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Phosphoric acid requirement for treatment of chemical clogging in drip irrigation system

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Abstract
Emitter clogging is a serious problem in drip irrigation system. Acid treatment is an effective method for rectification of clogging in which acid is injected in the system with irrigation water for lowering the pH of water. An experimental study was conducted to assess the amount of phosphoric acid to bring down the pH of water to the desired level of 4.0. Twenty two groundwater samples of pH varying from 7.22 to 8.53 were used. The amount of phosphoric acid required for 1000 litre of water varied from 43 ml for sample having initial pH 7.65 to 532 ml for sample having initial pH 8.43. The amount of acid required depends on initial pH and strength of acid used. The major factor governing the acid requirement was HCO_3^-content of water. Two polynomial equations were developed for estimating the amount of acid required for 1000 liters of water as a function of the initial pH and HCO_3^- content of water.

Keywords: Drip, clogging treatment, pH, irrigation water

Introduction

Drip irrigation refers to application of water in small quantity at the rate mostly less than 12 lph as drops to the root zone of the plants through a network of plastic pipes fitted with emitters. Drip irrigation is suitable for applying précised amount of water or fertilizers to the crop. Drip Irrigation prevents soil erosion, saves water and fertilizer can also supplied by it (Pooja *et al*. 2017) [9]. Drip irrigation method is a very efficient and economical method but it also has some disadvantages. The most difficult problem of drip irrigation system which users face is clogging of emitters can seriously interfere with uniform distribution of irrigation water and system-applied fertilizers. Non uniform application of water fertilizer may result in reduced yield and crop quality. In a study, it was revealed that even 5 to 20 % clogging of emitters greatly reduced the uniformity (Gontia *et al.,* 1998) [4].

Water quality is the main factor that causes plugging of emitter (Gilbert and Ford, 1986) [3]. There are various other factors such as microbial activity that leads to formation of algae cells which form aggregates and plug the emitters. The dripper suffers from clogging due to escape particles of quarts sand from the filters coursing ununiformed water supply that will greatly affect the quality of system service and increase the maintenance cost (Mohammed Ali 2016) [6]. As a result, emitter clogging is one of the key factors that determine whether drip irrigation systems can success (Qingsong *et al.,* 2008) [10]. Partial clogging caused by bio-film build-up and particles accumulated in the corners of torturous pathways is the main mechanism of emitter clogging (Cararo *et al*. 2006) [1]. Partial and total clogging of emitters is closely related to the quality of the irrigation water, and occurs as a result of multiple factors, including physical, biological and chemical agents (Mohammad AZ, 2015) [8]. The emitter clogging will be more if irrigation water contains excess amount of the ingredients as dissolved calcium, bicarbonates, iron, manganese and magnesium (Gilbert and Ford, 1986; Hills *et al*. 1989) [3, 5]. Therefore it is necessary to improve the design and manufacture of anti-clogging drip irrigation emitters (Mohammed Ali, 2010) [7]. Precipitation occurs frequently in water having high pH (more than 7.0). Hills *et al.* (1989) [5] concluded that water relatively high in multivalent cations, high pH and high temperature is contributive to chemical clogging and salt content in water is a critical factor in chemical clogging. Acid treatment is very effective in preventing and dissolving alkaline scales. To prevent precipitation of calcium and magnesium salts which appears as white film in the flow path of drippers, continuous injection of acid to maintain pH of 6.0 – 6.5 is adequate.

Phosphoric acid (H_3PO_4), sulfuric acid (H_2SO_4) and hydrochloric acid (HCL) can be used for treatment of chemical clogging in drip irrigation system. Phosphoric acid is also a fertilizer source, can be used to lower the pH of irrigation water. Phosphoric acid should be injected carefully in hard water as it may cause precipitation of calcium carbonates.

Diluted phosphoric acid should be used for injection in irrigation water. Dilution should be performed in a non-metal, acid-resistant mixing tank.

Material and methodology

Groundwater samples of different farms as received and tested in the soil and water testing lab of the Department of Soil Science were collected to determine the acid requirement for treatment of chemical clogging in drip irrigation system. Asper objective of study phosphoric acid solution of low concentration was prepared to lower the pH of groundwater samples to the target level. Phosphoric acid solution of 0.01 N was prepared from aqueous phosphoric acid (88% conc.). To bring down the pH of groundwater samples to the desired level, it was necessary to determine the amount of acid required. As different samples have different composition and pH, volume of acid used was also different.

Titration test was performed with 22 water samples to determine the volume of acid required to reduce pH of 40 ml water samples to the target level 4.0. Volume of acid required for pH reduction of irrigation water depends on pH, normality of acid solution used for titration and also on the initial and target pH level of water. A titration curve was prepared to determine the volume of acid required to bring down the pH upto target level for 1000 litre of irrigation water.

Volume of H_3PO_4 (88% conc.) required for 1000 litre of water was estimated as below:

$$V_{1000} = 21.21 \times N_p \times V_t / V_s$$

Where,

V_{1000} = Volume of H_3PO_4 (88% conc.) required for lowering pH of 1000 liter of irrigation water to the desired level, ml

N_p = normality of H_3PO_4 solution

V_t = volume of 0.01N H_3PO_4 solution used in titration, ml

V_s = volume of water sample used, ml

Result and Discussion

The pH and EC_e values of samples ranged from 7.22 to 8.53 and 292 to 42100 µS m^{-1} respectively. The effect of H_3PO_4 addition on the pH of water samples of different pH is shown in Fig.1-7. The volume of acid varied from 8.1 ml for water having pH 7.65 to 100.4 ml for water having pH 8.4.

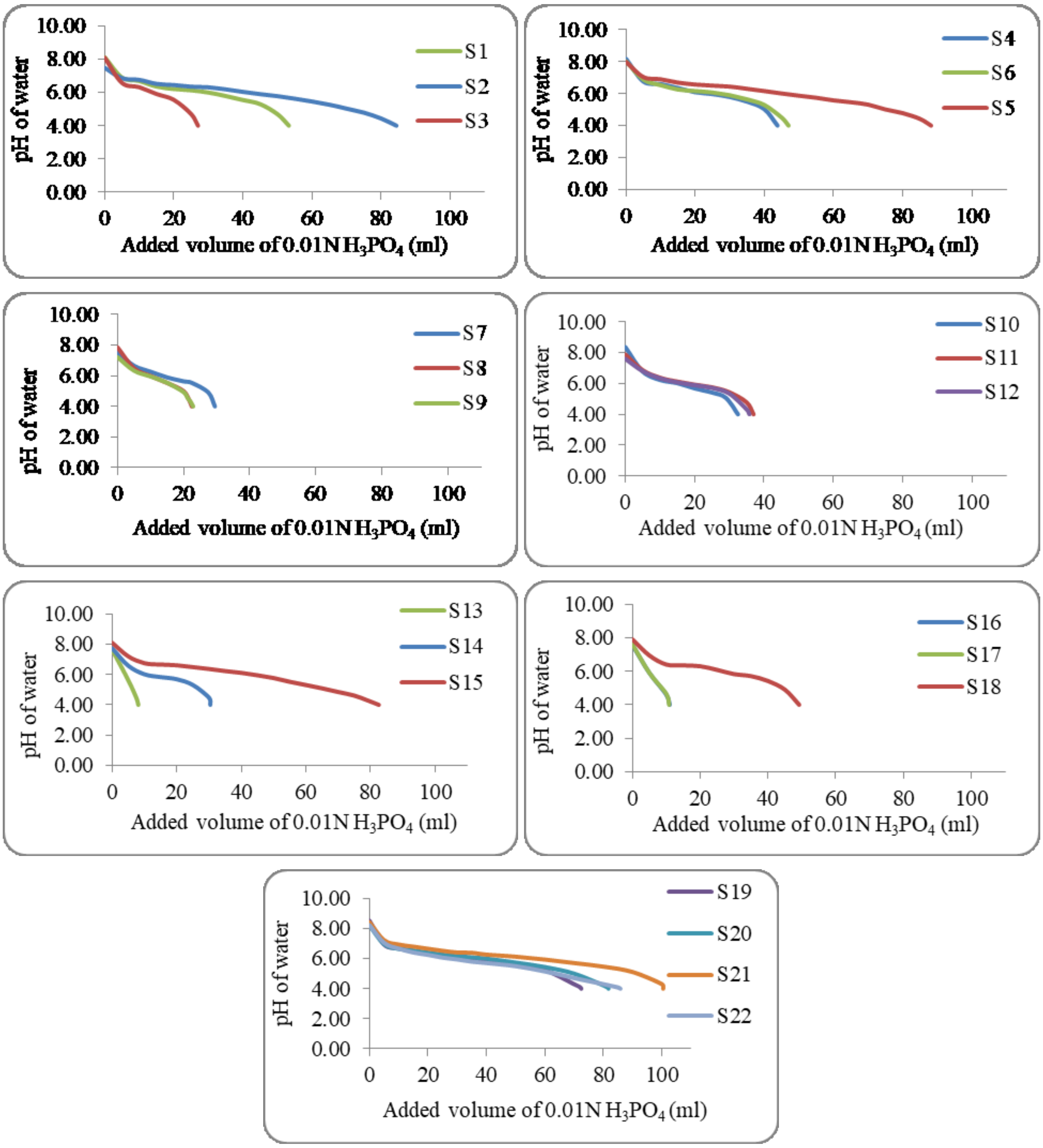

Fig 1-7: Effect of addition of H_3PO_4 (0.01N) on pH of 40 ml of different water samples.

In general the acid requirement increased with increase in initial pH of water sample, however, it was not true for all the samples. For sample S_{13} (pH = 7.65), the acid requirement was 8.1 ml while for sample S_9 (pH = 7.22) the acid requirement was 22.9 ml.

The estimated volume of H_3PO_4(88 % conc.) required as function of initial pH of water to lower pH of 1000 litre of water sample is shown in Fig. 8.

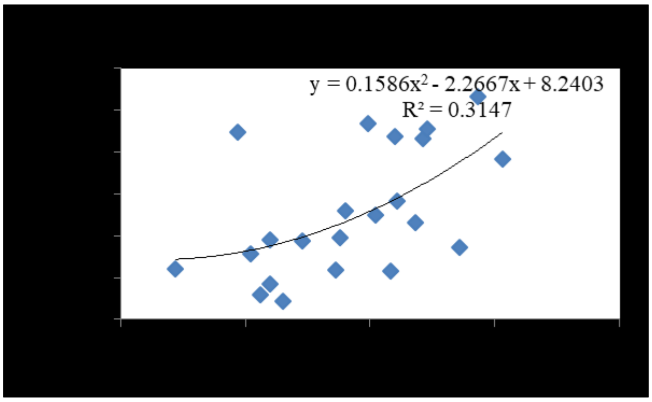

Fig 8: Relationship of H_3PO_4 requirement for 1000 litre of water with initial pH of water.

The following polynomial equation was fitted between amount of H_3PO_4 (88 % conc.) required for 1000 liters of water (y) and initial pH (x) of water sample:

$y = 0.1586x^2 - 2.2667x + 8.2403$

$R^2 = 0.315$

Low value of R^2 suggests that there are factors other than pH, which also influence the acid requirement.

A critical examination of Fig. 9 suggests that as HCO_3^- content in water increases amount of acid required also increases.

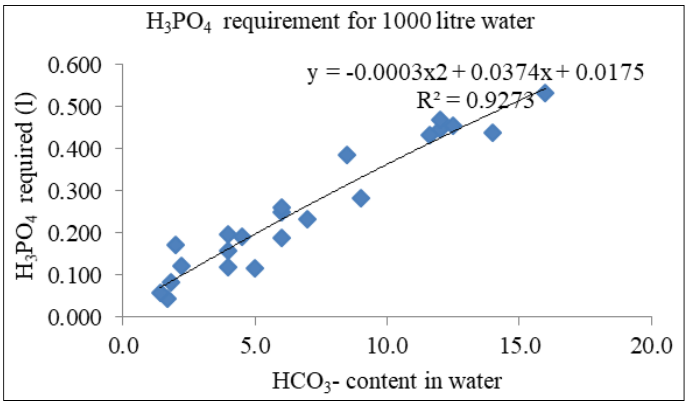

Fig 9: Effect of HCO_3^- content on acid requirement.

Higher value of R^2 for HCO_3^- as compared to pH suggests that HCO_3^- is more important than the initial pH of the sample in determining the H_3PO_4 requirement for lowering pH.

H_3PO_4 requirement predicted is shown in Fig. 10 and following relationship was developed:

$y = -0.19548 + 0.03188\ HCO_3^- + 0.029595\ pH$

$R^2 = 0.933$

Where y = predicted H_3PO_4 requirement

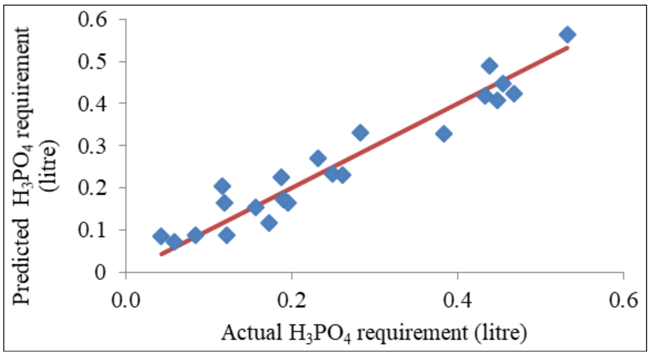

Fig 10: Comparison of predicted & actual acid requirement. Prediction is based on both pH & HCO_3^-.

Conclusions

The following conclusions were drawn from the study:

1. Acid requirement to lower down the pH of water to 4.0 depends on initial pH and HCO_3^- content of water but mainly on the HCO_3^- content of water.
2. The amount of H_3PO_4 (88% conc.) required to bring down the pH of 1000 litre of water ranged from 43 ml for water sample having the initial pH 7.65 & HCO_3^- = 1.7 to 532 ml for sample having pH 8.43 & HCO_3^- = 16.0.
3. On the basis of the polynomial equations a relation was developed to estimate the amount of H_3PO_4 (88% conc.) required to lower the pH of 1000 litre of water to the desired level (pH = 4.0) as a function of initial pH and HCO_3^- content of water.

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