Physico-chemical properties of rain water harvested under different situations in lateritic soils

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Physico-chemical properties of rain water harvested under different situations in lateritic soils"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Physico-chemical properties of rain water harvested under different situations in lateritic soils"** is a record of research work done independently by **Mr. Abdu Ibrahim Hassen** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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DEDICATED TO MY MAJOR ADVISOR,

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ABBREVIATIONS

BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
Ca	Calcium
CD	Critical difference
Cl	Chloride
COD	Chemical oxygen demand
COH	College of Horticulture
$dS\ m^{-1}$	Deci Siemens per metre
EC	Electrical conductivity
Fe	Iron
ha	Hectare
INTIMASI	Integrated technology information management for agricultural sustainability and innovation
K	Potassium
kg	Kilo gram
KP	Kotteppadom
L	Litre
me	Milli equivalent
mg	Milligram
Mg	Magnesium
N	Nitrogen
No.	Number
NO_3	Nitrate
OC	Organic carbon

P	Phosphorus
ppm	Parts per million
RF	Rainfall
RSC	Residual sodium carbonate
RWH	Rainwater harvesting pond
SAR	Sodium adsorption ratio
SR	Surface runoff
TDS	Total dissolved solids
USDA	United States Department of Agriculture
W	Well

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INTRODUCTION

I. INTRODUCTION

Kerala experiences about six months of rainfall and upto six months of dry period. Although the average annual precipitation of Kerala is estimated as 3000 mm, availability of water has become a severe constraint during the dry months. Kerala receives 60 per cent of the annual rainfall during SW monsoon (June – August), 25 per cent during NE monsoon (September – November) and the remaining during summer showers. The uneven temporal distribution of rainfall, the highly undulated topography and the low water retention capacity of soils cause moisture stress for most of the crops during summer season.

Rainfall data for the period, 1980-2006 reveals that the KAU campus received a mean annual rain fall of 2760 mm, out of which 74 per cent was obtained in south west monsoon, 15 per cent in north east monsoon and 11 per cent in summer. Because of the steep topography of Kerala, more than 90 per cent of the rainfall received drains to Arabian Sea within 24 to 48 hours (Visalakshi, 2007).

Studies on temporal variation in monthly, seasonal and annual rainfall over Kerala for 1871–2005 by Krishnakumar *et al.* (2009) revealed significant decrease in SW monsoon rainfall and an increase in post monsoon season. Rainfall during winter and summer seasons showed an increasing trend. The mean annual rainfall over Kerala showed a long term declining trend. The annual rainfall from 1999 to 2005 was less by 9.8 per cent. A relatively wet period (excess rainfall) was seen in earlier decades from 1900 to 1980. A decrease of 72.4 mm only was noticed during the study period of 135 years as against the normal rainfall of 2817 mm. Overall, a decline of 232.6 mm was noticed during the study period of 135 years indicating that on an average, the south west monsoon rainfall decline was about 1.7mm per year. The seasonal rainfall during the post monsoon was significant and increasing trend was noticed. It also showed through the trend line that an increase of 93.9 mm was noticed during the study period of 135 years. The winter rainfall had an increasing tendency, indicated that winter rainfall increased from 1900 to 1950. It also showed through the trend line that an increase of 15.7 mm only was noticed during the study period of 135 years (Krishnakumar *et al.*, 2009).

In the mid-lands of Kerala, where the lateritic soil predominates, the soil and water loss through erosion is very common. Lateritic soils comprise a wide variety of red and brown fine-grained residual soils of light texture. They are characterized by the presence of iron and aluminum oxides or hydroxides, particularly those of iron, which give the colours to the soils. It is hoped that the study on nutrient loss due to rain fall through a gentle slope of 5 – 10 per cent will give primary information on nutrient loss during a particular period of the tropical climate.

The quality of irrigation water has become more serious problem than quantity in different parts of the world as water quality is getting deteriorated day by day with contaminants and pollutants. Water quality is influenced by many environmental factors such as sewage disposal, industrial wastes, heavy metals, soil, effluents and fertilizers. The environmental condition and geology of the area influence water quality to a great extent. This may result in changes in physical, chemical and biological properties. Therefore, physico-chemical analysis is very crucial to assess water quality and it's suitability for irrigation. Quality analysis also gives better understanding of the complex processes of interaction between the climatic and biological processes. The main problem related to irrigation water quality is water salinity. The most common parameters used for determining irrigation water quality, in relation with its salinity, are EC and TDS. In India about 15 per cent of the land is affected by soil salinity and alkalinity; and in arid and semi-arid zones 56 per cent of the land has been affected due to poor quality of irrigation waters (Ramamoorthy, 1970).

Water being the most vital input, rain water harvesting, conservation and irrigation are of great importance for saving the crops from drought stress. Rain water harvesting is essential because the surface water is inadequate to meet our demand and we have to depend on ground water. Rain water harvesting technologies are simple to install and operate. In Kerala, groundwater samples were examined and quantified for major cations and anions, irrigation quality parameters and most of the ground water samples were acidic in nature (Akhil *et al.*, 2013).

In view of the importance of quality of water used for irrigation and loss of nutrients via surface run off, this study entitled "Physico-chemical properties of rain water harvested under different situations in lateritic soils" was taken up.

The project aims to compare the physico–chemical properties of rain water collected directly from rainfall, rain water harvested from a roof top, irrigation water in pond, well and surface run off from a lateritic soil with a gentle slope.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The physicochemical properties of water includes the salt contents and salt inducing parameters, abundance of nutrients, trace elements, alkalinity, acidity, hardness and the amount of suspended solids. A brief review of the physico-chemical properties of water and soil regarding quality of water and impact of surface run off are presented in this chapter.

2.1 Physicochemical properties of different sources of water

The physiochemical properties of water includes various parameters like; EC, sodium adsorption ratio (SAR) values, sodium hazards, HCO_3^- and residual sodium carbonate (RSC) which are used to know the suitability of the groundwater for irrigation purposes.

2.1.1 Rain Water harvesting

According to UNESCO (2000) rain water harvesting can deliver some major benefits such as augmentation of surface water sources, increase infiltration of rain water into the subsoil, mitigation of the effects of droughts and drought proofing, reduction of run off and soil erosion, improvement in the quality of water and saving of energy in lifting of ground water.

Rain water harvesting is essential because the surface water is inadequate to meet our demand and we have to depend on ground water. Due to rapid urbanization, infiltration of rain water into the sub-soil has decreased drastically and recharging of ground water has diminished. Rain water harvesting technologies are simple to install and operate. Local people can easily be trained to implement such technologies, and construction materials are also readily available. Rain water harvesting is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Even though average rainfall of Kerala is quite high (3000 mm), most of it is lost as surface run off because of highly undulating topography of the region. The erosivity of rainfall varies from 700 – 900 mm/hr for 1000 – 2000 mm rainfall, 1000 – 2700 mm/hr for 2000 – 3000 mm rainfall, 1700 - 3200 mm/hr for 3000 – 4000 mm of total rainfall (Thomas and Raghunath, 1987).

Under rainfed condition, harvesting of rain water and conservation of soil moisture are the two ways to supplement soil moisture. Harvesting of rain water and *in situ* conservation of soil moisture are the viable alternatives to irrigation. There are many reports about different ways of rain water harvesting and their effects on growth and yield of fruit crops like plum, sweet oranges etc (Arora and Narayan, 1987).

Water being the most vital input, rain water harvesting, conservation and irrigation are of great importance for saving the crops from drought stress. The moisture stress period, however, varies as reported by Rao and Vamadevan (1988). Among the various natural endowments, the availability, quality and cost effective distribution of water has become a serious issue of concern to the people as a whole and farming community in particular. The feasibility of rain water harvesting in a particular locality is highly dependent upon the amount and intensity of rainfall (Gould, 1992).

Varadan (1997) quantified the water demand and water deficit of various upland crops of Kerala based on the soil and climate in different regions. This deficit could be overcome to a great extent by increasing the soil moisture storage by adopting *in situ* rain water harvesting techniques.

The most popular and inexpensive rain water harvesting structure for large scale adoption in the watersheds of Kerala is the rain water pits dug out in soil. They store water during rain, which would have otherwise lost by run off. The collected water percolates into the deeper layers of soil and ultimately recharges the underground water (Nair, 2004).

2.1.2 Ground water

Ground water is the under-ground water that occurs in the saturated zone of variable thickness and depth below the earth's surface. Ground water is utilized through wells using various lifting devices. Use of open wells is a traditional method of tapping ground water. Use of tube wells, however, is a subsequent development. Water well is a hole, usually vertical, excavated in the earth for bringing ground water to surface. They are two types, open and tube wells (Reddy, 2007).

Visveswaran (1995) in a study on characterization of soil and irrigation water in sugarcane belt in Palakkad, Kerala found that EC for bore well recorded the highest value of 1.91 dS m^{-1}, the EC of other sources like open well, canal and river water were less than 1 dS m^{-1}. Irrespective of the sources, SAR recorded the highest value during pre monsoon period. The open well had highest SAR and bore well the lowest. The Cl^- and $SO_4^{=}$ content were the highest for bore well.

A research was conducted on groundwater quality assessment for drinking and irrigation purposes by Akhil *et al.* (2013) during July 2009 to January 2011 in some specific hot spot areas of Kasaragod District, Kerala, India. Groundwater samples were examined and quantified for major cations and anions, microbiological parameters, irrigation quality parameters such as sodium adsorption ratio (SAR), residual Mg/Ca ratio and per cent Na. Most of the ground water samples were acidic in nature and fluoride concentrations were below the desirable limit. Concentration of iron exceeds the desirable limit of 0.3 mg L^{-1} during monsoon (2009) and pre monsoon (2010) periods.

2.1.3 Surface run off

Surface run off will vary between catchments as a result of differences in topography, soils, and rainfall characteristics. This can be an important component in watersheds that are located in the mountainous terrain. Studies conducted on the watersheds of Western Ghats in Kerala have shown surface run off of 40 - 80 per cent of the annual rainfall. The humus cover in plantations is very poor compared to natural forest and the laterisation of the ground reduces the infiltration of water. Hamilton and King (1983) have shown that converting natural forests into plantations can reduce the water holding capability and the outflow.

The effect of varying land slopes viz. 0.5, 2.5, 4.5 and 9.5 per cent was studied on soil, water and nutrient losses, and productivity of rice-barley cropping system during 1989-90 to 1990-91 at Dehradun, Uttar Pradesh, India. The highest grain yield of rice (3.26 t ha^{-1}) and barley (3.31 t ha^{-1}) was observed at 0.5 per cent slope, which was reduced by 14.4, 29.1 and 43.6 per cent, and 16.9, 39.6 and 47.4 per cent at 2.5, 4.5 and 9.5 per cent slope, respectively. However, the losses of water (run off), soil and nutrients increased as the degree of slope increased, and were observed to be the highest at 9.5 per cent slope. The run off increased by 48.7, 157.7 and 240.7 per cent; soil loss by 125.5, 427.7 and 814.9 per cent; and loss of nutrients (available N, P and K, and exchangeable Ca and Mg) by 89.9, 170.3 and 295.0 per cent with increase in land slope from 0.5 to 2.5, 4.5 and 9.5 per cent, respectively. The nutrient losses ranged from 9.1-38.7 kg ha^{-1} and 5.6-24.9 kg ha^{-1} respectively for N and K, while the loss of available P was negligible at all the slopes (Sewa *et al.*, 2001).

2.1.4 Quality of irrigation water

The quality of irrigation water may affect both crop yields and soil physical conditions, even if all other conditions and cultural practices are favourable or optimal. In addition, different crops require different irrigation water qualities. High-quality crops can be produced only by using high-quality irrigation water. Characteristics of irrigation water that define its quality vary with the source of water. Therefore, testing irrigation water prior to selecting a site and the crops to be grown are critical. The quality of some water sources may change significantly with time or during certain periods (such as in dry/rainy seasons), therefore it is recommended to have more than one sample taken in different time periods. The parameters which determine the irrigation water quality are divided to three categories: chemical, physical and biological (Reddy, 2007).

The quality of irrigation water is of particular importance in arid zones where extremes of temperature and low relative humidity result in high rates of evaporation with consequent deposition of salt which tends to accumulate in the soil profile. The physical and mechanical properties of the soil such as dispersion of particles, stability of aggregates, soil structure and permeability are very sensitive to the type of exchangeable ions present in irrigation water. Thus, when effluent use is being planned, several factors related to soil properties must be taken into consideration (FAO, 1985).

Table 1. Desirable level of nutrients and other components of irrigation water.

Sl. No	Water quality measurements	Desirable range
1	pH	5.8 to 6.0
2	Alkalinity	0.75 - 2.6 meq/L $CaCO_3$
3	Soluble salts	(EC) < 1.5 d S m^{-1}
4	Hardness	100 to 150 mg /L $CaCO_3$
5	Calcium (Ca)	40 to 100 ppm
6	Magnesium (Mg)	30 to 50 ppm
7	Sodium (Na)	< 50 ppm
8	Sulfate (SO_4^{2-})	< 50 ppm
9	Chloride (Cl^-)	< 100 - 150 ppm
10	Boron (B)	< 0.5 ppm
11	Fluoride (F^-)	< 0.75 ppm

(Elizabeth and James, 2001).

The chemical characteristics of irrigation water refer to the content of salts in water as well as to parameters derived from the composition of salts in water;

parameters such as electrical conductivity / total dissolved solids (EC/TDS), sodium adsorption ratio (SAR), alkalinity and hardness. The main problem related to irrigation water quality is water salinity. Water salinity refers to the total amount of salts dissolved in water but it does not indicate which salts are present in it. The most common parameters used for determining irrigation water quality, in relation with its salinity, are EC and TDS.

Assessment of groundwater quality and hydrochemical evaluation of groundwater has been studied by Ahmad and Khan Naziain (2013) in Udaipur and Rajsamand district of Rajasthan, India. Hydrochemical analysis has been carried out based on concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-}. Sodium adsorption ratio (SAR), per cent sodium (per cent Na), Permeability Index (PI), pH, Total dissolved solids (TDS), Total hardness (TH) and trilinear diagrams have been studied. SAR values ranged from 5.76 mg L^{-1} to 30.68 mg L^{-1}. per cent sodium value ranged from 64.76 to 94.26 per cent. Permeability Index ranged from 33.46 to 99.58 per cent. The pH values ranged from 7.71 to 8.61. The value of hardness ranged from 76 to 1024 per cent. Sodium and permeability index results indicate that the groundwater in the basin is suitable for irrigation use.

Rekha (2003) has undertaken field studies in four Indian villages: Bikaner (Rajasthan); Raichur (Karnataka); Solan (Himachal Pradesh); and Thiruvananthapuram (Kerala). While the villages surveyed in Bikaner and Raichur were faced with severe water shortage even for drinking, water for irrigation seemed to be an immediate requirement in the villages of Solan. In the villages surveyed in the relatively water-abundant district of Thiruvananthapuram, water problems were faced mainly by households in coastal villages.

Chukwuma *et al.* (2013) conducted a study to assess the physico-chemical and micro biological parameters of rain water collected in the open in Oko, Orumba North L.G.A. of Anambra State in China. In the study, direct harvested rain water was collected from three stations in Oko community and analyzed for the quality of harvested rain water within the region. Thirty-one water quality parameters were considered and analyzed in the laboratory. The laboratory results were compared to permissible water quality level as recommended by National Agency for Food and Drug Administration and Control. The comparative parameters analysis showed that the samples of rain water collected were within the permissible limit, except for pH which was slightly acidic.

Non-point source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the run off moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. Loadings of pollutants from NPS enter water-bodies via sheet flow, rather than through a pipe, ditch or other conveyance (Gander, 2007).

These pollutants include:

• Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;

• Oil, grease, and toxic chemicals from urban run off and energy production;

• Sediment from improperly managed construction sites, crop and forest lands, and eroding stream-banks;

• Salt from irrigation practices and acid drainage from abandoned mines;

• Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;

Atmospheric deposition and hydro-modification are also sources of nonpoint source pollution causing water quality problems. Such quality is also decided by solubility of the geological deposits, contact of water with sediments, time of interaction and special factors related to environment (Khopkar, 1995). The effects of non-point source pollutants on specific waters vary and may not always be fully assessed. However, these pollutants have harmful effects on drinking water supplies, recreation, fisheries, and wildlife. (Gander, 2007)

Suitability of water for irrigation is judged from long term effects on the soil productivity. Irrigation with poor quality water deteriorates the soil properties and creates conditions unfavourable for economic farming practices (Reddy, 2007).

2.1.5 Turbidity

Turbidity is a measure of the interference caused due to the presence of suspended matter to the passage of light. Generally water becomes turbid due to presence of silt, clay, organic and inorganic matter (Gupta, 2007).

2.1.6 pH

pH is an indicator of the acidity or basicity of water but is seldom a problem by itself. The normal pH range for irrigation water is from 6.5 to 8.4; pH values outside this range are an abnormal water quality. Normally, pH is a routine measurement in irrigation water quality assessment (Ayers and Westcot, 1985).

2.1.7 Electrical conductivity

Electrical conductivity is widely used to indicate the total ionized constituents of water. It is directly related to the sum of cations (or anions), as determined chemically and is closely correlated, in general, with total salt concentration. Electrical conductivity is a rapid and reasonably precise determination and values are always expressed at a standard temperature of 25 °C to enable comparison of readings taken under varying climatic conditions.

Table 2. Category of water based on salt content

No	Type of water	Salt content (mg L^{-1})
1	Fresh water	< 500
2	Marginal water	500 to 1,500
3	Brackish water	1,500 to 5,000
4	Saline water	> 5,000
5	Brine water	35,000
6	Bittern water	350,000

(Reddy, 2007)

2.1.8 Chemical oxygen demand (COD)

By definition, chemical oxygen demand is "a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant" for monitoring reduction-oxidation (redox) equilibrium during high level (Jantzen and Whitaker, 2004).

A research on physicochemical and bacteriological of rain water from various storage structures was conducted at monthly interval by Visalakshi (2007) and found that pH of the water samples was ranging from 7 to 7.5, which falls within the desirable limits. The dissolved oxygen contents showed an increase in value and the COD increase was negligible and it falls within the safe limits (Table 2.3).

Wang *et al.* (2013) with the data collected during 14 rainfall events in 2011 analysed air quality before raining, the rain water quality, the roof run off water quality, and effects of wet deposition on the pollution loads of roof run off water. According to the analysis, pollutants such as TOC, F^- and NO_3^- in run off mostly came from the wet deposition. The findings also revealed that some chemical reactions took place between the chemicals contained in wet deposition, e.g, NH_4^+, acetic acid, formic acid and oxalic acid, and the materials of the roof as well as the matter retained on the roof, and that quality of atmospheric air greatly affected the wet deposition in terms of the content of its components.

Table 3. Physico-chemical and bacteriological characteristics of water samples in different types of storage structures

Sl. No	Characteristics	Desirable limit	Ferro cement tank	PVC tank	Under ground tank	Lined pond	Micro filtered water	Open well
1	pH	6.5 – 8.5	7.04	7.32	7.13	6.52	7.2	6.2
2	Alkalinity (mg L^{-1})	< 200	40	52	32	18	30	12
3	TDS (mg L^{-1})	< 50	33.2	62.1	17.6	8.8	31.28	7.6
4	Total hardness (mg L^{-1})	<300	42	50	30	20	28	14
5	Ca (ppm)	< 75	10.4	12	11.2	7.2	6.4	4.0
6	Mg (ppm)	<30	3.89	4.86	0.486	0.486	2.92	0.972
7	Cl (ppm)	<250	22	26	18	18	24	12
8	F (ppm)	< 1	-	-	-	-	-	-
9	NO_3 (mg L^{-1})	<45	2.22	1.77	3.54	1.77	1.11	2.22
10	DO (mg L^{-1})	>4.0	6.9	5.2	6.6	6.3	9.0	6.7
11	COD (mg L^{-1})	Nil	Nil	10	11	11	1.0	Nil

(Visalakshi, 2007)

2.1.9 Biochemical Oxygen Demand (BOD)

It refers to the amount of oxygen that would be consumed if all the organics in one liter of water were oxidized by bacteria and protozoa. Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose this waste. If there is large quantity of organic waste in water supply, there will also be lot of bacteria working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) and therefore the BOD level will be high. As the waste is consumed or dispersed through water, BOD levels will begin to decline (APHA, 1992).

Nitrates and phosphates in a body of water can contribute to high BOD levels. Nitrates and phosphates are plant nutrients and can cause plant life and algae to grow quickly. When plants grow quickly, they also die quickly. This contributes to organic waste in water, which is then decomposed by bacteria. This results in high BOD level. When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in water is being consumed by the bacteria. Since less dissolved oxygen is available in water, fish and other aquatic organisms may not survive.

The range of possible values of BOD can vary considerably: water from an exceptionally clear lake might show a BOD of less than 2 ml/L. Raw sewage may give readings in the hundreds and food processing wastes may be in thousands. Microorganisms such as bacteria are responsible for decomposing organic waste. When organic matter such as dead plants, leaves, grass clippings, manure, sewage, or even food waste is present in a water supply, the bacteria will begin the process of breaking down this waste. When this happens, much of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live (APHA, 1992).

Table 4. Guideline for water quality parameters

Parameter	WHO Standard	BIS Indian Standard	BIS for irrigation
pH	6.5-8.5	6.5-8.5	5.5-9.0
DO (mg L^{-1})	5.0	3.0	-
BOD (mg L^{-1})	5.0	30.0	100
COD (mg L^{-1})	10.0	-	250
Salinity (ppm)	120.0	200.0	600
Ammonia (ppm)	0.3	0.5	-

(Anandhan *et al.*, 2013)

Jitendra Singh (2008) studied seasonal variations in physico-chemical parameters of Yamuna River (Deheradun) and observed that the maximum EC level had been recorded during rainy season because the rain water carried wastewater from various sources. The pH and hardness levels indicated moderate quality of water. The average value of dissolved oxygen (DO) and COD levels indicated the absence of organic pollution sources. Thus the study concluded that river water was not polluted, all results were within permissible limit when compared with National River water quality standards and Bureau of Indian Standards (BIS). The water from present or flowing in project study area was good for drinking. Some parameters like, Mg were found slightly higher than the limit, which require continuous monitoring and treatment processes if the water has to be used for drinking purposes.

2.1.10 Sodium adsorption ratio (SAR)

Excess sodium in irrigation water, relative to calcium and magnesium or to total salt content can affect soil structure, soil aeration, flow rate, permeability, infiltration etc.

Palanissami and Mosi (1973) reported that SAR of irrigation water showed tremendous influence on various soil characteristics. They observed that high proportion of Na in irrigation water increases sodium on the exchangeable complex of the soil and in turn increases the Na content in crop plant which reduces grain yield of the crop. SAR value ranges from 5.76 mg L^{-1}- 30.68 mg L^{-1}. per cent sodium value ranges from 64.76 - 94.26 per cent. Permeability Index ranges from 33.46 - 99.58 per cent. The pH values range from 7.71 - 8.61. The value of hardness ranges from 76 - 1024 per cent. Na and PI results indicate that the groundwater in the basin is suitable for irrigation use. Thus, the present study reveals that the groundwater in the basin is of moderate to good quality and is suitable for all uses.

Table 5. Classification of irrigation water (USDA)

Salinity Class	EC(dSm^{-1})	Total dissolved salts (ppm)	SAR
Low	< 0.25	< 150	< 10
Medium	0.25 to 0.75	150 - 500	10 to 18
High	0.75 to 2.25	500 - 1500	18 to 24
Very high	> 2.25	> 1500	> 24

(USDA, 2001)

Kutty *et al.* (2013) carried out a research on the physico-chemical parameters of drinking water of Soudhabad of the Malappuram district and found that almost all the values of the parameters measured for well water samples are too low to reach the standard values indicating clearly no pollution or very less pollution status of well water. The turbidity value of one sample is very high, which may be due to suspended particles in the tank (water is pumped directly into the tank without any process). The low pH values in the southern part of the village necessitated soil analysis. The well water is safe for human consumption and other purposes.

2.1.11 Alkalinity

Alkalinity is the sum of the amounts of bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and hydroxide (OH^-) in water. Alkalinity buffers water against sudden changes in pH. If the alkalinity is too low, any addition of acidic fertilizers will immediately lower the pH. In container plants and hydroponics, ions released by plant roots may also rapidly change the pH if alkalinity is low.

The physiochemical properties of irrigation water in Katsina, Nigeria were assessed by Adamu (2012) and he found that the mean pH of water ranged from 7.10 to 7.50, while the EC values across the sectors ranged from 50 to 60 dS/m. Metal cations in water ranged from 15.00 to 20.07; 5.41 to 16.22; 3.29 to 6.57; 14.83 to 15.00 cmol L^{-1} for Na, Ca, Mg and K respectively. The SAR ranged from 6.87 to 10.17, while the range of TDS values was from 31.00 to 36.00 mg $L^{-1.}$ The mean carbonate concentration detected in irrigation water was from 4.00 to 12.00 cmol L^{-1}, while the mean bicarbonate content ranged from 22.00 to 55.00 cmol L^{-1}. Chloride and nitrate were within 9.87 to 31.58 and 1.00 to 1.65 mg/kg, respectively. The residual sodium carbonate (RSC) ranged from 8.00 to 30.69 cmol L^{-1}. There was no detectable NH_4 in the irrigation water. It was recommended that adequate drainage with emphasis on surface drainage should be provided to reduce the risk of salinity whereas salt and sodium build up should be monitored regularly.

2.1.12 Chloride and Iron

Irrigation water that contains certain ions at concentrations above threshold values can cause plant toxicity problems. It normally results in impaired growth, reduced yield, changes in the morphology of the plant and even its death. The degree of damage depends on the crop, its stage of growth, the concentration of the ions, climate and soil conditions. The most common toxic ions that may be present in municipal sewage and treated effluents in concentrations to cause toxicity are: boron (B), chloride (Cl), sodium (Na) and Iron (Fe). Hence, the concentration of these ions will have to be determined to assess the suitability of water quality for use in agriculture.

The chemical parameters such as alkalinity, total hardness and the contents of Ca, Mg, Cl, Fe, etc in ferro cement tank were within the desired limits. These nutrients in lined pond water showed an increase in value with increase in total suspended solids and hardness. The dissolved oxygen content decreased and the COD was found to be increase (Table 2.3). The pH of water sample from lined pond was 6.84, 6.93 and 6.0 during the first, second and third month respectively. (Visalakshi, 2007).

2.2 Laterite soil and its physico-chemical properties

Laterites and lateritic soils form a group comprising a wide variety of red, brown, and yellow, fine-grained residual soils of light texture as well as nodular gravels and cemented soils. They may vary from a loose material to a massive rock. They are characterized by the presence of iron and aluminum oxides or hydroxides, particularly those of iron, which give colour to the soils.

Laterites are acidic in reaction (pH 5.0 – 6.2) and the surface layers often contain an appreciable proportion of gravel. The texture of the surface soils ranges from gravelly-loam to gravelly- clay loam. Theses soils contain fair amount of organic matter and nitrogen but are deficient in phosphorus, potassium and calcium. They are porous and well drained and respond to good cultural and management practices. Coconut, cassava, banana, vegetables, pulse etc, are grown on the laterite soils in the lower horizons while plantation crops like rubber are grown at higher elevations. Laterization is the removal of silicon through hydrolysis and oxidation that results in the formation of laterites and lateritic soils. The degree of laterization is estimated by the silica-sesquioxide (S-S) ratio [$SiO_2/(Fe_2O_3 + Al_2O_3)$]. Soil physical properties are estimated from the soil's texture, bulk density, porosity, water-holding capacity (Hillel *et al.*, 1982).

The presence or absence of hard pans usually presents barriers to rooting depth. These properties improved through additions of organic matter to soils. Therefore, the suitability of soil for sustaining plant growth and biological activity is a function of its physical properties such as porosity and water holding capacity. The result obtained from permanent observation trial on red loam soil under coconut revealed that no tillage plots improved the water retention character over cultivation alone comparable to the cultivated plots with organic and inorganic fertilization (John *et al.*, 2003).

2.2.1 pH and electrical conductivity

The soil pH is meant to measure acidity or alkalinity of soil and it gives the measure of activity of H^+ ions in the soil solution expressed in molarity. Electrical conductivity is directly related to the sum of the cations (or anions), as determined chemically and is closely correlated, in general, with the total salt concentration. Electrical conductivity is a rapid and reasonably precise determination and values are always expressed at a standard temperature of 25 °C to enable comparison of readings taken under varying climatic conditions.

2.2.2 Texture, bulk density and particle density

Soil texture refers to the relative proportion of soil separates viz., sand, silt and clay. The distribution of soil particles into fractions of different size is determined by mechanical analysis. Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. Bulk density typically increases with soil depth since subsurface layers have reduced organic matter, aggregation, and root penetration compared to surface layers and therefore, contain less pore space. Bulk density measurement reflects the history of management practices and affects numerous physical, chemical and biological properties of soils (Carter, 2005).

Study of a typical laterite soil profile in Kerala indicated that the soil was sandy loam in texture at surface 0 -15 cm and sandy clay loam at depth lower than 60 cm; the clay content increasing with depth from 8 – 23 per cent. Down the profile the bulk density decreased from 1.68 to 1.47 g/cm^3 but PD varied in a narrow range of 2.60 to 2.70 g/cm. the available soil water content throughout the profile ranged from 6.4 to 9.8 per cent by volume (Patro and Misra, 1985).

2.2.3 Chemical properties

The soil chemical properties affects soil-plant relations, water quality, buffering capacities, availability of nutrients and water to plants and other organisms, mobility of contaminants, and some physical conditions such as the tendency for crust to form. A study carried out in Sasumua of soil pH, electrical conductivity (EC), cation exchange capacity (CEC), soil organic carbon (% C), total nitrogen (% N), exchangeable potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}) were analyzed from samples taken at 0-30cm soil depth. Results showed change of soil reaction from pH 5.86 to 5.22 ($p < 0.005$), Mg^{2+} changed from 3.32 mg/kg to 1.04 mg/kg ($p < 0.001$), and K+ changed from 2.89 to 1.11 mg/kg ($p<0.001$) over the 30 year period. Ca^{2+} decreased by 62 per cent, N increased by 21 per cent and CEC increased by 27 per cent. No change was observed in per cent C (Kimigo and Kicheri, 2009).

According to Tejada and Gonzalez (2008), control soil (no organic treatment), cotton gin crushed compost (CC) and poultry manure (PM) at higher dose reduced aggregate instability by 21 per cent and 17.8 per cent, bulk density by 19.6 per cent and 16.9 per cent, and soil loss under simulated rain at 140 mm h^{-1} by 29.2 per cent and 25 per cent, respectively. Nutrient losses in the run off water and sediments were higher in organic-amended soils than in the control soil, particularly in the case of PM-amended soils in Guadalquivir Valley, Andalusia, Spain. The lower N/P ratios in run off water produced by CC and PM treatments suggest a lower eutrophication risk in water. They suggested that the variability in these results might be due to the different chemical natures of the wastes added to soil.

Otero *et al.* (2011) after carrying out physico-chemical analyses in soil and run off water samples found that potato farming had more severe impacts on soil quality, with substantial loss of the silt fraction (low silt levels of 11.9 per cent were found in soil composition) and resulted in much higher soil loss rate (5.67 g h^{-1}) compared to that of pastoral land use (0.61 g h^{-1}). Meanwhile, N and P average losses measured in run off were 1.22 mg N-NO_3 L^{-1} plus 0.12 mg P-PO_3 L^{-1} for the potato crop, and 0.86 mg N-NO_3 L^{-1} plus 0.09 mg P-PO_3 L^{-1} for the pastures, respectively. Finally, direct relationships appeared between the two agricultural practices evaluated and the loss of soil and nutrients.

A study was conducted on soil quality under different land use systems in Ultisol and it was found that the content of available nutrients in soil up to 60 cm depth varied from 188.16 to 638.69 kg ha^{-1} for N, 3.36 to 418.44 kg ha^{-1} for P and 120.88 to 773.96 kg ha^{-1} for K (Nithya, 2013).

2.2.5 Run off and its effect on soil nutrient status

The slope gradient influences the nutrient loss by run off flux and velocity on sloping land. As the slope gradient decreases, the nutrient loss decreases because of the increase in infiltration. The soil texture, porosity, and water content influence the motion of soil water and the transfer and form of nutrients in soil, through oxidation and de-oxidation. Vegetative coverage influences the infiltration coefficient of rain water into subsurface soil, and thus influences the run off flow velocity. Therefore, different sloping lands need to be managed in different ways (Hebal, 2003).

A study on transport of P, N, and sediment via run off from crop fields by Jokela and Casler (2011), especially where manure has been applied, found that during the calibration period both concentrations and loads of silage system and total and dissolved P and N varied by field and over 50 per cent of run off and dissolved P and N was from snowmelt run off. Linear regressions of treatment fields against the control field were highly significant for run off and concentrations and loads of all constituents. The estimated minimum detectable change (difference between means) was 10 to 30 per cent for most parameters, suggesting a reasonable probability of success in detecting change in the treatment period.

A study on losses of nutrients through leaching and surface run off from experimental composts was investigated by Ulen (1993) and found that nitrogen was leached resulting in elevated concern of mineral nitrogen under the composts. Thus to avoid groundwater pollution, the composting site should be carefully chosen. Although nutrient losses in surface run off were low, nutrients concern in the run off were high, indicating that the potential for this kind of loss is great. Thus, composts should be covered to reduce run off water.

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MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "Physico-chemical properties of rain water harvested under different situations in lateritic soils'' was carried out in the Department of Soil Science and Agricultural Chemistry, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2012 – 2013.

3.1 Details of location

Five different sources of rain water were selected in the main campus of Kerala Agricultural University, Vellanikkara. Geographically, the area is situated between a latitude of 10° 30' and 10° 35' N, longitude of 76° 15" to 76 ° 25' E and at an altitude of 72 m above mean sea level.

3.1.1. Climate and soil

The experimental site has humid tropical climate and the soil is lateritic and acidic. The soil belongs great group to 'Kandiustult' (Soil Survey Staff, 1997).

3.1.2. Period of the experiment

Water samples were collected for one year starting from the post monsoon period, from September, 2012 to August, 2013 at monthly intervals. Soil samples were collected before and after rains which caused enough run off during different periods.

3.1.3. Details of the experiment

Location: Vellanikkara

Sources of water: 5

(Rainfall, Rain water harvesting pond, Kotteppadom pond, well inside the campus and rain pits for surface run off) (Fig.1 and plates 1, 2, 3, 4, and 5)

1. Rainfall collected from Meteorological observatory located in Block 23
2. Rain water harvesting pond located in Block 21

Fig.1. Location of different sources of water at KAU main campus

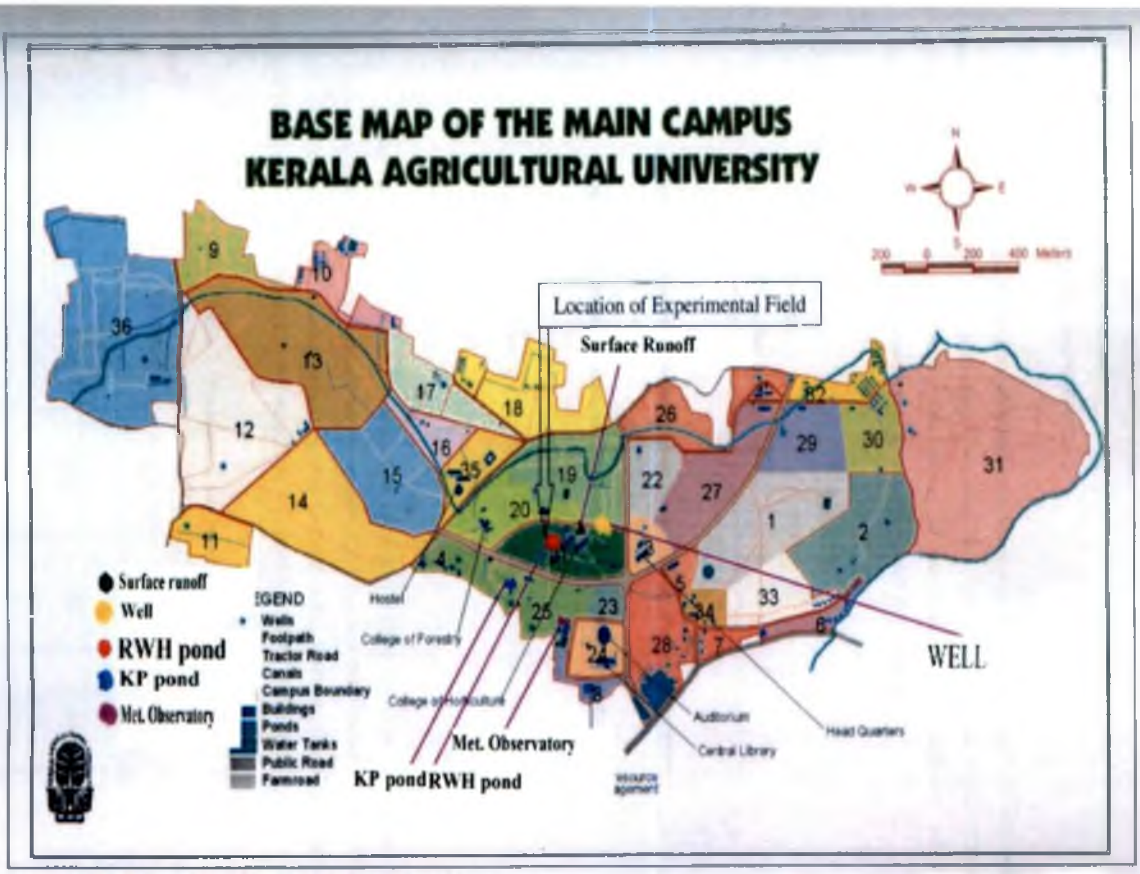


Fig. 1 The location of the different water sources

(Sajnanath, 2000)

Meteorological observatory - Block 23

Rain water harvesting pond - Block 21

Kotteppadom pond - Block 25

Well - Block 21

Surface run - Block 21

3. Kotteppadom pond located in Block 25
4. Well located in Block 21
5. Surface run off collected from rainpits dug in Block 21

3.2 Description of different water sources with notations used for study

The study area is located in College of Horticulture (COH) at the main campus KAU, Vellanikkarra. Water analysis was conducted on five main sources of water as given above.

3. 2. 1 Rainfall (RF)

The rain gauge installed in the observatory attached to Department of Agricultural Meteorology was monitored on sampling days to collect direct rainfall for physical and chemical analysis (Plate 1.).

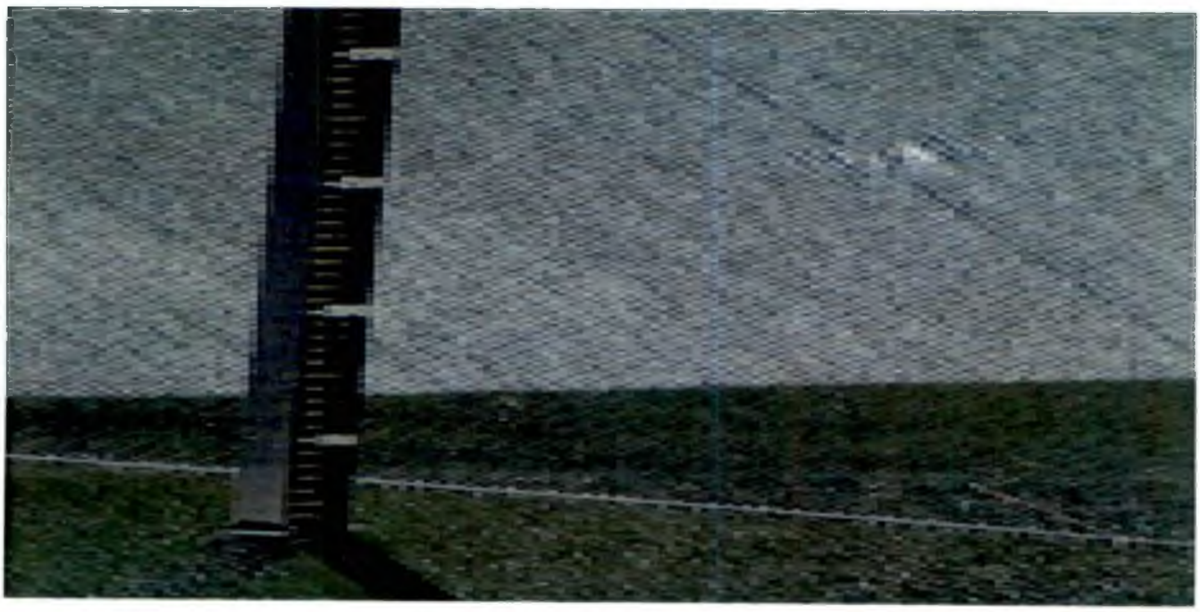
3.2.2 Rain water harvested (RWH)

A lined pond namely INTIMASI with a capacity of 10 lakhs litres excavated in 2009 near the library block was utilized for this study. This pond was constructed by the Department of Soil Science and Agricultural Chemistry at COH with an elliptical shape having a longer diameter of 24.2 m and a shorter diameter of 19 m that harvests rain water from the roof top of library block of the college. All the gutters of the roof catchment of library block are properly interconnected to each other with down pipes leading to the inlet of the pond to feed every drop of rainfall to the pond. The pond is lined with high density polyethylene (HDPE) sheet which prevents deep percolation and lateral seepage of the water. It is covered with shade net with floaters to reduce the evaporation loss. The harvested water is used for irrigation and other purposes.

Plate 1. General view of the Meteorological Observatory at College of Horticulture, Vellanikkara

Plate 2a. A view of rain water harvesting pond

Plate 2b. Measurement of level of water due to inflow to the rain water harvesting pond



3.2.3 Kotteppadom pond (KP)

The pond was dug in 2011 and is located near the paddy fields at Kotteppadom in the campus of College of Horticulture for irrigation purpose. This pond is an open source of irrigation water with a capacity of about one crore litres which collects surface run off flows from the nearby watershed and is attached to the Department of Agronomy. This is used to irrigate the paddy fields and vegetable crops of the area.

3.2.4 Well water (W)

The well is located near the crop museum and is attached to the Department of Pomology and Floriculture. The water from the well has been used continuously for irrigation of crops of the orchard and surrounding areas.

3.2.5 Surface run off (SR)

The site for surface run off study was located near the tapioca fields attached to the Department of Agronomy. Here a plot of area of 200.22 m^2 (14.2 m x 14.1 m) on a gentle slope of 5 – 10 per cent was identified. Four rain pits were dug with dimensions of 0.5 m x 0.5 m x 0.5 m on the surface and lined by polyethylene sheet to collect surface run off samples for physical and chemical analysis.

3.2 Collection of water samples

Collection of water samples from different sources were made every month for a year. Representative water samples were collected in polyethylene bottles according to standard procedure. Residues and other debris were removed when water samples were collected from the different sources. The collected samples were stored in polyethylene containers after recording the source and date of sampling. Rainfall water was collected from Meteorological Observatory attached to the Department of Agricultural Meteorology directly using rain gauge and clean container. The surface run off from slopy area was collected in rain pits lined with plastic sheet.

Plate 3. A view of Kotteppadom pond

Plate 4. A view of the well as a source of harvested water at College of Horticulture

Plate 5. A view of rain pit used to study the surface run off

3.3 Collection of soil samples (Run off study)

The impact of run off on soil nutrient status was studied by collecting soil samples during summer (December – March, 2013) and monsoon seasons (June – August, 2013). Soil samples were collected before the rains as well as after the receipt of rains in the above two seasons to assess the variation in the soil nutrient status before and after rains.

Four rain pits of size 0.5m x 0.5m x 0.5m were laid out on a plot of area 200 m^2 on gentle slope of 8 per cent. These rain pits were lined with high density polyethylene sheet uniformly at the base extending to the sides and covering the whole area inside. The outer border of the sheets was tightly anchored with bricks and stones.

Soil samples were collected from a depth of 15cm from all four sides of the pit. They were then mixed and composite samples were made. These samples were processed and stored in the polythene jars for further analysis. Similarly soil samples were collected from the other three rain pits.

3.4 Quantification of rain water

3.5.1 Quantification of rainfall

The total amount of rainfall received during the study period from September, 2012 to August 2013 was collected from the observatory attached to the Department of Agricultural Meteorology. The data were tabulated on weekly basis and monthly rainfall data was arrived at. The summation of monthly rainfall throughout the year gave the annual rainfall data.

3.5.2 Quantification of inflow of water into the RWH pond

The rain water falling on the rooftop area of the library block of COH was collected in water harvesting pond constructed for the purpose.

The shape of the pond was oval and the two diameters of the pond were measured on the surface (long and short diameters) to determine the volume of water. Similarly the dimensions at one meter interval towards the bottom of the pond were taken (Appendix 2). Quantification of inflow was done on the basis of volume of water accumulated in the pond. For this a meter gauge with a heavy metal base was installed at the center of the pond. The scale was marked to a height of 3m. The level of water depth in the pond was recorded from the measuring scale and the observations were recorded daily. The volume of inflow rain water was calculated using the formula.

$$V = \pi h(a \times b)$$

Where, V= volume of water (m^3)

a = long radius of the pond (m)

b = short radius of the pond (m)

h= height of water in the pond (m)

Before the onset of monsoon the level of water in pond slowly decreased and the initial level of water was recorded on May 24, 2013. The level of water started rising up further due to addition of rain water harvested from rooftop during monsoon period. The maximum level was recorded on July 27, 2013 and it declined slowly during the rest of the period. The inflow volumes during the rainy days were calculated. The difference between the maximum and minimum volume was the amount of rain water harvested in the pond during the study period. Observations were noted up to August, 2013.

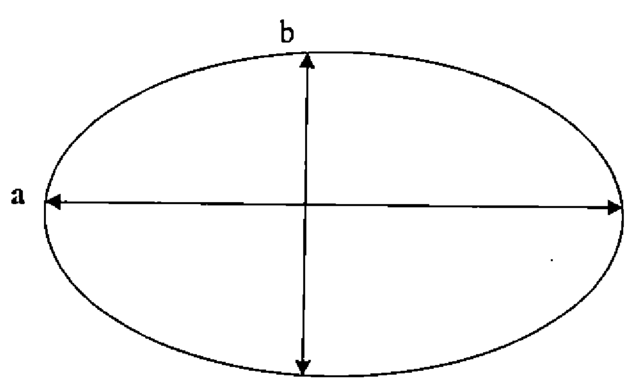


Fig. 2. Surface view of the pond.

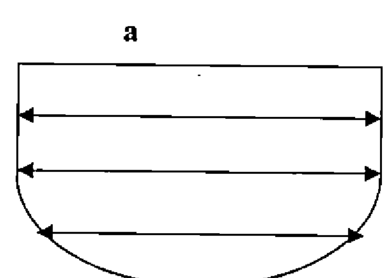


Fig.3. Cross sectional view of the pond

3.6 Water analysis

The details are furnished in Table 6.

Table 6. Methods of water analysis

Parameters	Method	Reference
Colour and turbidity	Visual analysis	Gupta (2007)
pH and EC	pH meter and conductivity meter	Jackson (1958)
Total dissolved solids (TDS)	Based on EC (TDS = 640 x EC)	Ayers and West Cott (1985)
Sodium (Na)	Flame photometer	Jackson (1958)
Calcium and magnesium	Neutral normal ammonium acetate extraction-atomic absorption spectrophotometer	Jackson (1958)
Chloride	Mohr's titration method	Motsara and Roy (2008)
Carbonates and bicarbonates	Acidimeteric titration	Richards (1954)
Iron (Fe)	Atomic Absorption Spectrophotometer	Jackson (1958)
Biological oxygen demand	Winkler method	APHA (1992)
Nitrate (No_3^-)	Reduction by Devarda's alloy and alkali distillation	Motsara and Roy (2008)
Chemical oxygen demand	Wet oxidation	Jantzen and Whitaker (2004)

3.7 Methods for determination of quality of irrigation water

3.7.1 Electrical conductivity (EC)

Electrical conductivity is used to indicate the total ionized constituents of water. It is directly related to the sum of the cations (or anions), as determined chemically and is closely correlated with the total salt concentration. EC was determined using a conductivity meter.

Table 7. Quality characterization of irrigation water based on EC

Salinity	Class	EC dS/m at 25 °C	Indian standards (dS/m)
C1	Low	< 0.25	< 1.5
C2	Medium	0.25 – 0.75	1.5 – 3.0
C3	High	0.75 – 2.25	3.0 -6.0
C4	Very high	2.25 – 5.00	> 6.0

(Reddy, 2007)

3.7.2 Sodium adsorption ratio (SAR)

Excess sodium in irrigation water relative to calcium and magnesium or to total salt content, can affect soil structure, soil aeration, flow rate, permeability, infiltration, etc. The determination of sodium was carried out directly with help of the flame photometer using appropriate filters and standard curves. The ratio has been calculated from the contents of sodium, calcium and magnesium as follows.

$$SAR = \frac{Na\,(meq/l)}{\sqrt{\frac{Ca\,(meq/l) + Mg\,(meq/l)}{2}}}$$

Table 8. Quality characterization of irrigation water based on SAR and RSC

Sodium hazards	Class	SAR	RSC (meq L^{-1})
C1	Low	< 10	< 2.5
C2	Medium	10 to 18	2.5 – 5.00
C3	High	18 to 26	5.0 – 10.0
C4	Very high	>26	> 10

(Reddy, 2007)

3.7.3 Residual sodium carbonate (RSC)

Alkalinity is the sum of the amounts of bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and hydroxides (OH^-) in water. It is expressed as mg L^{-1} or meq L^{-1} $CaCO_3$. The estimation of RSC was based on simple acidimeteric titration using different indicators that work in the alkaline and acidic pH range lower than 6.0.

$$RSC\ (me\ L^{-1}) = (CO_3 + HCO_3) - (Ca + Mg)$$

Table 9. Relationship between EC, SAR and RSC

Class	Rating	EC x 10^3	SAR	RSC
A	Good	< 2	<10	< 2.5
B	Normal	2 to 4	<10	< 2.5
C	Sodic	< 4	>10	> 2.5
D	Marginally saline	4 to 8	<10	0.0
E	Poor	>8	>10	> 2.5

(Reddy, 2007)

3.7.4 Biochemical oxygen demand (BOD)

The Winkler method was followed to estimate BOD. This involved filling a BOD bottle completely with water and putting a stopper (no air is left to bias the test) immediately. It was then mixed properly by inverting several times. An orange brown flocculent precipitate was formed indicating that oxygen was present. The dissolved oxygen in the sample was then fixed using a series of reagents that form an acid compound which was then titrated with a neutralizing compound that results in a colour change. Titration involved the drop-by-drop addition of a reagent that neutralized the acid compound and caused a change in the colour of the solution. The point at which the colour changes was the "endpoint" and was equivalent to the amount of oxygen dissolved in the sample (APHA, 1992).

Samples were immediately titrated for initial dissolved oxygen (DO) and simultaneously another set of samples were kept in the incubator at 21°C for five days to determine final DO, and BOD was calculated by subtracting the initial from the final DO.

3.7.5 Chemical oxygen demand (COD)

It was measured for the oxygen equivalent of the organic matter content of a sample that was susceptible to oxidation by a strong chemical oxidant. In the COD method, the water sample was oxidized by digesting in a sealed reaction tube with sulphuric acid and potassium dichromate in the presence of a silver sulphate catalyst. The amount of dichromate reduced was proportional to the COD. A reagent blank was prepared for each batch of tubes in order to compensate for the oxygen demand of the reagent itself. Over the range of the changes of colour from yellow through green to brown were produced during titration. The colour was indicative of the chemical oxygen demand and was measured by titration. The results were expressed as milligrams of oxygen consumed per litre of sample.

3.8 Soil analysis

The methods adopted for the study are detailed under table 10.

Table 10. Methods of physico-chemical analysis of soil

Parameters	Method	Reference
pH and EC	1:2.5 soil water suspension- pH meter and conductivity meter	Jackson (1958)
Bulk density	Keen-Raczkowski brass cup	Piper (1942)
Particle density	Keen-Raczkowski brass cup	Piper (1942)
Water holding capacity	Keen-Raczkowski brass cup	Piper (1942)
Soil texture	International pipette method	Gupta and Dakshinamoorti (1980)
Organic carbon	Wet oxidation	Walkley and Black (1934)
Available nitrogen	Alkaline permanganometry	Subbiah and Asija (1956)
Available phosphorous	Bray-1 extract – colourimetry by spectrophotometer	Bray and Kurtz (1945)
Available potassium	Neutral normal ammonium acetate extraction- flame photometer	Jackson (1958)
Exchangeable calcium and magnesium	Normal ammonium acetate extraction- atomic absorbtion spectrophotometer	Jackson (1958)
Exchangeable Iron (Fe)	Normal ammonium acetate extraction- atomic absorbtion spectrophotometer	Jackson (1958)

3.9 Statistical analysis

The rainfall received during the entire period of study was categorized into four seasons viz. post monsoon (Sept. – Nov., 2012), summer (Dec., 2012 - Mar., 2013), pre monsoon (April – May, 2013), and monsoon (June – August, 2013). The mean values for the different parameters for irrigation water quality for each season was found out. The data generated were analyzed by comparing with the available standard values and using suitable statistical tool like analysis of variance. The *t* – test was used to interpret soil analysis.

RESULTS

4. RESULTS

4.1 Distribution and quantification of rainfall

The range of monthly rainfall during the study period from September, 2012 to August, 2013 was between 0 and 1031.8 mm. The highest amount (mm) was observed in June, 2013 and the lowest in January, 2013 (Table 11). The total amount of rainfall was 2872.0 mm (Appendix 1).

Table 11. Monthly rainfall (mm) for the year, 2012 - 2013.

Year	2012				2013							
Season	Post monsoon			Summer				Pre monsoon		Monsoon		
Rainfall (mm)	384.1			118.8				99.1		2270.0		
Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Rainfall (mm)	191.8	145.6	46.7	19.8	0	84.4	14.6	0	99.1	1031.8	932.3	305.9

4.2 Quantification of rain water in the pond

The lowest amount of rainfall collected in the pond at the start of the experiment was taken as the initial volume and the highest amount collected was considered as the final volume (Appendix 2).The rain water harvested from the rooftop of library block of the College of Horticulture varied from 139.72 m^3 to 765.20 m^3. Therefore, the amount of rain water harvested during the study period was 625.48 m^3 which is 62. 5 per cent of its storage capacity.

4.3 Water quality studies

The water samples from different sources of water viz, direct rainfall (RF), rain water harvested from roof top in the pond (RWH), Kotteppadom pond (KP), well (W) and surface run off(SR) were analyzed for various physico-chemical parameters such as colour, turbidity, pH, EC, TDS, COD, BOD, SAR, RSC, Cl^-, NO_3^- and Fe during post monsoon (Sept. – Nov., 2012), summer (Dec., 2012 - Mar., 2013), pre monsoon (April – May, 2013), and monsoon (June – August, 2013) seasons.

4.3.1 Colour / turbidity

The colour of water samples varied from colourless for rain water to yellowish brown for surface run off during the different seasons (Table 12). The colour of water from harvesting pond, KP pond and well were light coloured, light yellowish, and yellowish respectively.

When comparing turbidity, it was found that rain water was not turbid. Water from rain water harvesting pond was less turbid as compared to that of water from KP and well. Surface run off was more turbid during monsoon period.

Table 12. Colour / turbidity of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)
RF	Colour less/ free	Colour less/ free	Colour less/ free	Colour less/ free
RWH	Colour less /less turbid	Light greenish/ less tubid	Brown-green/ moderately turbid	Colour less/ slightly turbid
KP	Colour less / slight turbid	Light yellow/ less turbid	Yellowish-brown/ moderately turbid	Yellowish /less turbid
W	Colour less/ free	Colour less/less turbid	Yellowish / moderately turbid	Light red/ moderate
SR	Colour less / slightly turbid	Light yellow/less turbid	Yellow /moderate	Yellowish-brown /more turbid

RF- Rainfall

RHW – Rain water harvested

KP – Kotteppadom pond

W - Well

SR- Surface run off

4.3.2 pH

The pH of water samples from rainfall showed variation between different periods and it varied from 5.54 (post monsoon) to 6.44 (pre monsoon). The range for the water samples from the rain water harvested, kotteppadom pond, well, and surface run off were comparatively narrow. The ranges were 6.10 (post monsoon) to 6.38 (pre monsoon), 6.26 (post monsoon) to 6. 69 (summer), 6.21 (monsoon) to 6.47 (summer) and 5.72 (summer) to 6.40 (monsoon) for the water samples from the rain water harvested, kotteppadom pond, well, and surface run off respectively. In general, the pH was low for the rain water from rainfall and surface run off during different seasons. The pH of rainfall during post monsoon was found to be the lowest of all. The difference in mean pH of the irrigation water from all sources during different seasons was not found significant.

Table 13. pH of water samples from different sources.

Sources	Post monsoon (S_1)	Summer (S_2)	Pre monsoon (S_3)	Monsoon (S_4)	Mean
RF	5.54	5.76	6.44	6.02	5.94
RWH	6.10	6.19	6.28	6.38	6.24
KP	6.26	6.69	6.33	6.52	6.44
W	6.35	6.47	6.39	6.21	6.36
SR	5.93	5.72	6.09	6.40	6.04
Mean	6.04	6.17	6.31	6.31	† 0.483* / NS

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.3 Electrical conductivity (EC)

The EC (dS m^{-1}) of water samples from well exhibited a wide range between different seasons and it varied from 0.023 (post monsoon) to 0.136 (pre monsoon). The range for water samples from rainfall, rain water harvested in pond, kotteppadom pond, well and surface run off were between 0.023 - 0.031, 0.029 - 0.040, 0.118 - 0.132, 0.121- 136 and 0.060 - 0.110 respectively. The EC during summer and pre monsoon were higher than that of post monsoon and monsoon periods for water from all sources. The EC value of water from well during entire period of study was higher than that of other sources. During the pre monsoon period, the well water recorded the highest EC of 0.136 dS m^{-1} followed by Kotteppadom with 0.132 dS m^{-1}.

In general, the EC was comparatively low for water sample from rainfall and rain water harvested in the pond during the different seasons. The EC of rainfall (RF) was found to be the lowest during all the four seasons. The analysis of variance revealed that the mean value of EC of water from all sources was highly significant and it was significant during the different seasons.

Table 14. Electrical conductivity (dS m^{-1}) of water samples from different sources

Sources	Post monsoon (S_1)	Summer (S_2)	Pre monsoon (S_3)	Monsoon (S_4)	Mean
RF	0.023	0.026	0.031	0.024	0.03
RWH	0.030	0.037	0.040	0.029	0.03
KP	0.121	0.127	0.132	0.118	0.12
W	0.130	0.135	0.136	0.121	0.13
SR	0.080	0.102	0.110	0.060	0.09
Mean	0.08	0.09	0.09	0.07	† 0.012* / †0.011*

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.4 Total dissolved solids

The TDS (mg L^{-1}) values of water from different sources range were 14.94 (RF) and 86.85 (W). The range was wide for surface run off as compared to others during the different seasons. The range for water samples from rain water harvested in pond, kotteppadom pond, and surface run off were between 18.94 – 25.70, 75.29 - 84.51, and 38.57 - 70.40 respectively. The TDS during summer and pre monsoon were higher than that of post monsoon and monsoon periods for water from all sources. In general, the values of TDS were comparatively higher for water samples from well and Kotteppadom pond during the different seasons. The TDS values were lower for water samples from direct rainfall and rain water harvested in the pond in the different periods. The TDS of rainfall (RF) was the lowest during the different seasons. The difference in the mean value of TDS of water was significant between the different sources.

Table 15. Total dissolved solids (mg L^{-1}) of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)	Mean
RF	14.94	16.61	19.84	15.40	16.70
RWH	18.94	23.58	25.70	18.79	21.75
KP	77.65	81.31	84.51	75.29	79.69
W	83.48	86.10	86.85	77.40	83.45
SR	51.33	64.96	70.40	38.57	56.31
Mean	49.27	54.51	57.46	45.09	†7.887** / †7.055*

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level NS - Non significant

4.3.5 Chemical oxygen demand (COD)

The COD (mg L^{-1}) values ranged between 4.40 and 59.00, the lowest for rainfall during post monsoon and the highest for water from KP pond in monsoon period. The COD values were lower for water from rainfall than the others irrespective of different seasons. In the case of rain water, the COD ranged between 4.40 (post monsoon) and 6.93 (monsoon). In general, the COD values showed an increasing trend between post monsoon and pre monsoon seasons. During summer, the highest COD was observed for well water (52.81) followed by surface run off (51.24), KP pond (46.12), rain water harvested (32.05) and rainfall (4. 61). Monsoon season samples had comparatively higher COD values than that of other sources. The analysis of variance revealed that the difference in the mean values of COD of water from all resources was significant in different periods of the year.

Table 16. Chemical oxygen demand (mg L^{-1}) of water samples from different sources

Sources	Post monsoon (S_1)	Summer (S_2)	Pre monsoon (S_3)	Monsoon (S_4)	Mean
RF	4.40	4.61	5.95	6.93	5.47
RWH	19.05	32.05	33.11	31.72	28.98
KP	39.95	46.12	56.37	59.00	50.36
W	48.14	52.81	55.64	57.24	53.46
SR	41.75	51.34	53.91	55.50	50.63
Mean	30.66	37.39	41.00	42.08	† 4.657** / †5.207*

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.6 Biological oxygen demand (BOD)

The BOD values varied between 0.33 for rain water during post monsoon and 1.30 for well water in monsoon periods. There was almost regular increasing trend for this parameter from post monsoon to monsoon period for all sources of water except RHW. The value of BOD in well water during post monsoon was appreciably higher than that of other water sources and the value remained rather constant throughout different seasons. The BOD during summer period was in the order of 1.15, 1.0, 0.96, 0.69 and 0.60 for well water, surface run off, Kotteppadom pond, water from rain water harvested and rainfall respectively. During the monsoon season, the lowest BOD was observed for water from direct rainfall (0.68) closely followed by rain water harvested (0.78).

The analysis of variance indicated that the difference in mean value of BOD of rain water was highly significant in five water sources and it was significant during different seasons.

Table 17. Biological oxygen demand (mg L^{-1}) of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)	Mean
RF	0.33	0.60	0.62	0.68	0.56
RWH	0.58	0.69	0.83	0.78	0.72
KP	0.76	0.96	1.18	1.26	1.04
W	0.87	1.15	1.26	1.30	1.15
SR	0.78	1.00	1.20	1.24	1.06
Mean	0.66	0.88	1.02	1.05	†0.092** / †0.082*

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.7 Sodium adsorption ratio (SAR)

Well water recorded the highest value of 9.05 (pre monsoon) and the rain water the lowest value of 2.57 (post monsoon). The highest sodium adsorption ratio (SAR) was observed in well water in all seasons followed by Kotteppadom pond during the different seasons. The water from Kotteppadom pond showed consistently higher values during different seasons. The highest SAR value of 9.05 was noticed for well water followed by Kotteppadom pond (8.96). In general, rain water (RF) and rain water harvested in the pond (RWH) showed lower values which remained almost constant throughout the different seasons. The analysis of variance revealed that the difference in the mean values of SAR of the water from all sources was significant during the different periods of the year.

Table 18. Sodium adsorption ratio of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)	Mean
RF	2.57	2.59	2.60	2.59	2.59
RWH	4.10	4.33	4.55	4.34	4.33
KP	6.11	8.57	8.96	7.06	7.68
W	5.24	8.26	9.05	8.02	7.64
SR	4.43	6.72	7.04	5.64	5.96
Mean	4.49	6.09	6.44	5.53	†1.172** / †1.048*

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.8 Residual sodium carbonate (RSC)

The RSC (me L^{-1}) values varied between 0.13 for water from rainfall to 0.56 for water from well during the experimental periods. The range for water sample from rainfall, rain water harvested in pond, kotteppadom pond, well and surface run off were 0.13-0.18, 0.33 - 0.36, 0.47 - 0.55, 0.42 - 0.56 and 0.45 – 0.49 respectively. The values for this parameter were greater during summer and pre monsoon seasons for water from all sources.

In general, the values of RSC were comparatively higher for water samples from the well and Kotteppadom pond during different seasons. The RSC of rain water was noticed as the lowest during the different seasons. The difference in the mean value of RSC was found to be significant both among the sources and seasons.

Table 19. Residual sodium carbonate (me L^{-1}) of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)	Mean
RF	0.15	0.16	0.18	0.13	0.15
RWH	0.34	0.36	0.35	0.33	0.35
KP	0.47	0.52	0.55	0.49	0.51
W	0.42	0.53	0.56	0.52	0.50
SR	0.45	0.48	0.49	0.47	0.47
Mean	0.36	0.41	0.43	0.39	†0.038** †0.035*

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.9 Nitrate (NO_3^-)

Nitrate content (mg L^{-1}) varied between 0.20 (RWH) to 0.78 (KP) during different seasons. In the case of rainfall, the NO_3^- content varied between 0.42 and 0.57. Maximum values were recorded for water from KP closely followed by well water, surface run off and rainfall. The water from RWH recorded minimum values for NO_3^- during the different seasons. During monsoon, the highest content of NO_3^- (0.78) was observed for KP and the lowest (0.30) for rain water harvested in the pond. The difference in mean nitrate contents of water from all sources during the different seasons was not found to be significant.

Table 20. Nitrate content (mg L^{-1}) of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)	Mean
RF	0.42	0.48	0.36	0.57	0.39
RWH	/0.20	0.24	0.28	0.30	0.18
KP	0.54	0.67	0.68	0.78	0.67
W	0.52	0.53	0.51	0.56	0.51
SR	0.45	0.49	0.48	0.54	0.46
Mean	0.46	0.45	0.38	0.51	NS / NS

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.10 Chloride (Cl^-)

Chloride content (mg L^{-1}) of water samples from all sources showed a wide range and it varied from 11.20 (monsoon) to 27.50 (pre monsoon) during different seasons. The values for the water samples from the rain water harvesting pond, kotteppadom pond, well, and surface run off were comparatively higher than that of rain water. The ranges were 20.07 (post monsoon) to 22.70 (pre monsoon), 24.20 (post monsoon) to 27.50 (pre monsoon), 24.07 (monsoon) to 26.60 (pre monsoon) and 18.10 (post monsoon) to 23.70 (pre monsoon) for the water samples from the rain water harvested, kotteppadom pond, well, and surface run off respectively.

The variance analysis revealed that the difference in the mean content of chloride of rain water from the different sources was significant during different seasons.

Table 21. Chloride content (mg L^{-1}) of water samples from different sources

Sources	Post monsoon (S1)	Summer (S2)	Pre monsoon (S3)	Monsoon (S4)	Mean
RF	12.01	13.00	13.10	11.20	12.33
RWH	20.07	21.60	22.70	20.50	21.22
KP	24.20	26.80	27.50	24.80	25.83
W	24.93	25.25	26.60	24.07	25.21
SR	18.10	21.90	23.70	21.00	21.18
Mean	19.86	21.71	22.72	20.31	NS †17.67**

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.3.11 Iron (Fe)

The Fe content (mg L^{-1}) ranged between 0.02(RF) to 0.12 (W) during different seasons. The highest content of Fe (0.12) was observed in well water during summer and the lowest (0.02) from rainfall during post monsoon period (Table 22). In case of well water, the Fe content varied between 0.09 and 0.12 during the different seasons.

During monsoon period, the highest Fe content was observed for water from well and kotteppadom pond (0.09) and the lowest for rainfall (0.05).

The statistical analysis revealed that the Fe content of water from all sources differed significantly between the sources but not between seasons.

Table 22. Iron content (mg L^{-1}) of water samples from different sources

Sources	Post monsoon (S_1)	Summer (S_2)	Pre monsoon (S_3)	Monsoon (S_4)	Mean
RF	0.02	0.05	0.07	0.05	0.05
RWH	0.05	0.08	0.07	0.07	0.07
KP	0.09	0.11	0.08	0.09	0.09
W	0.10	0.12	0.10	0.09	0.10
SR	0.06	0.07	0.08	0.06	0.07
Mean	0.06	0.09	0.08	0.07	† 0.018** / NS

† CD for respective mean comparison * Significant at 5 % level ** Significant at 1 % level
NS - Non significant

4.4 Soil analysis – surface run off study

Soil samples from the run off experimental area near tapioca field were analyzed for various physico-chemical parameters such as pH, EC, OC, available N, P, K, Ca, Mg, Fe, BD, PD and WHC during summer showers (December - March), and monsoon (June – August). The data for the different parameters were found out both before and after rainfall during the respective seasons. The mean values of these parameters and per cent changes along with t-values are presented in the Table 23.

Before studying the change in the above parameters soil texture was also found out. The per cent of the different soil separates were 68.12 per cent for sand, 25.38 per cent for silt and 6.50 per cent for clay. Textural class of the soil was found to be sandy loam.

During summer, there was significant change for the parameters like pH, OC, as well as available nutrients like K, Ca, Mg, Fe, and the per centages of decrease were 1.67, 0.67, 37.94, 25.46, 5.62 and 8.85 respectively. Water holding capacity of the soil was also decreased by 4.79 per cent and the BD increased to the extent of 1.47 per cent. During monsoon pH, and available nutrients like N, P and K decreased and the percentages of decrease were 3.19, 23.68, 26.24, and 49.32. Water holding capacity also decreased by 7.29 per cent but BD increased to the extent of 1.44 per cent.

4.4.1. Soil pH

The pH of soil samples before rains was higher during summer than monsoon season. The pH of soil samples decreased after rain. There was a decrease of 1.67 per cent after rains during summer and 3.19 during monsoon. The statistical analysis applying t-test revealed that the difference in mean pH values before and after rain during summer was significant and the difference was also significant during monsoon period.

4.4.2. EC of the soil

The electrical conductivity (dS m^{-1}) of soil before rains (0.059) in summer decreased to lower value (0.054) after rain. During monsoon, the EC value of 0.071 observed before rains decreased to 0.051 after rains.

The t-test revealed that the difference in mean EC content of the soil before and after rain during both summer and monsoon seasons were not significant (Table 23).

Table 23. Physico-chemical properties of soil (mean) from the run off study area

Sl No		Summer (December, 2012 - March, 2013)				Monsoon (June, 2013 – August, 2013)			
	Parameters	Before rain (Dec.)	After rain (Mar)	t – value	Per cent change over initials	Before rain (May)	After rain (Aug.)	t – value	Per cent change over initials
1	pH	5.41	5.32	3.89*	1.67	5.33	5.16	5.765*	3.19
2	EC (dS m^{-1})	0.059	0.054	1.476^{NS}	8.47	0.071	0.051	1.504^{NS}	28.17
3	OC (per cent)	1.18	1.17	3.162*	0.67	1.39	1.16	2.33^{NS}	16.73
4	BD (Mg m^{-3})	1.36	1.38	3.511**	1.47	1.39	1.41	0.577^{NS}	1.44
5	PD (Mg m^{-3})	2.53	2.55	6.877**	0.79	2.54	2.56	2.016^{NS}	0.79
6	WHC (per cent)	30.87	29.39	3.912*	4.79	28.27	26.21	7.459**	7.29
7	Porosity (per cent)	46.34	45.62	1.814^{NS}	1.55	45.28	44.01	1.772^{NS}	2.81
8	Available N (kg ha^{-1})	417.09	344.96	2.342^{NS}	17.29	476.67	363.78	3.455*	23.68
9	Available P (kg ha^{-1})	16.52	15.12	0.103^{NS}	8.47	12.88	9.50	8.66*	26.24
10	Available K (kg ha^{-1})	297.80	184.80	3.135*	37.94	365.80	185.40	8.065*	49.32
11	Available Ca (mg kg^{-1})	183.40	136.70	3.379*	25.46	214.40	139.50	1.608^{NS}	34.93
12	Available Mg (mg kg^{-1})	25.08	23.67	22.043**	5.62	25.99	18.26	1.894^{NS}	29.74
13	Available Fe (mg kg^{-1})	30.97	28.23	5.00*	8.85	17.02	13.35	0.647^{NS}	21.56

* Significant at 5 % level ** Significant at 1 % level NS - Non significant

4.4.3 Organic carbon

The organic carbon content (per cent) of soil before rain (1.18) in summer decreased to lower value (1.17) after rain. During monsoon, the OC content was found to be the highest (1.39) before rain and the lowest (1.16) after rains (Table 4.13). The t-test revealed that the difference in mean OC content of the soil before and after rain during summer was significant but in monsoon season it was non-significant.

4.4.4 Bulk density (BD)

The mean values of BD (g cm^{-3}) of the soil increased after rain in both seasons. The value increased from 1.36 and 1.38 during summer and from 1.39 to 1.41 during monsoon. The changes were almost similar in both the seasons. The t-test revealed that the difference in mean BD values of the soil before and after rain during summer was significant but monsoon season was not found to be significant (Table 23).

4.4.5 Particle density

The particle density (PD) (g cm^{-3}) of soil increased after rain in both seasons. The changes in particle density (0.79) were less than one per cent. The value increased from 2.53 and 2.55 during summer and from 2.54 to 2.56 during monsoon. The t-test revealed that the difference in mean PD values of the soil before and after rain during summer was significant but in monsoon period it was non-significant.

4.4.6 Water holding capacity

The water holding capacity (per cent) of the soil exhibited a range from 26.21 to 31.10 per cent in the two different seasons. The mean values of WHC showed a decreasing trend after rains. The percentage decrease of water holding capacity was higher in monsoon than that of summer. The t-test revealed that the difference in mean WHC values of the soil before and after rain during summer and monsoon period was significant (Table 23).

4.4.7 Porosity

The porosity (per cent) of the soil before rain was 46.34 and 45.28 during summer and monsoon respectively. The porosity decreased by 1.55 per cent during summer and 2.81

per cent during monsoon after receipt of rains. The porosity was estimated from the present findings of bulk and particle densities. The difference in mean porosity values of the soil before and after rain during summer and monsoon period was non-significant.

4.4.8 Available nitrogen

The mean available nitrogen content (kg ha^{-1}) of soil decreased from 417.09 to 344.96 during summer and from 476.67 to 363.78 during monsoon. The highest content of available nitrogen (476.67) was observed before rain and the lowest (344.96) in summer showers after rain when different periods were compared (Table 23). The t-test revealed that the difference in mean nitrogen content of the soil before and after rain during monsoon was significant though during summer was non-significant.

4.4.9 Available phosphorus

In the run off study area, mean phosphorus content (kg ha^{-1}) of soil showed a decrease after rain in summer and monsoon seasons. The value decreased from 16.52 to 15.12 kg ha^{-1} during summer and from 12.88 to 9.50 during monsoon. The highest (16.52) value was observed in summer period and the lowest (9.50) value was observed in monsoon season after receipt of heavy rain. The t-test revealed that the difference in mean phosphorus content of the soil before and after rain during summer was non-significant (Table 23); but in monsoon it was significant.

4.4.10 Available potassium

The potassium content (kg ha^{-1}) of soil was found to be the highest (365.80) in May, 2013 before rain and the lowest (184.80) in summer after rain. In both seasons, the mean potassium content of soil decreased greatly with increased surface run off. The decrease was more (49.32 per cent) during monsoon. The t-test revealed that the difference in mean K content of the soil before and after rain during summer and monsoon was significant (Table 23).

4.4.11 Available calcium

The content (mg kg^{-1}) of this cation was also influenced by rains in both seasons. The content of calcium varied from 214.40, to 136.70 mg kg^{-1}. The lowest (136.70) value was observed during summer showers and the highest (214.40) value during monsoon period. There was a decrease of 25.46 per cent in the available calcium content during summer and 34.93 per cent during monsoon after rains. The t-test revealed that the difference in mean Ca content of the soil before and after rain during summer was significant but in monsoon period it was not found to be significant (Table 23)

4.4.12 Available magnesium

The magnesium content (mg kg^{-1}) of soil was found to be the highest (25.99) before rains during monsoon and the lowest (18.26) after rains (Table 23). The mean magnesium content of soil showed a decreasing trend after rain in summer as well monsoon seasons. Though the content decreased by 29.74 per cent in monsoon, the decrease during summer was relatively less (5.62 per cent). The t-test revealed that the difference in mean Mg content of the soil before and after rain during summer was highly significant however, in monsoon period it was non significant (Table 23).

4.4.13 Available iron

The study of surface run off indicated that the mean iron content (mg kg^{-1}) of soil showed a decreasing trend during both the seasons. The highest value was observed in monsoon and the lowest value in monsoon season after rain. Here also the content of Fe was decreased by 21.56 per cent during monsoon as compared to 8.85 per cent during summer. The t-test revealed that the difference in mean Fe content of the soil before and after rain during summer was significant, but in monsoon period it was non significant (Table 23).

DISCUSSION

5. DISCUSSION

5.1 Quantification of rain water

The monthly rainfall ranged between 0 and 1031.8 mm (Table 11). There was wide variation in the amounts between summer and monsoon seasons during period of the study (Appendix 1).

The level of water the rain water harvesting pond from rooftop of library block of the College of Horticulture varied from 139.72 m^3 to 765.20 m^3 between the initial and final stages of the experiment. During the start of the experiment, small amount of water in the pond decreased to a minimum due to high evaporation. Thereafter, the water level increased and reached the maximum which was taken as the final volume for calculation (Appendix 2). Thus the amount of rain water collected during the study period was found to be 625.48 m^3 which was only 62.5 per cent of its storage capacity. The full capacity was not attained probably due to less rainfall during the study period.

5.2 Water quality

5.2.1 Colour and turbidity

The colour of the samples ranged between colourless for water from direct rainfall and yellowish brown for water from surface run off during the different seasons. This variation in colour may be mainly due to turbidity, the presence of sand, silt, clay particles, organic matter and other debris in run off during rainy seasons. The rain water harvested in the pond and well water were comparatively more turbid in pre monsoon than that of the other three seasons due to high temperature, less quantity of water contained, abundance of flora and fuana and absence of recharge from the ground or rainfall. During pre monsoon, the turbidity was relatively higher in KP pond as compared to the other three seasons. This may be due to excessive evaporation loss and use of water which resulted in very minimum water which remained mixed with clay at the bottom. The turbidity was comparatively more in run off than that of the other sources due to accumulation of mud in the rain pits.

5.2.2 pH

The pH of water harvested from the different sources varied from 5.54 to 6.40 in different seasons (Fig.4). The pH of rain water exhibited a narrow range of variation and almost all were towards neutral (Ananthan, 1994). This trend was observed in both pre monsoon and monsoon seasons. The pH of irrigation water in the study area was not found to be adverse and hence suitable for irrigation. A similar observation was made by Visalakshi (2007).

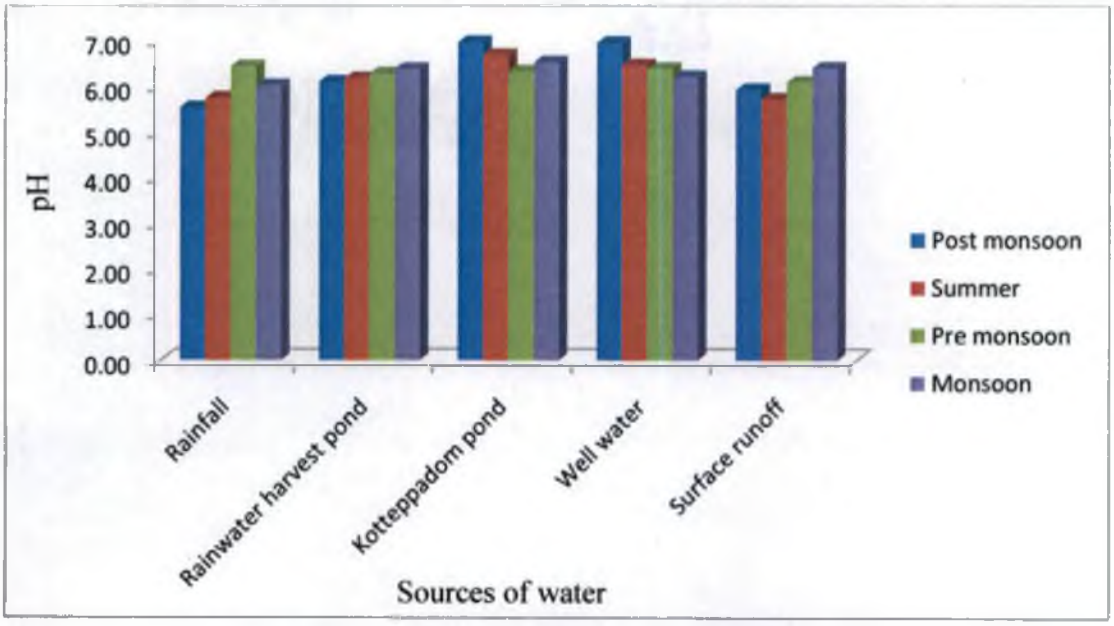


Fig.4. pH of water from different sources during different seasons

5.2.3 Electrical conductivity (EC)

The EC of water from all sources showed an increase during the three seasons commencing from the post monsoon towards pre monsoon with the highest values in pre monsoon (Fig.5). There was a decrease in EC in the monsoon period and it was the lowest during this period. This may be due to dilution consequent to heavy rain. Water from KP and well recorded relatively higher EC than that of others since they have direct contact with soil beneath dissolving some of the salt containing minerals as observed by Adamu (2012).

Based on the Indian standards, the EC values of water from all the sources were under low salinity class (Table 14) thereby indicating that there was no salinity problem during any of the seasons and hence suitable for irrigation.

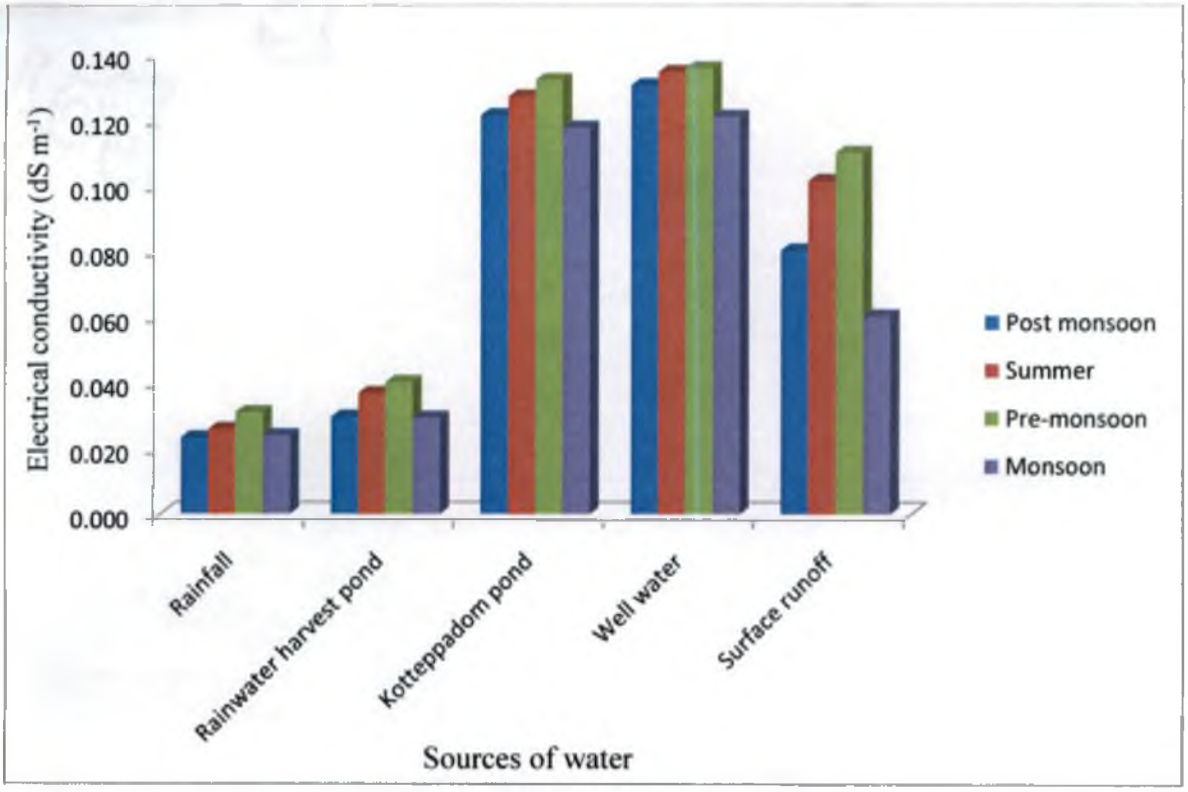


Fig.5. EC of water from different sources during different seasons.

5.2.4 Total dissolved solids

The total dissolved solids (TDS) in water was estimated based on the EC of the samples. Salinity was more in water from the well and Kotteppadom pond than that of rain water harvested and surface run off in different seasons (Fig.6). This may be mainly due to the type of sources from where samples were collected. Water from KP and the well recorded relatively higher TDS than that of others since they have direct contact with soil on ground to dissolve some of the salt containing minerals (Shankar *et al.*, 2011). The rain water harvesting pond and surface run off pits were lined with thick polyvinyl sheets preventing direct contact with salt containing minerals. This explains the reason for low TDS for the water from these two sources. The lowest TDS was recorded for rain water directly collected (RF) into rain gauge.

In general, the TDS observed was comparatively lower during the monsoon due to heavy rainfall received and freshwater inflow to the different sources. Similar trend in the salinity values were reported from Vellar estuary (Sreenivasan, 1998). In the present study, the salinity was higher in the months of April to May due to low rainfall, rise in temperature, decreased fresh water inflow, and drainage.

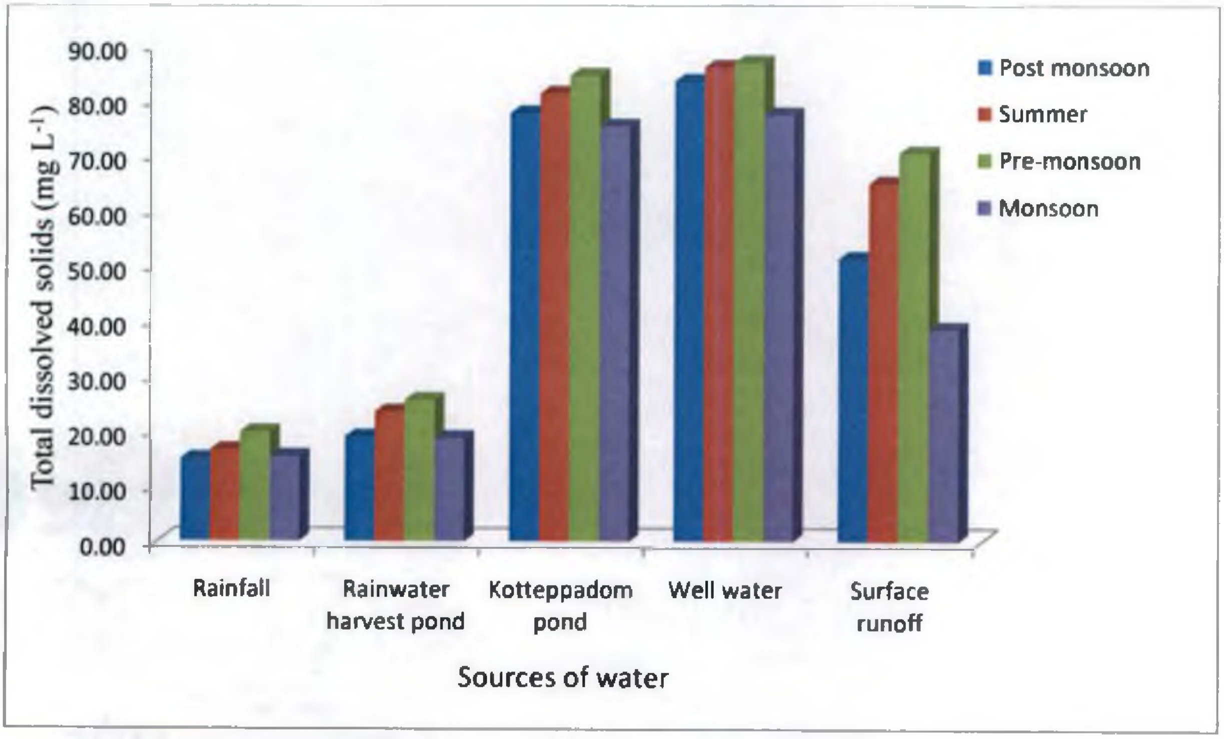


Fig.6. TDS of water from different sources during different seasons.

The TDS values were relatively higher in summer and pre monsoon than that of monsoon period. This may be due to high temperature and consequent accumulation of salt during dry seasons. The TDS values for water from all sources sharply decreased during monsoon due to dilution effect of heavy rain. Water from all sources is suitable for irrigation (Reddy, 2007).

5.2.5 Chemical oxygen demand (COD)

Rain water received from direct rainfall had the lowest COD values, since it was free of pollutants and soil minerals or salts. In Kotteppadom pond, the COD (mg L^{-1}) values varied from

39.95 to 59.00 in different periods (Fig.7). The highest COD values were observed during monsoon at KP pond. This may be due to heavy rains. There was remarkable decrease in temperature and high water current which washed out the drains containing the agricultural (fertilizers and pesticides) and organic residues from the watershed surrounding the pond. In RHW, the COD values were comparatively low because pure rain water was collected directly from rooftop which was free of pollutants and contaminants from fertilizers or organic matter. Similar results were observed by Jindal and Sharma (2011).

In the case of well water, COD varied from 48.14 to 57.24 and the highest was observed in monsoon. This may be due to cool temperature, more organic residues and water current with minerals. The lowest value was observed in post monsoon period with light rain that recharged ground water with less pollution. During monsoon period, surface run off recorded comparatively higher COD than that of other seasons probably due to higher amount and intensity of rains causing a run off rich in pollutants (Memon *et al.*, 2006).

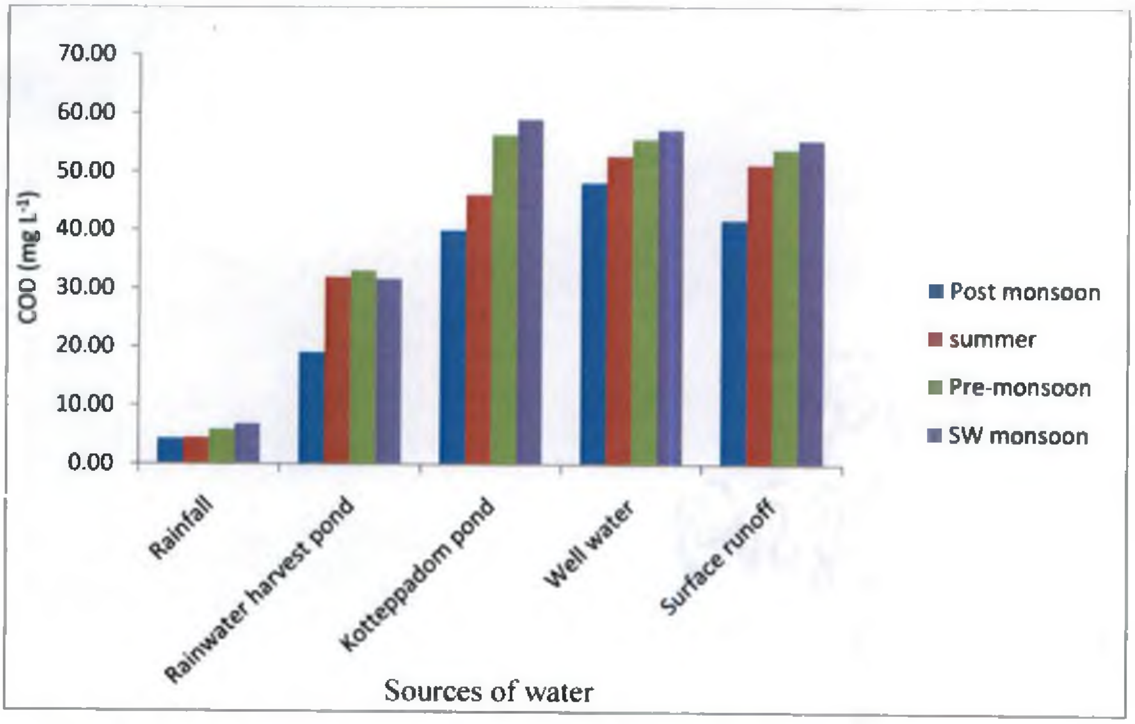


Fig.7. Chemical oxygen demand of water during different seasons

In general, the BOD values of irrigation water from all sources were very low and under the permissible limit by WHO (1971) and BIS Indian standard (Table 17) and hence suitable for irrigation.

5.2.7 Sodium adsorption ratio

During summer, SAR values of water from all sources were high but following the rainfall during the monsoon period, there was sharp decrease in SAR values for the samples from Kotteppadom pond, well and surface run off (Fig.9). This was due to dilution effect of heavy rain. Similar observation was also made by Akhil *et al.* (2013). Relatively higher SAR values in all four seasons were noticed for well water followed by water from Kotteppadom pond than that of run off water, rain water and rain water harvested and this may be due to more chance to dissolve sodium containing minerals in these two sources of water as water has direct contact with soil beneath it (Shankar *et al.*, 2011).

In general, rainfall (RF) and rain water harvested in the pond (RWH) showed lower values for SAR which remained almost constant throughout different seasons. There was not any addition or dissolution of minerals in the water harvested from rooftop in the pond.

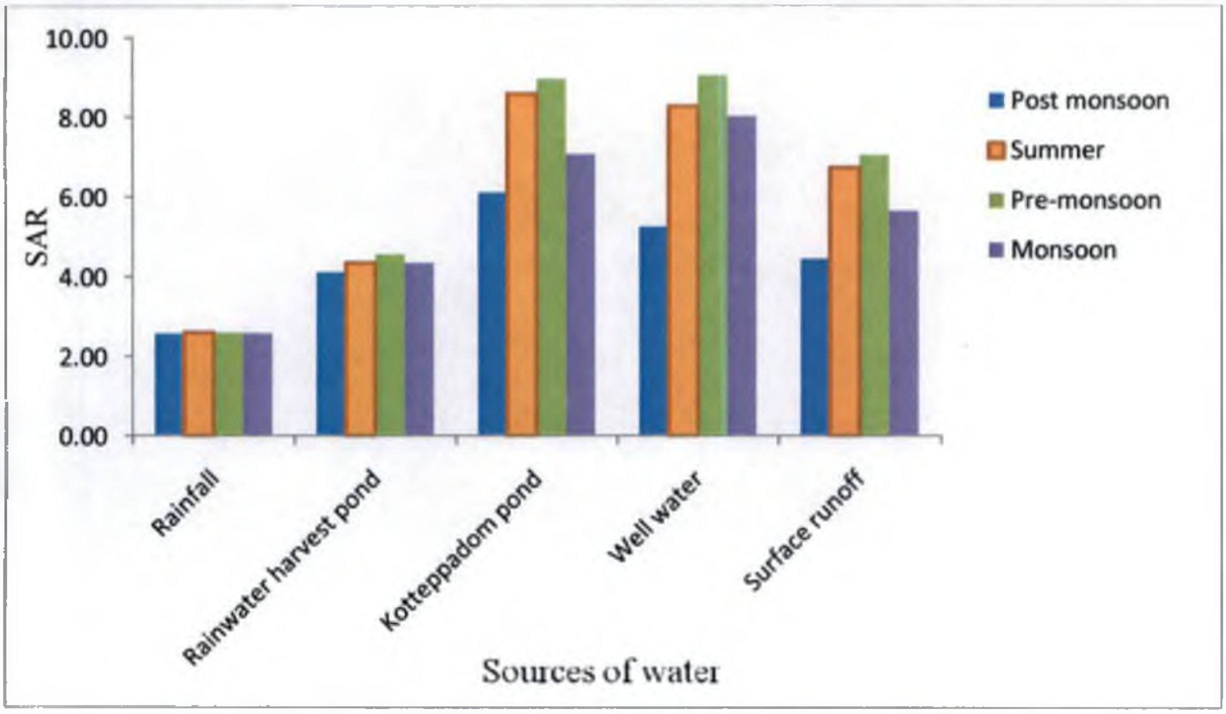


Fig.9. Sodium adsorption ratio of water from different sources during different seasons.

The rain water and rain water harvested in the pond were under the class 'low' of sodium hazard based on Indian standards (Table 18). This indicates good irrigation water quality for the above two sources while well water, run off and water from KP were comparatively higher during summer (Ahmad and Khan, 2013).

5.2.8 Residual sodium carbonate (RSC)

The RSC (me L^{-1}) of water from all sources was estimated from carbonate, bicarbonate, calcium and magnesium contents of irrigation water in different periods of the year. The RSC values varied from 0.15 to 0.56 in different seasons and the lowest (0.15) was for rain water during post monsoon (Fig.10). This can be attributed to sufficient Ca and Mg contents in almost equal amounts as CO_3 and HCO_3 in the water. Similarly the highest value (0.56) for water from KP pond in pre monsoon period may be because of less Ca and Mg contents. In general the RSC values for water from all the sources in different seasons were low and within the desired range (Table 19) and these waters were safe and suitable for irrigation.

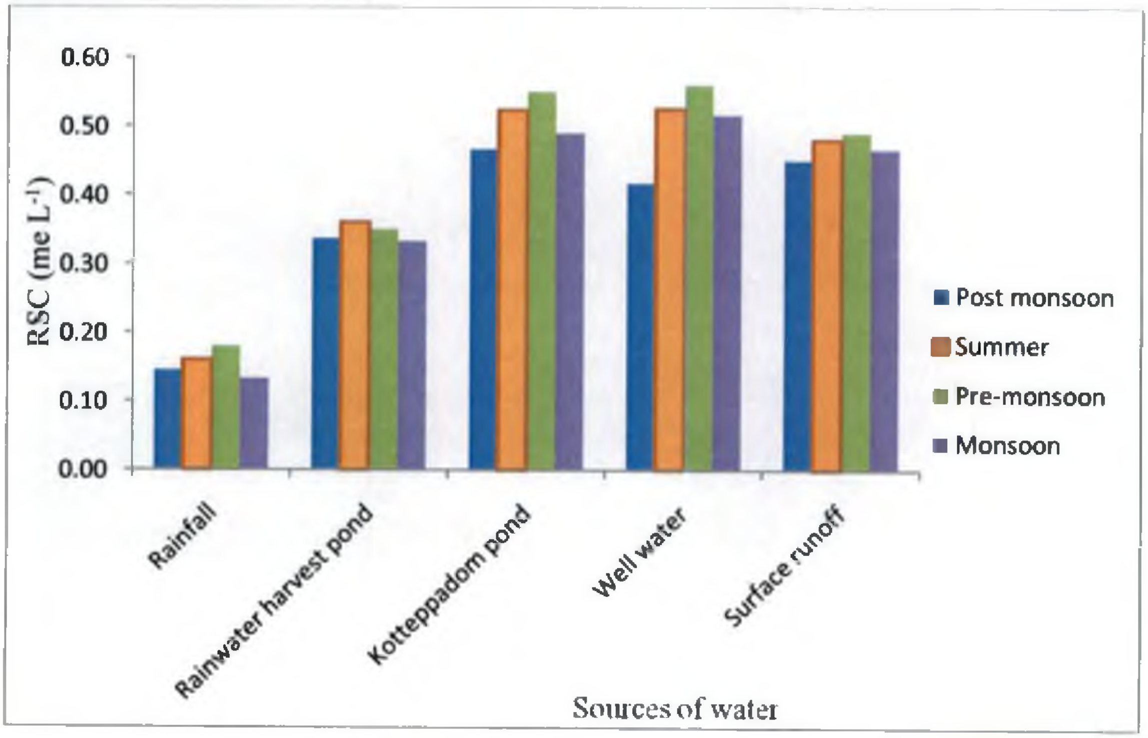


Fig.10. Residual sodium carbonate of water from different sources during different seasons.

5.2.9 Nitrate

The NO_3^- (mg L^{-1}) content of rain water exhibited a narrow range of variation in different seasons except for monsoon where a slightly higher value (0.57) was observed (Fig.11). This might be due to the first rain of monsoon during this period. Water from KP pond and well recorded relatively higher NO_3^- content than that of others in different seasons mainly due to the fertilizers, manures and pesticides used in the paddy fields and farm nearby (Wang *et al.*, 2013). The content of NO_3^- in the rain water harvested in the pond was comparatively low in the different periods. During monsoon, the NO_3^- content of surface run off was relatively high due to nutrient loss from bare soil near the rain pits. However, the highest value observed for all sources during the monsoon period may be due to heavy rainfall, low temperature, fertilizers and manures carried by the current of water. Similar types of results were also observed by Tejada and Gonzalez (2008).

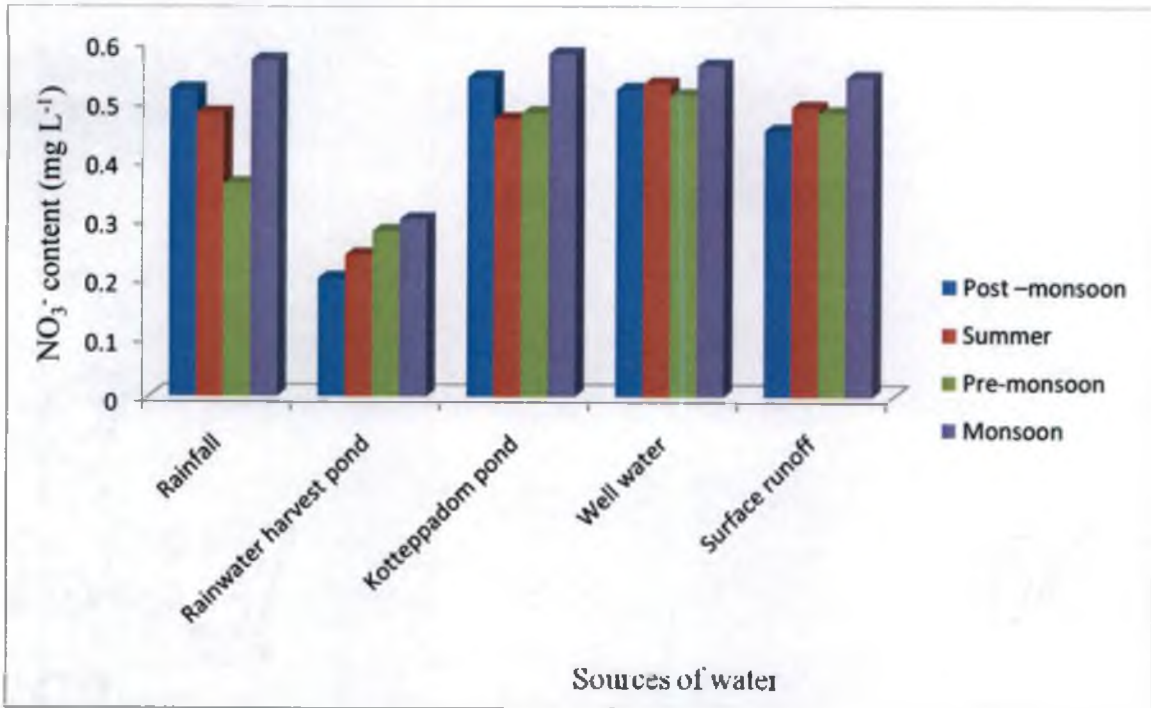


Fig. 11. Nitrate content of water from different sources during different seasons.

5.2.10 Chloride

The Cl^- (mg L^{-1}) content ranged between 11.20 and 27.50 in different seasons (Fig.12). During pre monsoon period, the highest Cl^- content was noticed in all sources due to high temperature and evaporation. In all the sources, the Cl^- content showed an increasing trend commencing from post monsoon towards pre monsoon season then sharply decreased in monsoon period due to dilution effect of heavy rain (Adamu, 2012). In general, all the values of these irrigation waters at different seasons were in desirable level (Table 21) and are suitable for irrigation.

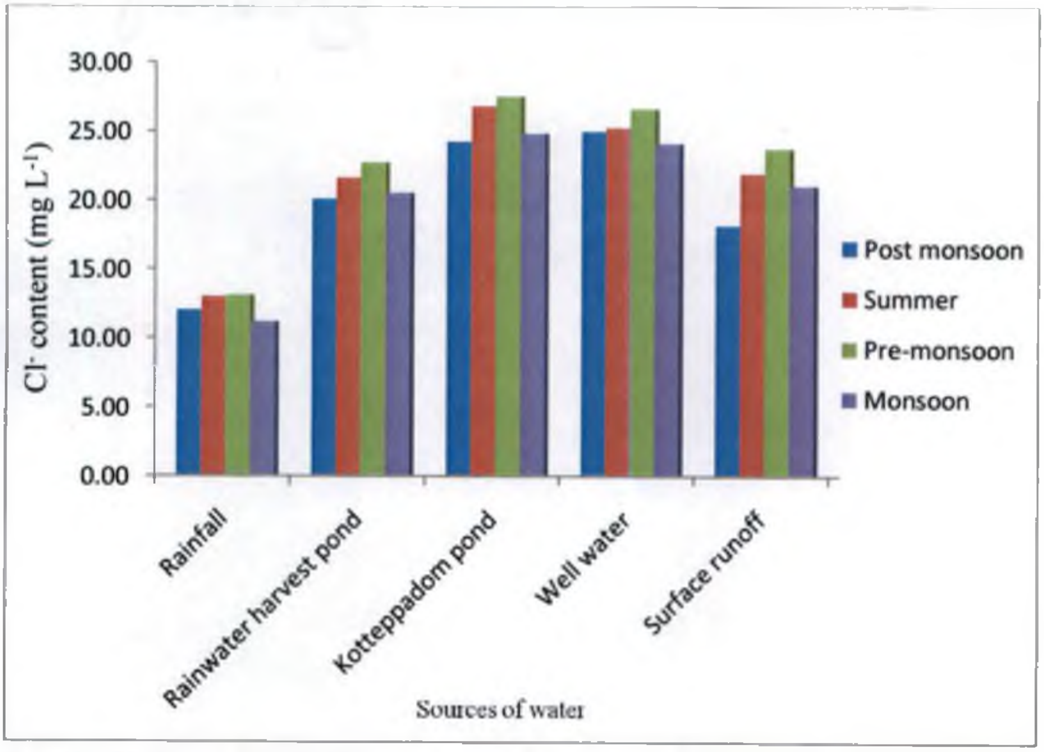


Fig. 12. Chloride content of water from different sources during different seasons.

5.2.11 Iron

The Fe (mg L^{-1}) content of irrigation water varied from 0.02 to 0.12 in different seasons (Fig. 13). The highest content (0.12) was observed in well water during summer period. This could be due to contact with ground consisting of lateritic soil rich in iron. The values for Fe rain water and surface run off registered an increasing trend during the three consecutive periods but during monsoon period there was a marginal decrease which might be due to heavy rain (Gander, 2007). In general, Fe content in all water sources in different seasons were in the desirable range (less than 0.3ppm) and hence suitable for irrigation.

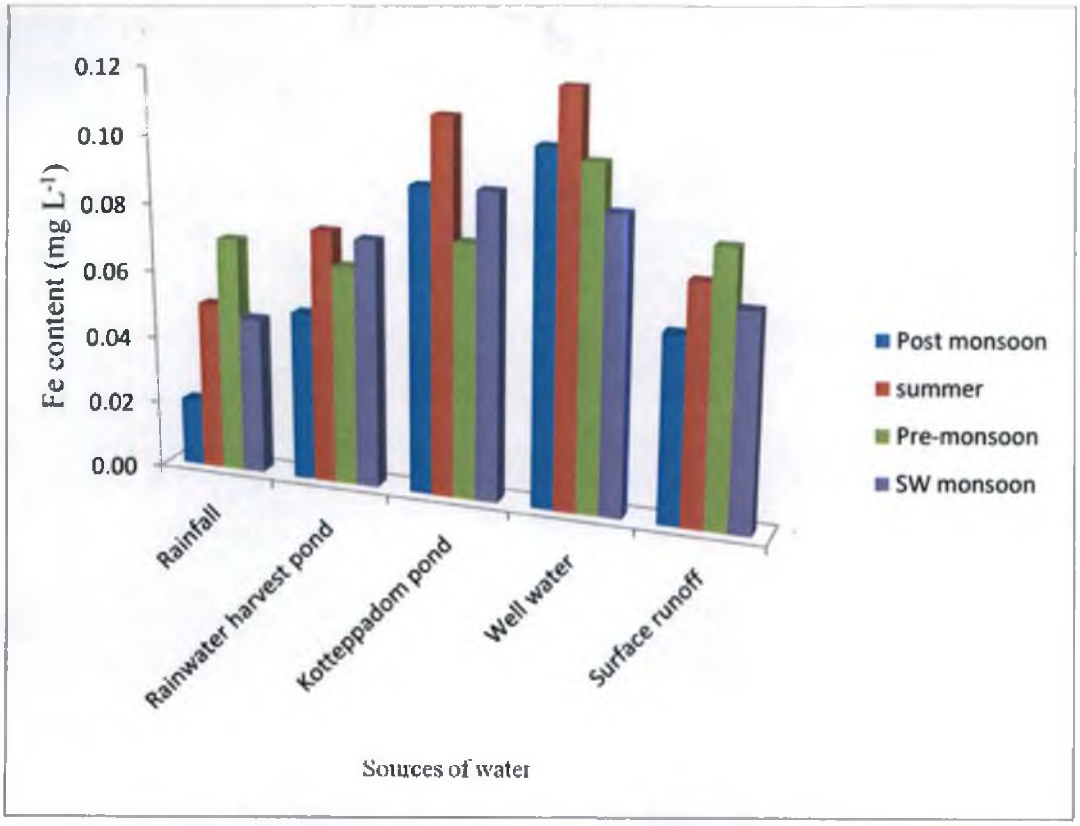


Fig.13. Content of Fe of water from different sources during different seasons.

5.3 Physico-chemical properties of surface soil

5.3.1. pH

The mean value of pH ranged from 5.16 to 5.41 (Fig.14). The lowest value (5.16) was observed during monsoon after rain because of removal of bases from bare soil and leaching by heavy rain. The soil pH exhibited a decreasing trend after rain. The pH of the soil samples decreased after rain in both summer (1.67 %) and monsoon (3.19 %) but the per cent decrease was more in monsoon than that of summer season because of intensity and amounts of rainfall.

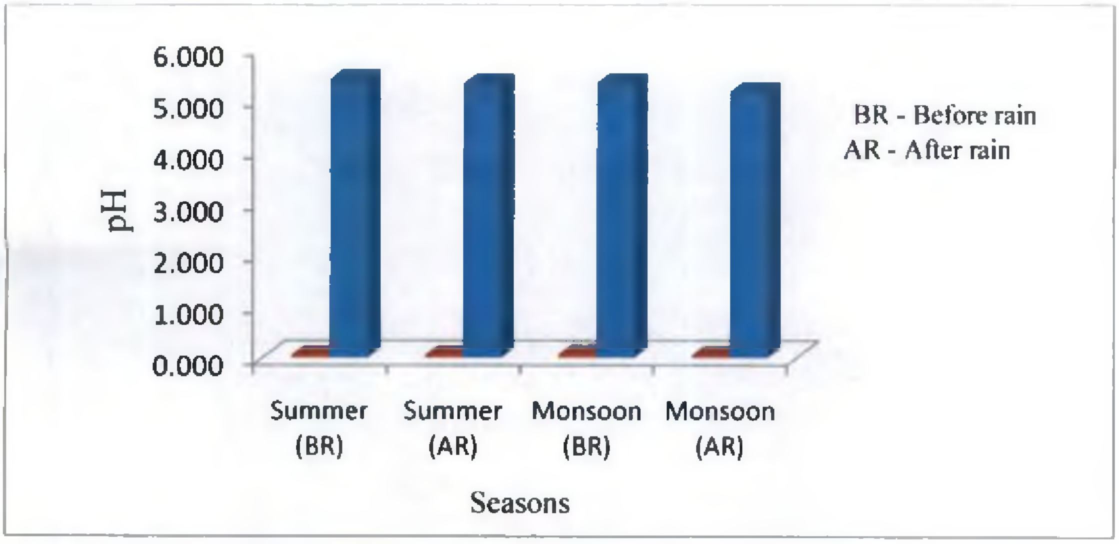


Fig.14. pH of the soil before and after rain

5.3.2. EC of Soil

The highest (0.01) value was observed due to high temperature and high evaporation that led to accumulation of salt bearing minerals and the lowest (0.051) value in monsoon after heavy rainfall was received. The mean electrical conductivity of soil showed a decreasing trend after rain.

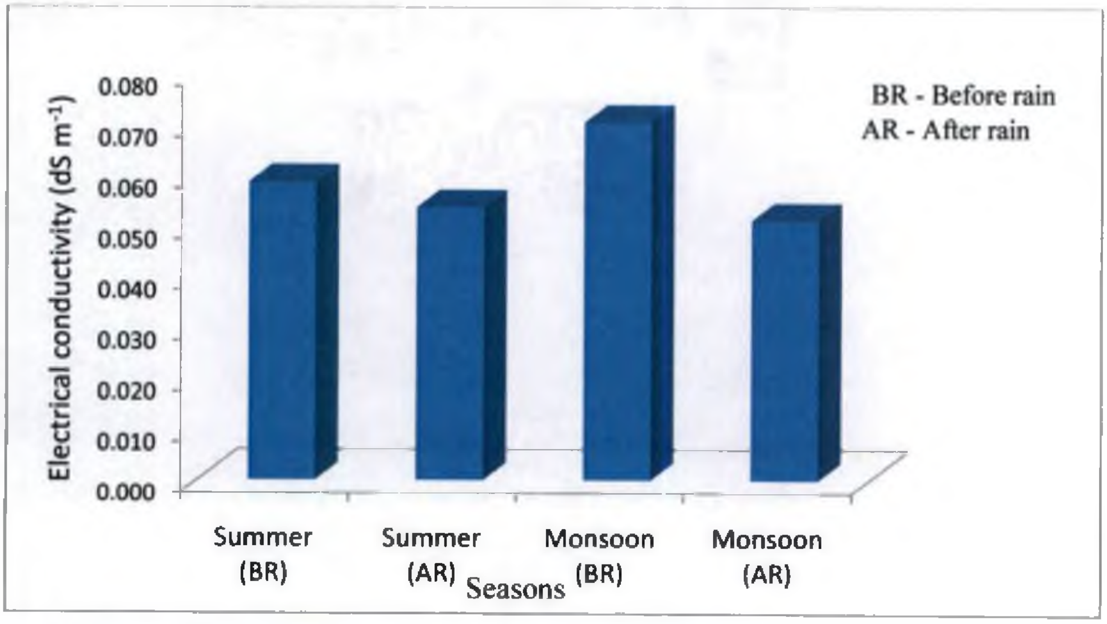


Fig.15. Electrical conductivity of the soil before and after rain

During summer, EC was reduced by 8.51 per cent after rain and 27.3 per cent after monsoon. This is because the nutrients were washed out by surface run off on slopy landscape and due to the effect of dilution of rain water as well as leaching down of salts. The rain brought down temperature daily which further reduced evaporation and consequent concentration of soluble salts (Sewa *et al.*, 2001).

5.3.3 Bulk density

The highest value (1.41) was observed during monsoon may be due to the impact of heavy rain that produced substantial surface run off to washout organic matter, to reduce pore space and increase compaction of the soil (Fig. 16). The lowest value (1.35) was noticed during monsoon period probably due to decomposition of organic matter. The values of BD in soil exhibited an increasing trend in the different periods of the year depending on the intensity and amount of rain fall and loss of organic matter.

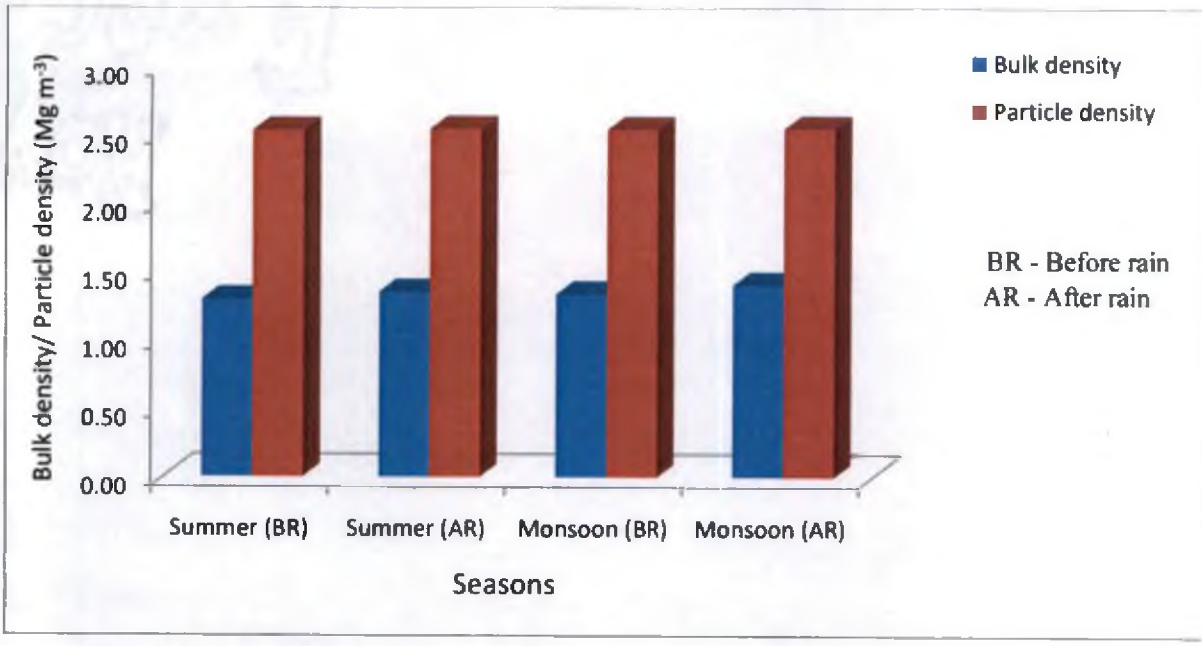


Fig.16. Bulk density and particle density of the soil before and after rain

5.3.4 Particle density (PD)

The particle density (g cm^{-3}) of soil in the two seasons ranged between 2.53 and 2.56 (Fig. 16). The value of PD showed an increase during summer and monsoon. There was slight change over the initials after rain during both seasons but the per centage increase during monsoon period was higher than that of summer probably due to differences in intensity and amount of rainfall receipt (Sewa *et al.*, 2001).

5.3.5 Organic carbon

The organic carbon content (per cent) of soil was found to be the highest (1.39) before rain in monsoon and lowest (1.16) after the receipt of monsoon (Fig.17). This great loss (16.73 %) in OC content of soil may be due to the effect of erosion by run off in bare top soil (Tejada and Gonzalez 2008). During different periods, the content of organic carbon ranged between 1.16 and 1.39 with slight decrease after getting rainfall depending on the intensity and amount of rainfall. The organic carbon showed a decreasing trend after rain in both seasons due to the effect of surface run off.

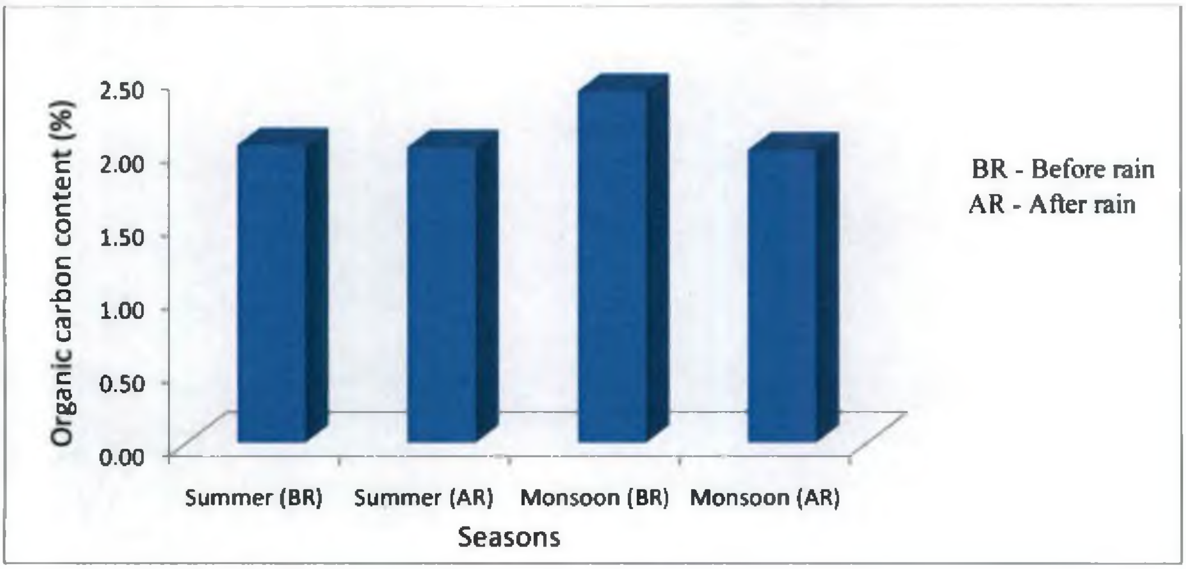


Fig. 17.Organic carbon content of the soil before and after rain

5.3.6 Available nitrogen

The highest (476.67) was observed in monsoon period before rain because of application of fertilizers and decomposition of OM and the lowest (344.96) after rain during summer. It was found that 23.68 per cent of available nitrogen was lost by water erosion during monsoon period. Similarly 17.29 per cent of reduction over the initial available nitrogen content of soil was noticed during summer season. Similar results were observed by Tejada and Gonzalez (2008).

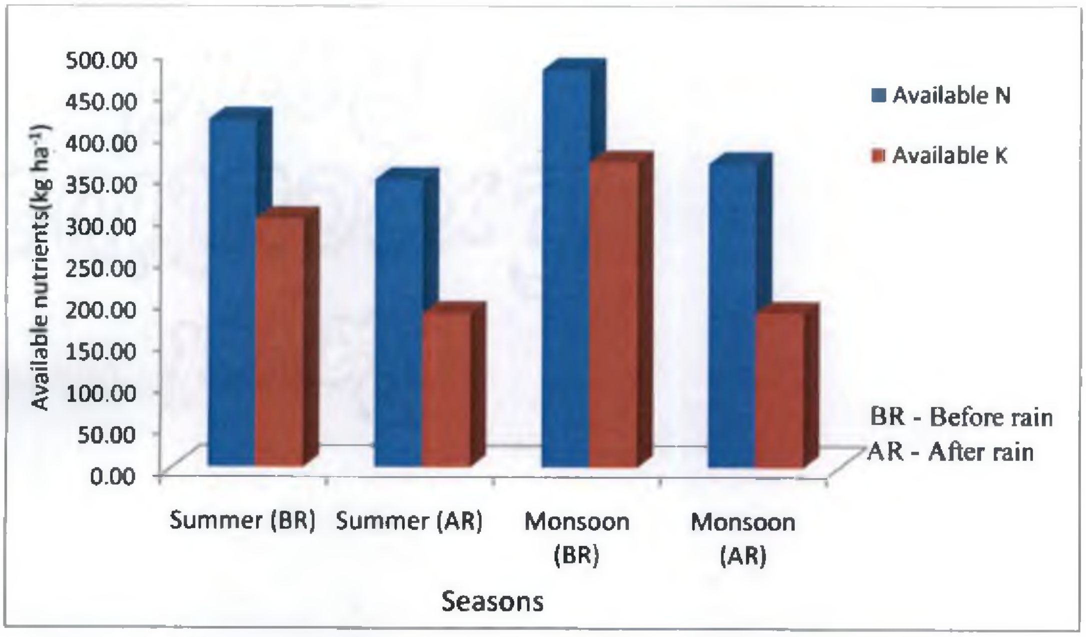


Fig.18. Available N and K content of the soil before and after rain

5.3.7 Available phosphorous

In the run off study area, the mean (kg ha^{-1}) of soil showed a decrease after rain in summer and monsoon seasons (Fig.19). The content of available phosphorus ranged from 9.50 to 16.52 in the two seasons. During summer period, 8.47 per cent of available P was washed out by run off and during monsoon 26.24 per cent of phosphorous content of soil was lost due to heavy run off from top soil (Tejada and Gonzalez, 2008).

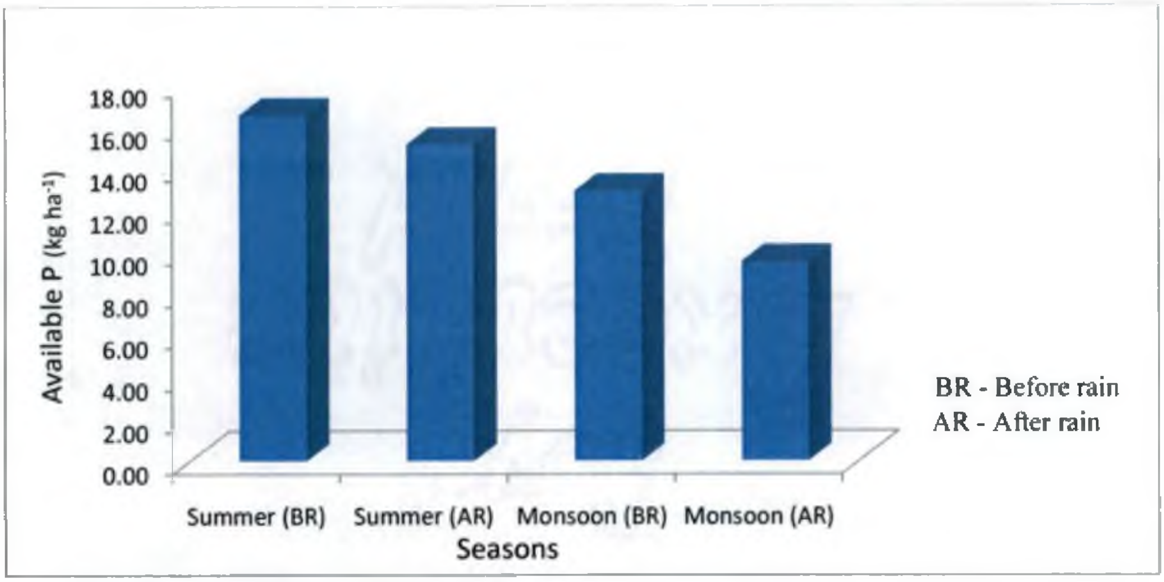


Fig.19. Available P content of the soil before and after rain

5.3.8 Available potassium

The available K content (kg ha^{-1}) of soil was found to be the highest (265.8) before the rains in monsoon (Fig.18). This might be due to application of fertilizers and decomposition of OM and lowest (184.8) in summer period after rain. This was because about 37.94 per cent of the available K content of the soil was eroded by surface run off during summer and 49.32 per cent in monsoon periods (Tejada and Gonzalez, 2008). In both seasons, the mean potassium content of soil decreased greatly with the increase of run off amount since K was easily leached out.

5.3.9 Available calcium

The highest (214.40) value was observed before rain during monsoon and lowest (136.70) after rain during summer. During monsoon, 34.93 per cent of the available Ca was lost by run off. During summer showers, there was, however, 25.46 per cent reduction over the initial content of available Ca in the soil. This was in accordance with the findings of Sewa *et al.* (2001).

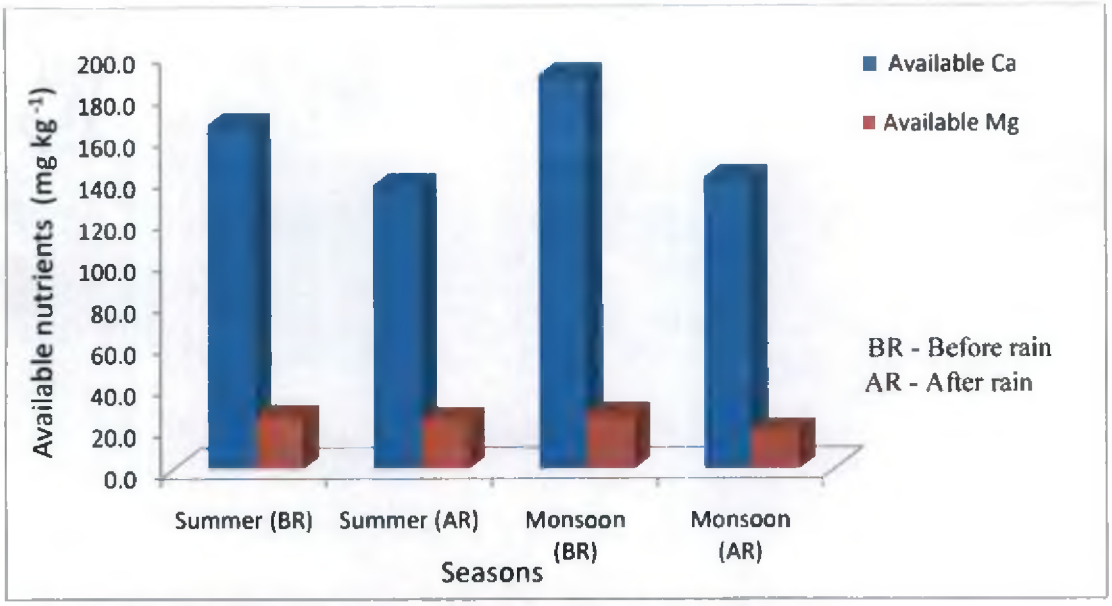


Fig. 20. Available Ca and Mg of soil before and after rain

5.3.10 Available magnesium

The magnesium (Mg) content (mg kg^{-1}) of soil was found to be the highest (25.99) before monsoon (Fig.20). This may be due to the addition fertilizers and organic matters accumulation in the area. The mean Mg content of soil showed a decreasing trend after rain in summer and monsoon seasons. This may be due to the removal by leaching, erosion and surface run off. The content of available Mg of the soil decreased by 5.62 per cent during summer but during monsoon, there was 29.74 per cent reduction over the initial content of available Mg in soil. This was due to the high amount and intensity of rainfall during monsoon than that of summer period.

5.3.11 Available iron

The highest value (30.97) was observed in summer and the lowest value (13.35) in monsoon season (Fig.21). The mean iron content of soil showed a decreasing trend in both seasons due to the impact of surface run off. During summer, there was 8.85 per cent decrease in available Fe after rain but during monsoon season 21.56 per cent reduction over the initial Fe content occurred. The may be due to higher amount of rainfall with more intensity during the latter period. This loss of this micronutrient might have occurred due to soil erosion by heavy rain.

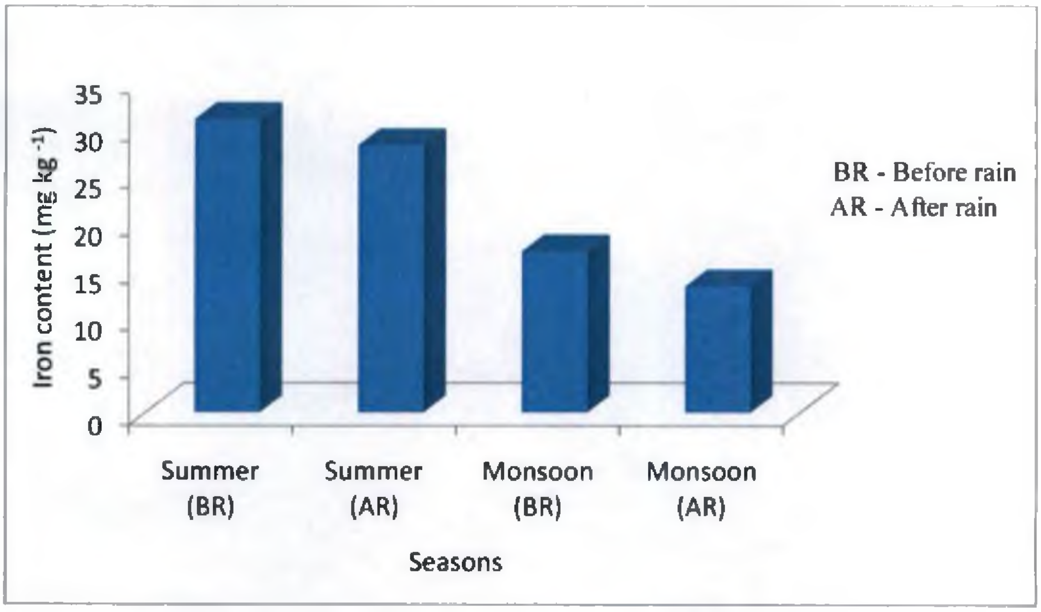


Fig. 21. Iron content of the soil before and after rain

5.3.12 Water holding capacity

The mean values of WHC showed a decreasing trend during summer and monsoon due to the effect of rain (Fig.22). The WHC decreased after rain in both seasons as the soil approached the saturation level. The per cent decrease was higher in monsoon than that of summer due to the difference in quantity and intensity of rain water.

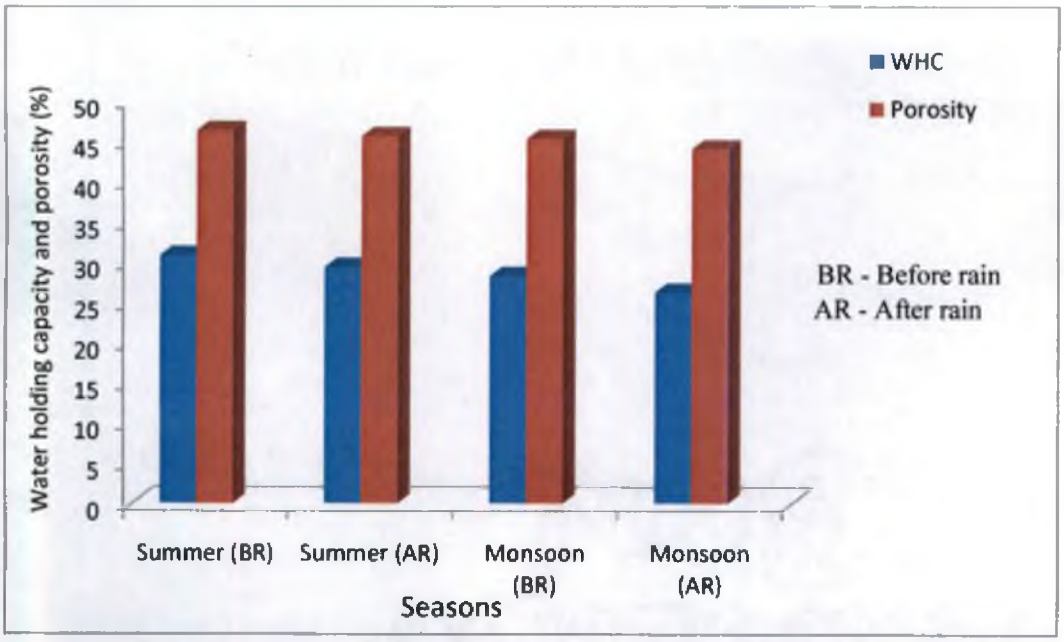


Fig. 22. Water holding capacity and porosity of the soil before and after rain

5.3.13 Porosity

The porosity (per cent) was estimated from the data on bulk density and particle density. The values of porosity showed a decreasing trend after rain in both summer and monsoon seasons (Fig.22). There was reduction over the initial value of porosity after rain during summer and monsoon periods probably due to loss of organic matter by run off and compaction. The per cent (4.81) decrease during monsoon was higher than that of summer (3.87) because of more intensity and amount of rain during monsoon period.

Summary and conclusion

- Iron (mg L^{-1}) content of water varied from 0.02 (RF) to 0.12 (W) in the different seasons. The mean Fe content of water from all sources differed significantly.

- Mechanical analysis of the soil samples revealed that the soil belonged to sandy loam. textural class

- Soil reaction of the samples had shown that the soil is acidic in nature and the soil reaction ranged between 5.16 and 5.41.

- The value of electrical conductivity of the soil during monsoon ranged between 0.051 and 0.071 dS m^{-1}. The value of electrical conductivity decreased during summer and monsoon seasons due to dilution effect of rain water and the per cent decrease were 8.47 and 28.17 respectively.

- The values of bulk density of soil exhibited an increasing trend after rains. The t-test revealed that the difference in mean BD values of the soil before and after rain during summer was significant.

- The particle density (g cm^{-3}) of the soil ranged between 2.53 and 2.56.

- The content of organic carbon in the soil ranged between 1.17 and 1.18 during summer and 1.16 and 1.39 during monsoon. Slight decrease was noticed after receipt of rainfall depending on the intensity and amount of rainfall.

- Water holding capacity of soil exhibited a decreasing trend after rains during summer and monsoon seasons. The t-test revealed that the difference in mean values Water holding capacity of the soil was significant.

- Among the major nutrients, loss of available nitrogen was higher than that of phosphorus during summer. The loss of these two nutrients were almost similar during monsoon. The loss of available potassium was more and were 37.94 and 49.32 per cent during summer and monsoon seasons respectively.

different seasons. The range for water sample from rain water harvested in pond, Kotteppadom pond, and surface run off were between 18.94 – 25.70, 75.29 - 84.51, and 38.57- 70.40 respectively.

- Chemical oxygen demand (mg L^{-1}) values of water from the different sources varied from 4.40 to 59.00 in the different seasons. The difference in the mean values of COD of water from all sources was significant in the different periods of the year.

- Biological oxygen demand values ranged between 0.33 for rain water during post monsoon and 1.30 for well water during monsoon period. The values of water from all sources were very low and under the permissible limit by WHO and BIS Indian standard and hence suitable for irrigation.

- The well water recorded the highest sodium adsorption ratio value (9.05) during summer and the rainfall water the lowest value (2.57) during post monsoon. The analysis of variance revealed that the difference in the mean values of SAR of the water from all sources were significant during the different periods of the year.

- Residual sodium carbonate values varied between 0.13 for water from rainfall and 0.56 for water from well during the different seasons. In general, the residual sodium carbonate values for water from all the sources in different seasons were low in alkalinity and within the desired range.

- Content (mg L^{-1}) of nitrate varied between 0.20 (RWH) to 0.78 (KP) during different seasons. The difference in the mean nitrate content of the irrigation water from all sources during the different seasons was not found to be significant

- Chloride (me L^{-1}) content ranged between 11.20 and 27.50 in the different seasons. During pre monsoon period, the highest chloride content was noticed in all sources due to high temperature and evaporation loss.

- Iron (mg L^{-1}) content of water varied from 0.02 (RF) to 0.12 (W) in the different seasons. The mean Fe content of water from all sources differed significantly.

- Mechanical analysis of the soil samples revealed that the soil belonged to sandy loam. textural class

- Soil reaction of the samples had shown that the soil is acidic in nature and the soil reaction.ranged between 5.16 and 5.41.

- The value of electrical conductivity of the soil during monsoon ranged between 0.051 and 0.071 dS m^{-1}. The value of electrical conductivity decreased during summer and monsoon seasons due to dilution effect of rain water and the per cent decrease were 8.47 and 28.17 respectively.

- The values of bulk density of soil exhibited an increasing trend after rains. The t-test revealed that the difference in mean BD values of the soil before and after rain during summer was significant.

- The particle density (g cm^{-3}) of the soil ranged between 2.53 and 2.56.

- The content of organic carbon in the soil ranged between 1.17 and 1.18 during summer and 1.16 and 1.39 during monsoon. Slight decrease was noticed after receipt of rainfall depending on the intensity and amount of rainfall.

- Water holding capacity of soil exhibited a decreasing trend after rains during summer and monsoon seasons. The t-test revealed that the difference in mean values Water holding capacity of the soil was significant.

- Among the major nutrients, loss of available nitrogen was higher than that of phosphorus during summer. The loss of these two nutrients were almost similar during monsoon. The loss of available potassium was more and were 37.94 and 49.32 per cent during summer and monsoon seasons respectively.

- The content of secondary nutrients of soil showed a decreasing trend after rain in summer and monsoon seasons due to leaching and run off. The decrease was more for calcium and magnesium during monsoon as compared to summer.

- The mean Iron content (mg kg^{-1}) of the soil varied from 13.35 to 30.97 mg kg^{-1} during the period of study. The highest (30.97) value was observed in summer and lowest (13.35) value during monsoon season.

- In general, water samples from all sources rain water were safe and suitable for irrigation. The rainfall and rain water harvested in the rain water harvesting pond were found to be superior to water from other sources.

Future line of work

Water from different sources can be evaluated by conducting pot culture experiments in short duration crops like vegetables and ornamentals. Based on the results of the pot culture study, field experiments on selected crops can be done. Run off studies need to be done in different slopes under different soils and cropping patterns.

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APPENDICES

Appendix 1a. Weather data during the study period (2012)

Month	Max. Temp. (°C)	Min. Temp. (°C)	Mean RH (%)	Wind speed (Km/hr)	Sunshine (hrs)	Mean sunshine (hrs)	Total rainfall (mm)	Rainy days	Total evpn. (mm)	Mean evpn. (mm)
Jan.	32.80	21.30	57.50	6.3	71.25	9.5	0.00	0	158.2	5.27
Feb.	35.10	22.20	53.50	5.5	68.25	9.1	0.00	0	163.1	5.83
Mar.	35.20	24.20	67.50	3.5	57	7.6	3.50	1	154.7	5.16
Apr.	34.70	24.80	73.00	3.4	49.5	6.6	101.90	8	131.8	4.39
May	32.60	25.30	76.00	3.0	45	6	117.30	5	111.7	3.72
Jun.	30.10	23.90	85.50	2.7	21	2.8	551.50	23	78.4	2.61
Jul.	30.00	23.70	84.50	2.9	24	3.2	375.80	19	80.9	2.70
Aug.	29.20	23.00	86.00	2.6	21.75	2.9	616.50	18	71.1	2.37
Sep.	30.40	23.30	82.50	2.3	34.5	4.6	191.80	14	79.4	2.65
Oct.	32.20	23.50	77.00	3.2	46.5	6.2	145.60	11	103.8	3.46
Nov.	32.60	22.70	69.00	3.0	56.25	7.5	46.70	3	100.7	3.36
Dec.	33.00	23.20	58.00	6.7	60.75	8.1	20.00	0	157.4	5.25

Appendix 1b. Weather data during the study period (2013)

Month	Max. Temp. (^oC)	Min. Temp. (^oC)	Mean RH (%)	Wind speed (Km/hr)	Sunshine (hrs)	Mean sunshine (hrs)	Total rainfall (mm)	Rainy days	Total evpn. (mm)	Mean evpn. (mm)
Jan.	34.1	22.54	50.6	4.92	61.94	8.86	0	0	34.66	4.96
Feb.	34.95	23.2	55.5	-	59.925	8.575	84.4	2	35.75	5.1
Mar.	35.175	24.825	68.25	-	48.025	6.85	14.6	2	33.525	4.775
Apr.	34.8	25.32	72	-	41.8	5.98	0	0	32.2	4.32
May	33.15	24.75	77.75	2.475	28.125	3.75	99.1	7	24.775	3.55
Jun.	28.525	22.75	90	1.5	6.325	0.9	1031.8	26	16.225	2.325
Jul.	28.38	22.68	90.2	2	5.12	0.74	932.3	31	17.7	2.52
Aug.	30.2	23.075	82.75	1.95	34.025	4.85	305.90	16	19.775	2.825
Sep.	29.825	22.1	84.75	1.675	26.125	3.725	344.1	16	17.55	2.5
Oct.	30.96	22.92	81.6	1.88	37.56	5.38	369.8	17	18.68	2.66
Nov.	32.55	23.8	73.75	2.975	42.775	6.125	82.0	5	21.3	3.025
Dec.	31.85	22.2	61.25	5.4	58.95	8.125	0.5	0	30.425	4.15

Appendix 2. Observations on level of water in the pond

Date of Observation	Radius (r_1)(m)	Radius (r_2)(m)	Area (m^2)	Height (m)	Volume (m^3)
18/05/13	10.3	8	258.74	0.61	157.83
20/05/13	10.3	8	258.74	0.58	150.07
22/05/13	10.3	8	258.74	0.54	139.72
24/05/13	10.3	8	258.74	0.56	144.89
26/05/13	10.3	8	258.74	0.58	150.07
28/05/13	10.3	8	258.74	0.60	155.24
30/05/13	10.3	8	258.74	0.84	217.34
1/6/2013	10.9	8.5	290.92	1.42	413.11
3/6/2013	10.9	8.5	290.92	1.60	465.47
4/6/2013	10.9	8.5	290.92	1.59	462.56
7/6/2013	10.9	8.5	290.92	1.74	506.20
9/6/2013	11.5	9	324.99	1.80	584.98
11/6/2013	11.5	9	324.99	1.81	588.23
13/6/2013	11.5	9	324.99	1.90	617.48
15/6/2013	11.5	9	324.99	1.92	623.98
18/06/13	12.1	9.5	360.94	1.95	703.84
21/06/13	12.1	9.5	360.94	1.98	714.67
22/06/13	12.1	9.5	360.94	2.10	757.98
24/06/13	12.1	9.5	360.94	2.00	721.89
27/06/13	11.5	9	324.99	1.90	617.48
29/06/13	11.5	9	324.99	1.91	620.73
2/7/2013	11.5	9	324.99	1.88	610.98
5/7/2013	11.5	9	324.99	1.89	614.23
8/7/2013	11.5	9	324.99	1.92	623.98
11/7/2013	11.5	9	324.99	1.89	614.23
13/07/13	11.5	9	324.99	1.88	610.98
15/07/13	11.5	9	324.99	1.86	604.48
17/07/13	11.5	9	324.99	1.85	601.23

Date of Observation	Radius (r_1)(m)	Radius (r_2)(m)	Area (m^2)	Height (m)	Volume (m^3)
19/07/13	11.5	9	324.99	1.87	607.73
23/07/13	11.5	9	324.99	1.90	617.48
25/07/13	11.5	9	324.99	1.95	633.73
27/07/13	12.1	9.5	360.94	2.12	765.20
30/07/13	11.5	9	324.99	1.93	627.23
3/8/2013	11.5	9	324.99	1.84	597.98
5/8/2013	11.5	9	324.99	1.82	591.48
7/8/2013	11.5	9	324.99	1.80	584.98
9/8/2013	11.5	9	324.99	1.68	545.98
12/08/13	10.9	8.5	290.92	1.57	456.75
15/08/13	10.9	8.5	290.92	1.56	453.84
17/08/13	10.9	8.5	290.92	1.55	450.93
19/8/13	10.9	8.5	290.92	1.42	413.11
21/8/13	10.9	8.5	290.92	1.30	378.20
23/8/13	10.9	8.5	290.92	1.30	378.20
25/8/13	10.9	8.5	290.92	1.28	372.38
27/8/13	10.9	8.5	290.92	1.27	369.47
1/9/2013	10.9	8.5	290.92	1.29	375.29
5/9/2013	10.9	8.5	290.92	1.46	424.74
7/9/2013	10.9	8.5	290.92	1.50	436.38
11/9/13	10.9	8.5	290.92	1.62	471.29
15/9/13	11.5	9	324.99	1.76	571.98
17/9/13	11.5	9	324.99	1.80	584.98
21/9/13	11.5	9	324.99	1.82	591.48
23/9/13	11.5	9	324.99	1.80	584.98
25/9/12	11.5	9	324.99	1.72	558.98
27/9/ 13	11.5	9	324.99	1.70	552.48
29/9/13	11.5	9	324.99	1.69	549.23

Physico-chemical properties of rain water harvested under different situations in lateritic soils

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Rain water harvesting is universally accepted as an important measure of water conservation throughout the world. The quality of irrigation water has become a more serious problem than quantity in different parts of the world. The characterization of quality of water is crucial for assessing the suitability for irrigation. Hence a study was taken up on "Physico-chemical properties of rain water harvested under different situations in lateritic soil" in the main campus of Kerala Agricultural University, Vellanikkara during September, 2012 to August 2013. The objective of the study was to compare the physico-chemical properties of rain water from different water sources in lateritic soil. Water was collected from five sources viz, rainfall (RF), rain water harvesting pond (RWH) , Kotteppadom pond (KP), well water (W) and surface runoff (SR). The experiment for surface runoff study was laid out in an area with a gentle slope between 5 – 10 per cent . Four rain pits were dug in this area with dimensions of 0.5 m x 0.5 m x 0.5 m and lined by polyethene sheet. Water samples were taken from these water sources for one year at monthly intervals and they were analyzed for various physico-chemical parameters such as colour, turbidity, pH, EC, TDS, COD, BOD, SAR, RSC, NO_3^-, Cl^- and Fe. The amount and distribution of rainfall received as well as the inflow to the rain water harvesting pond were also studied. Soil samples were collected from around rain-pits before and after rains and analyzed for the content of nutrients.

The total quantity of rainfall during the study period was 2872.0 mm. The maximum amount of rainfall was observed in June and the minimum in January, 2013. The amount of rain water harvested in pond during the study period was 625.48 m^3 which comes to 63 per cent of its storage capacity.

The quality of water from different sources was compared based on the results of physico-chemical analysis. It was found that pH was highest (6.69) for water from Kotteppadom pond during summer and lowest (5.54) for water from rainfall during post monsoon season. The EC and TDS values were maximum for well water during pre-monsoon season and there was significant difference among the different sources. There was no significant difference among the sources of water as regards the content of Cl^- and NO_3^- over the different seasons. The values for BOD and COD varied significantly over the different sources as also the seasons. Significant difference was observed for SAR and RSC values among the different sources and seasons.

Loss of nutrients from soil via surface runoff from a sloppy area was studied. Soil samples were analyzed for various physico-chemical parameters such as pH, EC, OC,

available N, P, K, Ca, Mg, Fe, BD, PD and WHC. The different parameters were estimated both before and after receipt of rainfall. The mean values of these parameters and percent changes along with t-value were found out. During summer, after the rains, there were significant changes for the parameters like pH, OC, as well as available nutrients like K, Ca, Mg, Fe, and the percentages of decrease were 1.67, 0.67, 37.94, 25.46, 5.62 and 8.85 respectively. The water holding capacity was also decreased by 4.80 per cent. During monsoon, available nutrients like N, P, K, and WHC decreased to the extent of 23.68, 26.24, 49.32 and 7.29 per cent respectively.

In general, it was found that the rainfall and rain water harvested in the water harvesting pond were superior to well water, KP pond water and surface run off water. Salinity was low for water from all the sources. Surface run off in an area with moderate slope (5-10 %) resulted in loss of nutrients like K, P, Mg and Ca.