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# Ground Improvement of Dune Sand Fields For The Purpose of Moisture Retention

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**Abstract**
Plant growth depends on the use of two important natural resources, soil and water. Soil provides the mechanical and nutrient support necessary for plant growth. Water is the major input for the growth and development of all types of plants. The availability of water, its movement and its retention are governed by the properties of soil. The properties like bulk density, mechanical composition, hydraulic conductivity etc depends on the nature and formation of soil and land use characteristics in addition to the weathering processes and the geological formations. Effective management of the resources for crop production requires the need to understand relationship between soil, water and plants. Study of soil and its water holding capacity is essential for the efficient utilization of irrigation water. Hence identification of geotechnical parameters which influences the water retention capacity and the method of adding admixtures to improve the retention capacity play an important role in Irrigation Engineering. This Paper aims to focuses on improving moisture retention of soil by addition of bentonite clay and experimental analysis for monitoring the variation of moisture retention.
**Keywords**: Mixture, Bentonite, Dune sand, Irrometer, Moisture retention.

## I. Introduction

When rainfall or irrigation water soaks into the soil, a certain amount is temporarily retained in the soil pores, and the remainder gradually percolates downward to the water table. The amount held in the upper soil depends on the amount of organic matter and the size, shape, and arrangement of mineral particles. In general, the more organic matter the soil contains the more water it will be able to absorb. Mineral particles affect water retention by determining the size and number of pores where water can be held. In soils with large, irregularly shaped sand particles, for example, large pores remain between the sand. Clay particles, by contrast, fit together more compactly, so that the pores are smaller but more numerous. The porosity of a soil is defined to be the volume of the pores as a percentage of the total volume of soil. Porosity provides a measure of the amount of water that each soil can retain in the root zone where it is available to plants.

Only a small fraction of water entering the soil remains in the root zone for a prolonged time period. If not taken up by plants, the remainder gradually percolates downward to become groundwater. The rate at which this percolation occurs is defined by another soil characteristic, the permeability, also called hydraulic conductivity, defined to be the case with which the soil transmits water. Although clay soils have higher porosity and can hold more water than sandy soils, permeability is lower because smaller pores conduct water at lower flow rates. Drainage of fields with clay soils, therefore, is slow compared with drainage in sandier locations. Movement of groundwater to a well also is much slower through clay than sand because of tighter retention of water in smaller pores. Most soils are a combination of sand, silt, and clay, and the percentages of these various particle sizes determine the amount of water held in soil pores and the amount and rate of percolation to greater depths. A clay soil may be unsuitable for crops because drainage is too slow, whereas a sandy soil may require irrigation because the water percolates quickly and does not remain in the root zone where it is available to plants.

How Soils Hold Water: The water-holding capacity of a soil depends on its type, organic matter content, and past management practices, among other things. Soils are classified into one of about a dozen standard texture classes, based on the proportions of sand, silt, and clay particles.

Available water capacity is the amount of water a soil can make available to plants, generally defined as the difference between the amount of water stored in a soil at field capacity and the amount of water stored in the soil at the permanent wilting point.

Plants get most of their water from the upper (shallow) portion of the root zone. The term effective root zone refers to about the upper half of the root zone depth, where roughly 70 percent of the plant’s water is taken up.

Use of Bentonite as Impervious Material: The interest in Bentonite has increased in the recent years because of the need for impervious materials and the inadequacy of natural sources. Bentonite is the primary admixture used in the design of materials that can replace the clay used for the purpose of impermeability. In the recent years many studies have been made on Bentonite and its compounds. Some papers constituting the base of this study are summarized below—

Studies on sand-Bentonite mixtures are mostly focused on rate determination and variations in physical properties. Adding Bentonite to the mixtures effects the compressibility property of the materials with high plasticity. In the passage from sandy state to clayey state, 2% value of Bentonite ration is known as the initial value (Bowles, 1998).The increase of Bentonite displays a linear increase on liquid limit, but it has a limited effect on plastic limit (Bowles, 1998).

Synthetic materials are very expensive, compacted clay liners (CCL) are the most common liner system in developing countries. (Ameta et al, 2008)

The permeability is greatly affected by adding Bentonite and reported reduced from $10^{-4}$ cm/s to $10^{-8}$cm/s after addition of 12% Bentonite with compaction at maximum dry density at optimum moisture content. (Ameta and Wayal, 2008)

The most important effect of adding Bentonite to soil is that the permeability of the soil decreases. This is mostly caused by the fact that as Bentonite enlarges approximately ten times when it is mixed with water, it fills the cavities of coarse material (Bowles, 1998).

Wang (1984) presented correlations about the properties used in the classification of soils showing variation of permeability according to maximum dry density and optimum water content.

In the laboratory studies Kenney et al. (1992), obtained the results that the permeability of sand Bentonite mixtures is dependent on the water content, chemistry of the system and its variations.

According to Kenney et al. (1992), obtaining Bentonite-sand mixtures with low permeability is dependent on the existence of adequate Bentonite in the mixture and the uniform distribution of this Bentonite in the mixture.

Cracks caused by drying are dependent on the water content and the amount of Bentonite used in the mixture. In the mixtures with a high level of Bentonite rate, the decrease of water content causes cracks in the surface.

Bentonite is soft in its natural state; it disintegrates in water and gives a greasy impression when touched. It has a high potential of water retention due to its very small grains with a large surface contact area. It easily absorbs oil and glycerin. Chapuis, Folk, Lundgren also did significant work in this field.

Methodology: The two main issues with sandy soils are the drainage and the heat factor. Sandy soils warm up very quickly, while they also are able to drain water away quickly. Because of this, it can be less nutrient-rich than it needs to be. However, there are some ways that you can help a sandy soil and make it better for crops listed below-Mulch - Mulch is a very good way to help keep the soil from drying out. Covering it with a good layer of mulch keeps the soil moisture as the sun has a harder time getting to it to evaporate the water.

Organic Matter - Whether this is compost or manure, or any other type of organic matter, adding it into the soil will not only help it out in giving it nutrients but it also helps improve water retention. The choice of organic matter will depend on availability.Fertilizers - For sandy soils, fertilization is done during the growing season. Fertilizers will help you feed your plants by turning up the microorganisms in the soil.

Coir Pith -Coir pith, a highly lignocellulosic material is available in large quantities as a byproduct of the coir industry.

Vermi Compost-Vermi compost is dark brown / black humus like material, soft in feel and free from any foul smell, live weed seeds and other contaminations. It is the excreta of earthworm, which is rich in humus.

## II. Experimental Analysis

For improving moisture retention of dune Sand fields of Western Rajasthan new methodology is undertaken. The Bentonite clay is added in Dune sand in combinations varying from 1% to 3%and the moisture retention or soil water suction is measured with the help of Irrometer. Combination 1 is 0% Bentonite, Combination 2 is 1 % Bentonite, Combination 3 is 2 % Bentonite and Combination 4 is 3 % Bentonite.

The Irrometer measures energy directly – the energy, that is the roots must exert to extract moisture from the soil – whereas other methods of making soil moisture determinations measure the total amount of soil moisture and then in effect, convert it into root energy for each type of soil by means of soil calibration charts. Obviously then, the Irrometer requires an entirely different unit of soil moisture measurement. The Irrometer gauge is graduated 0-100, the graduations representing hundredths of an atmosphere. The unit of measurement is centibars or kilopascals, with a gauge reading of 50 representing 1/2 atmosphere or about 7 pounds of negative pressure (vacuum). This reading is a direct measurement of how hard the root system has to work to extract water.

The following are typical of adjustments in irrigation treatments.

In hot, dry climates, irrigations start at the following readings for most crops:
10-35 in sandy soils / 35-50 in medium soils / 50-60 in fine textured soils

In cool humid climates – coastal areas, for example – it is often safe to delay irrigations until readings are 10 to 15 points higher in each case.

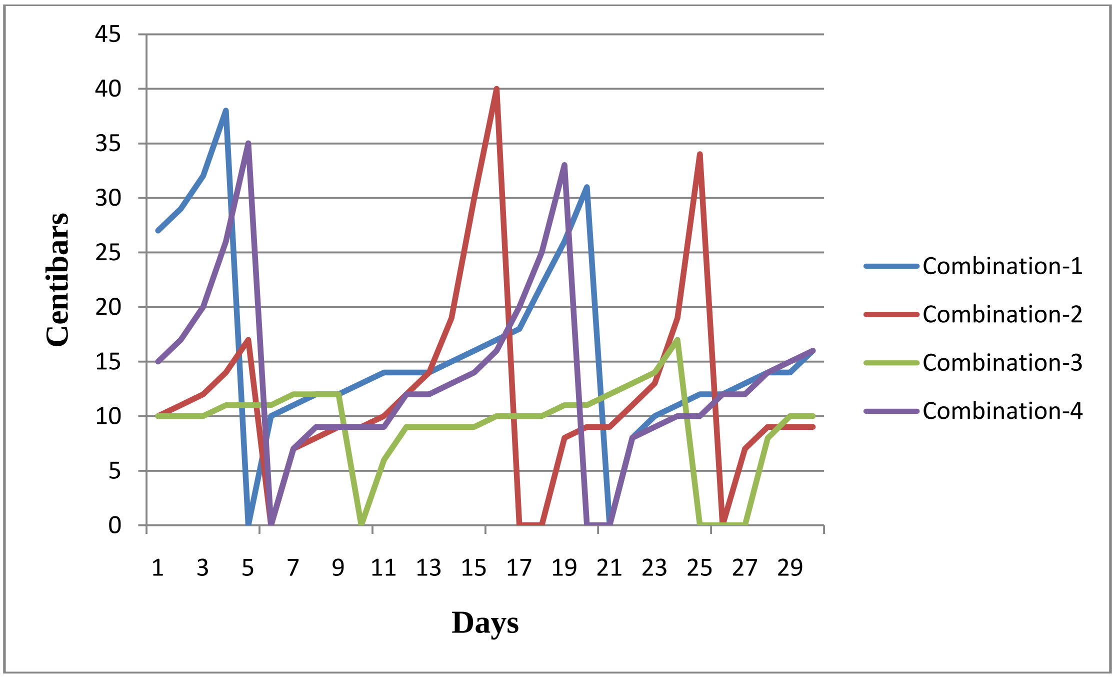
Four Iron Models (drums) are installed in the field located at Jodhpur. Drums are filled with proposed combinations of Dune Sand and Bentonite.Two Irrometers are installed in each drum one at 6 inches and other at 12 inches depth of soil. Papaya plants were planted in eachdrum. The plants were irrigated as per the monitored readings giving water stress and the watering frequencies are listed below for different combinations.

Irrigation frequency of plants –(Volume of water per watering-7 litres)

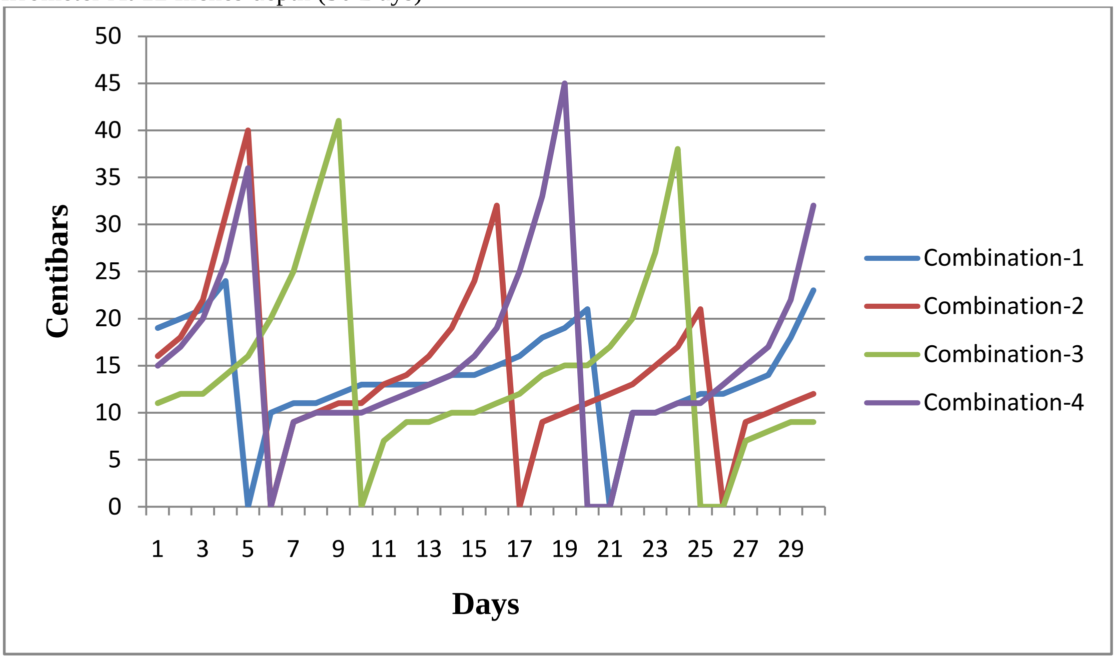
| **COMBINATION-1 IRRIGATED DATE** | **COMBINATION-2 IRRIGATED DATE** | **COMBINATION-3 IRRIGATED DATE** | **COMBINATION-4 IRRIGATED DATE** |
|---|---|---|---|
| 4/11/13 | 5/11/13 | 9/11/13 | 5/11/13 |
| 20/11/13 | 16/11/13 | 24/11/13 | 19/11/13 |
| 2/12/13 | 25/11/13 | 7/12/13 | 15/12/13 |
| 15/12/13 | 5/12/13 | 27/12/13 | 10/1/14 |
| 5/1/14 | 19/12/13 | 17/1/14 | |
| 24/1/14 | 12/1/14 | | |
| | | | |

The observations were taken from Irrometers at 6 inches and 12 inches depth at 8.30 am daily. Graphs were plotted between days and the Irrometers readings as shown below for three months.

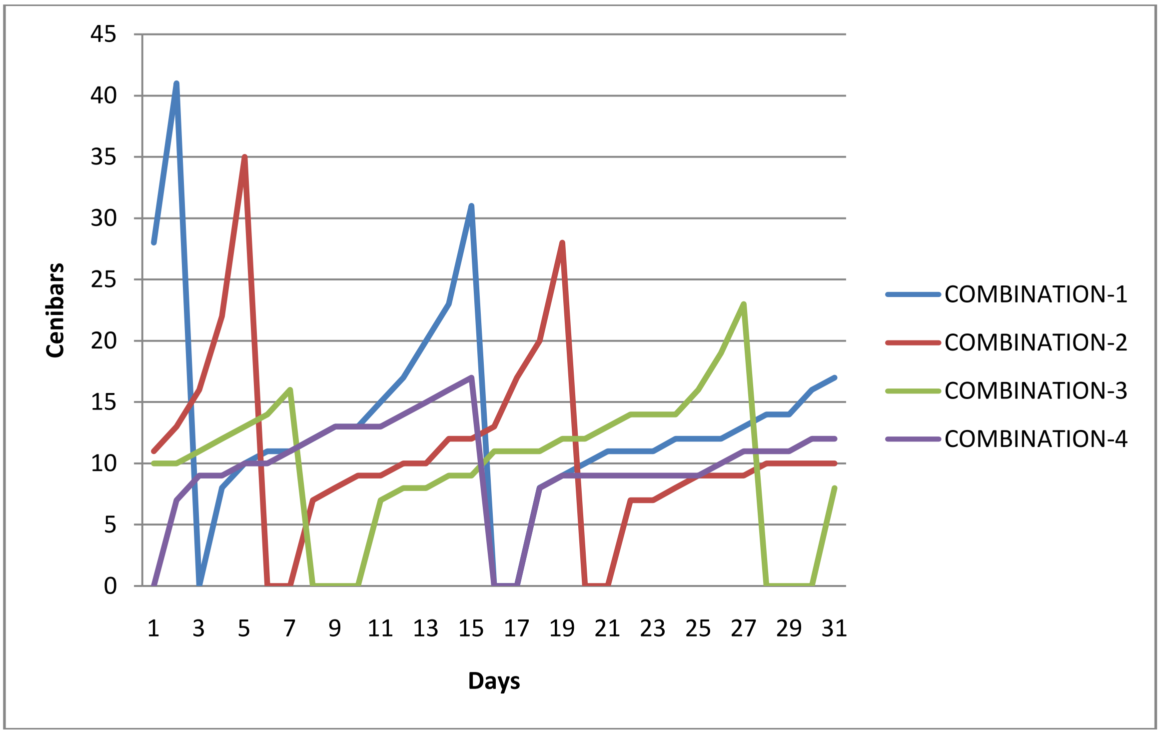
For Nov 2013 (30 days)For Irrometer At 6 Inches depth-



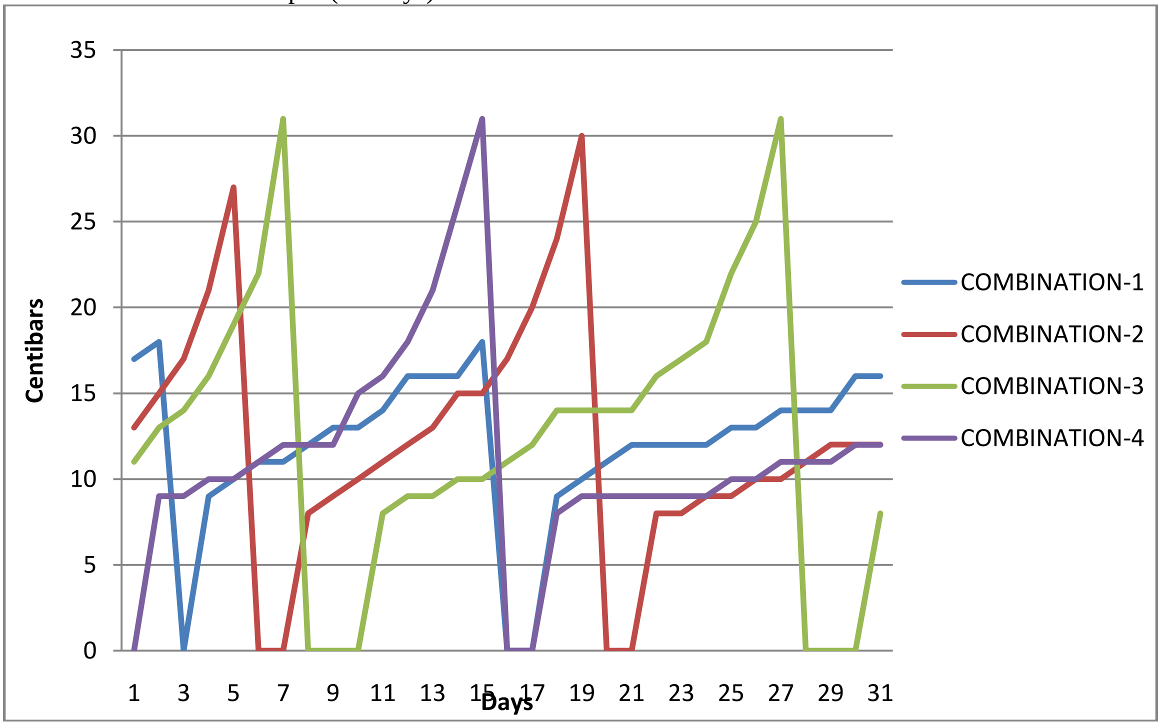

For Irrometer At 12 Inches depth (30 Days)-




For December 2013 (31 Days)
For Irrometer 6 inches depth

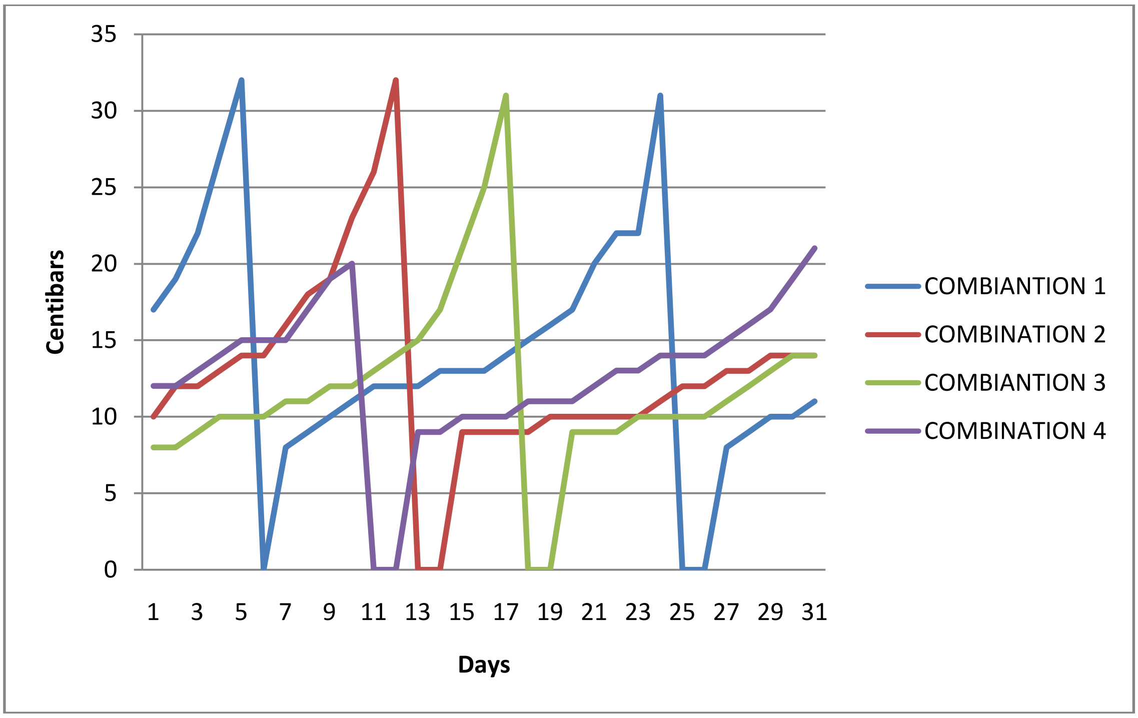



For Irrometer at 12 inches depth (31 Days)

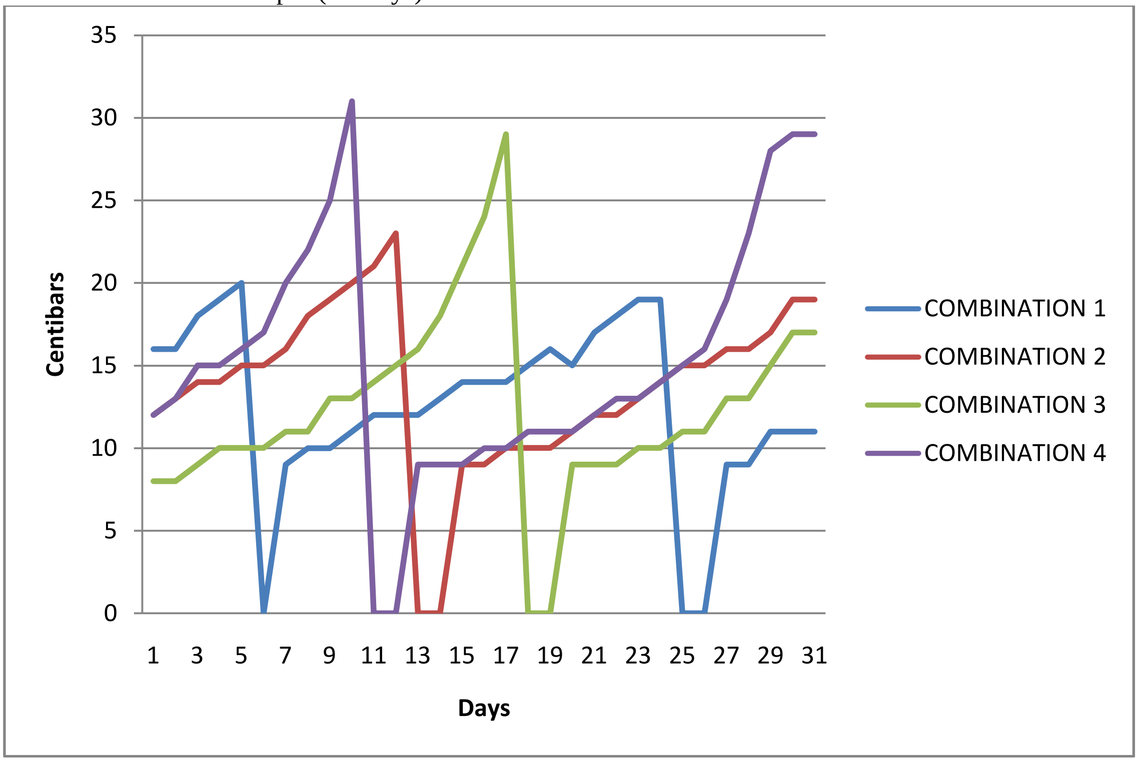



For January 2014 (31 Days)-

For Irrometer at 6 inches depth




For Irrometer at 12 inches depth (31 Days)




From the experimental analysis it is found that irrigation frequency of plants changes with different combination.Combination having higher bentonite requires less frequent irrigation while those having lower are irrigated more. This is because the infiltration of water reduces and water holding increases due to the addition of bentonite clay.

## III. Conclusion

When dune sand is mixed with 2-3% of bentonite, the Infiltration looses are reduced and addition of clay helps in greater moisture retention thus reducing the intensity of irrigation. The Irrometer reading above 30 for dune sand field's shows how hard the root system has to work to extract water and hence watering is needed. Under similar conditions the growth of the plants with Bentonite is greater as compared to that of the original field; greater growth will lead to early maturing of plants which will further decrease the irrigation requirement considerably. The experimental analysis shows that theaddition of Bentonite helps in greater moisture retention in plant thus reducing the intensity of irrigation.

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## References

[1] Ameta N. K. and Wayal A. S., “*Effect of Bentonite on permeability of dune sand”*, *Electronic Journal of Geotechnical Engineering (EJGE),* Vol.13, Bundle A, 2008.

[2] Ameta, N. K., Purohit, D.G. M. and Wayal, A.S. (2008), *Characteristics, problems and remedies of expansive soils of Rajasthan, India, Electronic Journal of Geotechnical Engineering,*Vol.13, Bundle A, 2008.

[3] Bowles JE (1998) “*Engineering Properties of Soil and Their Measurement*”, Mcgraw-Hill Book Company, Singapore”

[4] Chapuis, R.P. (1981) “*Permeability testing of soil-Bentonite mixtures,” Proceedings, 10th International conference on* Soil Mechanics and Foundation engineering, Stockholm, Vol.4,744-745.

[5] Chapuis, R.P (1990) “*Sand-Bentonite liners: predicting permeability from laboratory tests*” Can. Geotech. J. 27, 47-57

[6] Dr. Bushra S. Albusoda and Lubna A. Kh. Salem **,”** *Stabilization of Dune Sand by Using Cement Kiln Dust (CKD)*”Journal of Earth Sciences and Geotechnical Engineering, vol. 2, no. 1, 2012, 131-143 ISSN: 1792-9040(print), 1792-9660 (online)International Scientific Press, 2012

[7] Dr. Saad F.I. and AL-Abdullah*,” An approach in improving the properties of sand dunes”* Number4 .Volume13 ,Journal of Engineering(2006)

[8] Folk, R.L. (1954) “*The distinction between grain size and mineral composition in sedimentary-rock nomenclature*.” Journal of Geology 62: 344-359.

[9] Kar, A. (1994), “*Sand dunes and their mobility in Jaisalmer district*”,, Dikshit, K.R., Kale, V.S. and Kaul, M.N. (eds.), India: Geomorphological Diversity (Eds., K.R. Dikshit, V.S. Kale and M.N. Kaul). Rawat Publishers, jaipur, pp. 395-418.

[10] Kenny, T.C., W.A. Van Veen, M.A. Swallow and M.A. Sungaila (1992) “*Hydraulic conductivity of compacted Bentonite-sand mixtures*,” Can. Geotech. J. 29, 264-374.

[11] Jinliang HUANG , Zhenshun, Pengfei , Qingsheng , Jie LIN “*Analysis of rainfall runoff characteristics from a subtropical urban lawn catchment in South-east China*” Front. Environ. Sci. Engin. China DOI 10.1007/s11783-010-0287-x (2011).

[12] 11. Postel, Sandra (1999)”*Pillar of Sand”, Worldwatch Books,* New York.

[13] Lundgren, T.A. (1981) “*Some Bentonite sealants in soil mixed blankets*.” Proceedings, 10th International conference on Soil Mechanics and Foundation engineering, Stockholm, Vol.2, 349-354.

[14] *USDA-Natural Resources Conservation Service (1997),* NRCS Irrigation Guide. Natural Resources Conservation Service, Washington, DC

[15] Wang MC (1984).” *Soil compaction and Permeability Prediction Models*”, ASCE J. Environ. Eng., pp. 1063-1083.