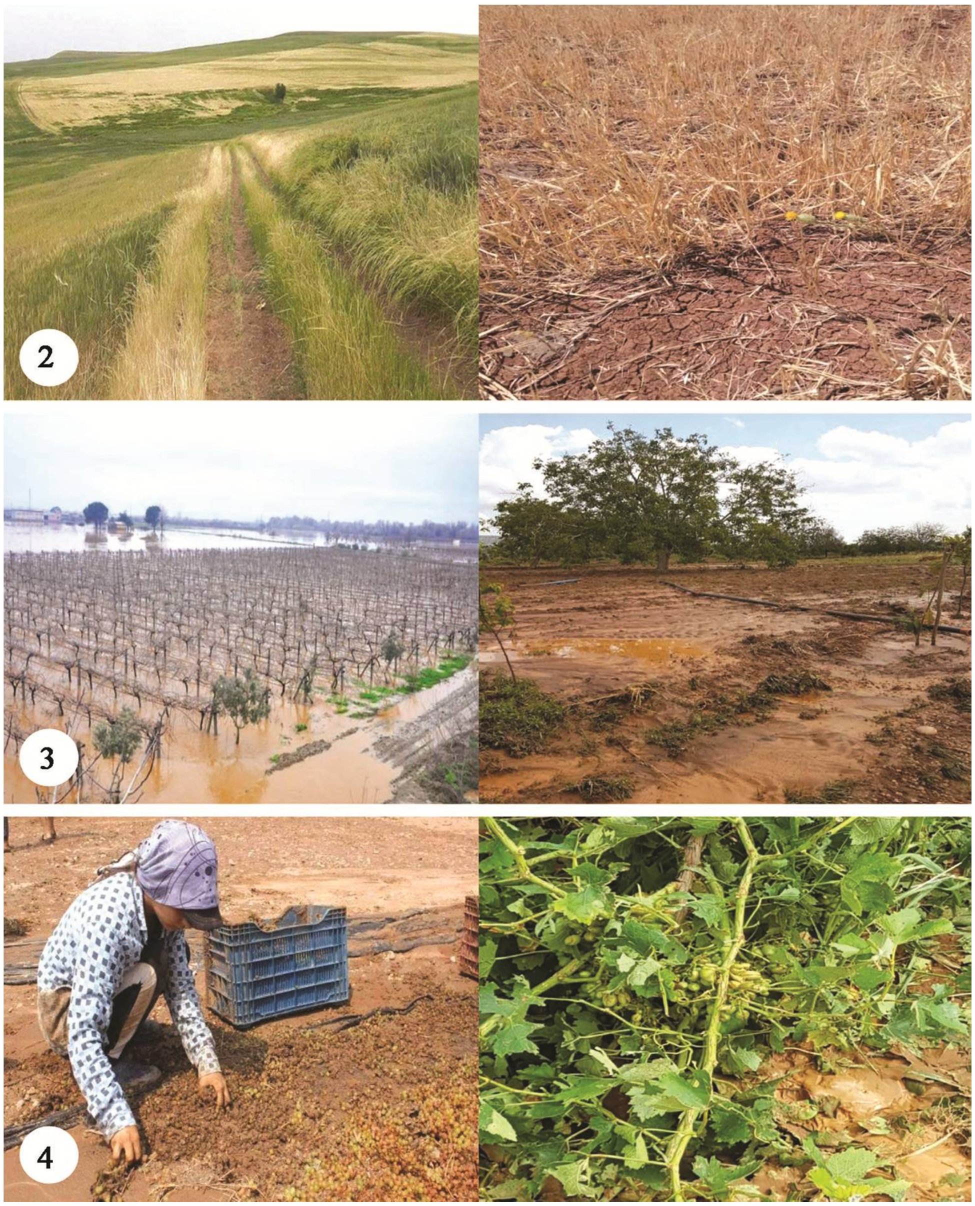


Fig. 1. Water Harvesting System (Anonymous 2022).

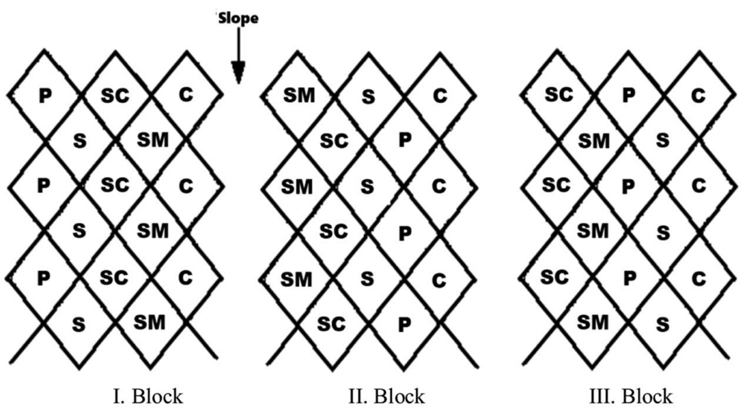
value was 8.7% under natural conditions. Ojasvi *et al.* (1999) reported that closed micro channels retained higher soil moisture than the control treatment in water harvesting. The plant height of the subjects covered with stone and marble pieces was 40-48% higher than the control subjects. Wang *et al.* (2008), in their study, obtained higher yields than the control application of straw mulch, which is one of the water harvesting methods applied to the corn plant. Wang *et al.* (2011) reported that evaporation decreased in areas where water harvesting stone and gravel mulch was applied. In terms of surface compaction, the compacted layer formed on the micro-basin surface was eroded by heavy rains, causing sediment loss. While less sediment loss occurred in straw cover, the least sediment loss was measured in stone cover. In this regard, the stones laid on the surface of the micro-basin prevented water and soil losses by creating a barrier. Since the micro-catchment surface is covered with plastic cover, the application providing the best erosion control was determined as plastic cover. In the three water years, the runoff transmission efficiency of the plastic cover was 59.4, 78.3 and 59.9%, respectively. Within three water years, the weakest water transmission occurred in the stone cover. The surface flow transmission efficiency measured in three water years with the stone cover application was measured as 3.7, 9.4, and 2.8%, respectively. In this study, the most successful rainwater harvesting cover was plastic mulch, while the most successful erosion preventing cover was stone mulch. Xiao-Yan *et al.* (2002), found that while the efficiency of the total rain runoff was 33% in the compacted plots, it was 8.7% in the untreated control plots. Xiao-Yan *et al*. (2000), reported that in semi-arid regions of China studies on maize plant growing on bare ridges, the average runoff efficiency was 7%; This value was measured as 87% on the ridges covered with plastic cover. As a result of this study, the mulch cover that collects the best surface flow is plastic cover; the most successful mulch cover that reduces the sediment loss is stone mulch, the most economical application: straw mulch cover.

With climate change, the water regime changes in agricultural areas and soil resources become inefficient due to drought or flash floods, and agricultural production decreases, causing social and economic damage. While droughts cause a decrease in yield, flood disasters causes erosion, increase of diseases and pests, and economic problems due to the difficulty of living conditions of producers it becomes difficult for the people of that area. With climate change,



Figs 2-4: 2. Drought in Grains (Anonymous 2021). 3. Winter Flood Damage in Vineyards in Kilis (Anonymous 2021). 4. Yield Losses in Grape Harvest (Anonymous 2018).

Fig.5. Stone Cover and Surface Compaction Runoff and Sediment Measurement System (Kuzucu 2013).

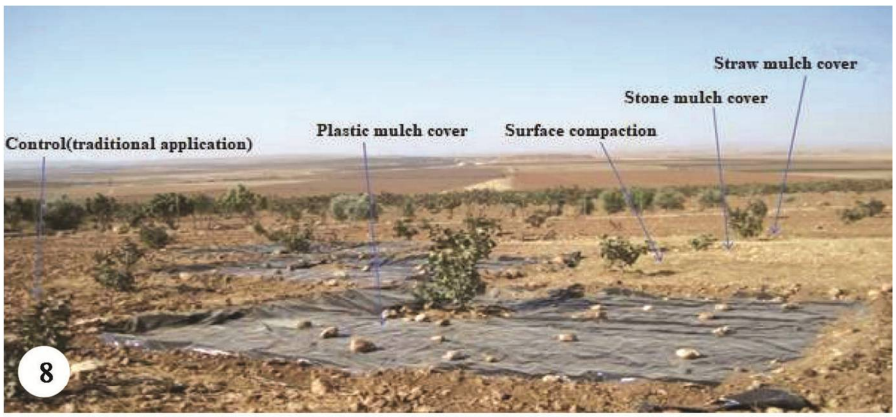


(P:plastic mulch, S:surface compaction, SC: stone cover, SM: straw mulch, C: control).

Fig. 6. Experimental Design.

Fig.7. View of the Experimental Area.

access to water resources for the people living in rural areas becomes more difficult. The absence of drinking water in the thirsty villages causes health problems to the poor people as well as the problems it brings in agricultural production. Preventing or minimizing the harmful effects of climate change will only possible with the development of new agricultural technologies. It is necessary to protect and improve the physical, chemical and biological properties of soils and to ensure the sustainability of existing water resources. In areas with low precipitation, it is important to protect every drop of water that falls and to use it in agricultural production.



Figs 8-9. 8. Plant Height Differences (Kuzucu 2013). 9. Plastic and Stone Mulch Covers (Kuzucu.2013).

Water scarcity in arid areas can be eliminated by harvesting rainwater. In the fight against climate change, efficient use of water can be achieved with water harvesting systems and it enables agricultural production in arid and semi-arid regions that do not receive sufficient precipitation. Rainwater harvesting, whose history dates back to ancient times, has been newly implemented in Turkey and successful results have been obtained. For these reasons, it has been seen that most of the rainwater harvesting systems in In Turkey are applicable and can reduce the damages of climate change. Rainwater harvesting, which is an economical and beneficial practice that aims to benefit from natural resources in agricultural production, reduces the effects of drought, stops and stores sudden flood waters and provides the opportunity to use them for dry periods. The method to be chosen in rainwater harvesting should be suitable for the climatic conditions of the region, soil characteristics, and type of plant to be grown and environmental factors.

References

Anonymous 2018. Ministry of Agriculture and Forestry Kilis Provincial Directorate of Damage Determination (Access date: 20.10.2022).

Anonymous 2021. Ministry of Agriculture and Forestry Kilis Provincial Directorate of Damage Determination (Access date: 20.11.2022).

Anonymous 2022. Water Harvest System https:/rain-water-harvest-what-is-how-to-cost-and-systems-1842 (Access date: 20.12.2022).

Cakmak, B., Aküzüm, T., Benli, B. 1999. The Water Problem in the World in the Twenty-First Century. 7th Kulturtechnique Congress, pp. 8-16, Nevsehir.

Kuzucu M 2013. Effects of MicroCathcment Water Harvesting Technique on Young Pistachio Trees Growth, Soil and Water Conservation in Semi-Arid Areas. PhD. thesis. Çukurova University Institute of Natural and Applied Sciences Department of Soil Science and Plant Breeding.

MGM 2023 2022 Areal Precipitation Report. https://mgm.gov.tr/veridegerlenen/yagis-raporu.aspx (Access date: 25.12.2022).

Ojasvı PR, Goyal RK and Gupta JP 1999. The Microcatchment Water Harvesting Technique for the Plantation of Jujube in an Agroforestry System Under Arid Conditions. Agricult. Water Manage. **41**(3): 139- 147.

Oweis T and Taimeh A 1994. Overall Evaluation of on-Farm Water Harvesting Systems in the Arid Regions. International Conference on Land and Water Resources Management in the Mediterranean Region, Valenzano, Bari, Italy 4-8 September, 1994. No.3, 763-781;13 ref.

Oweis T, Hachum A and Kijne J 1999. Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. SWIM paper no. 7. System-wide Initiative on Water Management, ICARDA and IWMI. International Water Management Institute PO Box 2075, Sri Lanka.

Oweis T, Prinz D and Hachum A 2001. Water Harvesting Indigenous Knowledge for the Future of the Drier Environments, International Center for Agricultural Research in the Areas (ICARDA), Aleppo, Syria.

Özfidaner M and Topaloğlu F 2020. Drought analysis in southeastern Anatolia with the standard precipitation index method. Soil Water J. **9**(2): 130-136.

Tuğrul T, Doğan S and Dursun S 2019. Drought Analysis of the Provinces in the Southeastern Anatolia Region. Konya J. Engineer. Sci. **7**(4): 705-712.

Xıao-Yan L, Jıa-Dong G and Xıng-Hu W 2000. Chinese Academy of InSitu Rainwater Harvesting and Gravel Mulch Combination for Corn Production in the Dry Semi-Arid Region of China. J. Arid Environ. **46**(4): 371-382.

Xiao-Yan L and Jıa-Dong G 2002. Compacted microcatchments with local Earth materials for rainwater harvesting in the Semiarid Region of China. J. Hydro. **257**(1-4): 134-144.

Xiao-Yan L, Zhao W, Song X, Wang W and X-Zhang Y 2008. Rainfall harvesting on slopes using contour furrows with plastic- covered 111 transverse ridges for growing Caragana Korshinskii in the semi-arid region of China. Agricultural Water Management **95**(5): 539-544.

Wang Y, Xıe S and Cecıl LM 2008. Effects of Rainfall Harvesting and Mulching Technologies on Water use Efficiency and Crop Yield in the Semiarid Loess Plateau, China. Agricul. Water Manage. **96**(3): 374-382.

Wang Y, Zhongkuı Xıe S, Malhı S, Cecıl L, Vera YZ and Zhınong G 2011. Effects of Gravel-Sand Mulch, Plastic Mulch and Ridge and Furrow Rainfall Harvesting System Combinations on Water Use Efficiency, Soil Temperature and Watermelon Yield in a Semi-arid Loess Plateau of Northwestern China. Agricul. Water Manage. **101**(1): 88-92.

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