Aerogation – An emerging technique

By

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DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

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DECLARATION

I, Minu Mariya Issac (2018-11-061) hereby declare that the seminar report entitled "Aerogation – An emerging technique" has been completed by me independently after going through references cited here and I haven't copied from any of the fellow students or previous seminar reports.

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20/01/2020 2018-11-061

CERTIFICATE

This is to certify that the seminar report entitled "Aerogation – An emerging technique" has been solely prepared by Minu Mariya Issac (2018-11-061), under my guidance and has not been copied from seminar reports of seniors, juniors or fellow students.

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CERTIFICATE

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1. Introduction

Subsurface drip irrigation (SDI) offers well-documented potential for improving water use efficiency in irrigated agriculture. However, SDI in common with other forms of irrigation is liable to exclude soil air (and therefore oxygen) around the root zone during and following irrigation events, thus reducing root function and crop performance. When SDI is practiced with aerogation (aerating the rhizosphere by way of the irrigation stream) it could transform the irrigation industry, for it provides a source of oxygen in a root environment that suffers from temporal hypoxia, and occasionally from anoxia. The oxygen is introduced into the irrigation stream by way of the venturi principle or with solutions of hydrogen peroxide.

Aerogation assures optimal root function, microbial activity, and mineral transformations, and leads to enhanced yield and water use efficiency under hypoxic conditions. It also improves plant performance and yield under irrigated conditions and offers scope to offset some of the negative impacts of compaction and salinity. The aeration status of irrigated soils deserves more attention than it has received in the past if we wish to unlock yield potential constrained by soil oxygen limitations.

2. Soil aeration

Soil aeration is a part of the gaseous cycle that involves the interchange of carbon dioxide and oxygen between living organisms, soil and the aerial atmosphere (Grable, 1996).

2.1. Composition of ideal soil

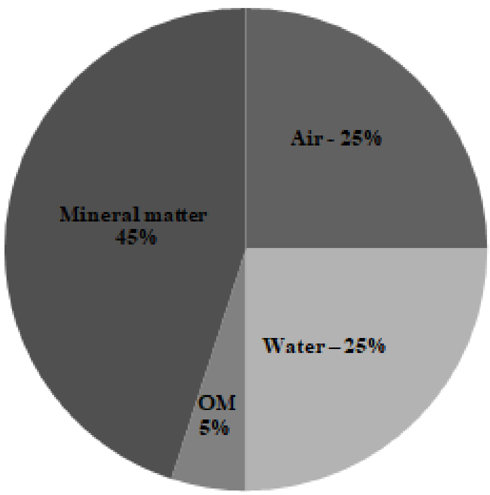


Figure 1. Composition of ideal soil

An ideal soil consists of 50% pore space and 50% solids. Out of 50% pore space 25 % each is occupied by water and air. In 50% solids, 45% is mineral matter(sand, silt and clay) and 5% is organic matter.

2.2. Major reasons for poor soil aeration

1. Excess moisture

When a soil is subjected to excess moisture, waterlogged condition is developed. This situation is generally found in poorly drained, fine textured soils having a minimum of macropores through which water can move very rapidly. It also occurs in well drained soils if the rate of water supply to the soil surface is sufficiently rapid.

2. Soil compaction

Soil compaction is the increase of bulk density or decrease in porosity of soil due to externally or internally applied loads. Compaction can adversely affect nearly all physical, chemical and biological properties and functions of soil. In agriculture it is mainly due to use of heavy machinery and livestock trampling.

2.3. Problems due to poor soil aeration

2.3.1. Reduced root respiration and restricted root growth

Poor soil aeration depress root respiration as a result root growth ceases

2.3.2. Poor absorption of water and nutrients

The permeability of root to water and ions under poor soil aeration is restricted

2.3.3. Aggravation of soil borne diseases

Due to high soil moisture, the soil borne pathogens like Pythium and Phytophthora cause diseases in plants

2.3.4. Nitrification decreases and denitrification increases

Nitrifying bacteria like Nitrosomonas, Nitrobacter requires oxygen for conversion of ammonia to nitrite. In case of poor soil aeration nitrification decreases and denitrification increases and loss of nitrogen happens. This will reduce Nitrogen Use Efficiency.

2.3.5. Reduced photosynthesis

Due to poor water absorption stomata gets closed and carbon dioxide concentration becomes reduced and results in reduced rate of photosynthesis.

3. Subsurface Drip Irrigation (SDI)

Subsurface Drip Irrigation is a low pressure high efficiency irrigation system that uses buried drip lines to deliever water directly beneath the root zone. Here the depth of laterals depends on the tillage practices and crop to be irrigated.

3.1 Components of SDI

As like the surface drip irrigation system all components are same. First main filter which is usually a screen filter which removes larger impurities. Then comes the chemical tank which is used to inject fertilisers or chemicals. After the tank there is secondary filter usually is sand filter to filter further impurities then main, submain, laterals and emitters fitted on laterals. In aerogation there will be an air injection unit in addition to this.

3.2. Advantages of SDI

3.2.1. Longer life

Since the drip lines are buried in the soil they are not directly influenced by the UV rays, temperature changes etc. Also lesser damage by animals and people.

3.2.2. High NUE and WUE

In this, the water along with the inputs like fertilizers are delievered directly beneath the root zone. It is efficiently utilized by the plant. Also high Water Use Efficiency (WUE) because surface run off and evaporation is prevented in this.

3.2.3. Less weed growth

Due to comparatively drier soil surface it prevents weed growth.

3.2.4. Higher yield

The water and nutrients are given directly beneath the root zone so healthy growth will be there and yield is increased.

4. Aerogation

It is the process of aerating irrigation water and employing Subsurface Drip Irrigation (SDI) to deliver it directly beneath the root zone. It is done by either mixing air or by mixing chemicals such as hydrogen peroxide with irrigation water.

4.1. Why aerogation in SDI???

SDI delievers water directly beneath the root zone and it develops a saturated front in the rhizosphere especially in heavy clay soils. Also the root mass is concentrated in small volume near the emitter. So any depletion in oxygen will adversely affect the plant growth. So inorder to provide sufficient oxygen aerogation can be done. Also when air injection alone is done in SDI it creates chimney effect which limits the area of oxygen diffusion.

5. Methods of aerogation

There are two different methods :

- Physical method - Mixing air
- Chemical method - Hydrogen peroxide

5.1 Physical method

This is done by mixing air at the rate of 12% by volume of irrigation water. In this method, the air injection unit is coupled in the pressurized irrigation line. The concentration of oxygen depends on the pressure differential between inlet and outlet ports of the injector.

Bhattarai *et al.*(2004) reported that in cotton and soybean the oxygen concentration of normal water is 3-8 mg/l and that of aerated water is 42 mg/l.

Figure 2. Air injection unit

5.2 Chemical method

In chemical method hydrogen peroxide is used. There are various uses of hydrogen peroxide as sanitizer, antiseptic and bleaching agent. Some studies have showed its potential to be used as source of oxygen for plants.H_2O_2 (50% v/v) is mixed at the rate of 1ml/L of irrigation water by using a chemical tank. When the oxygen concentration of aerated water was tested it was 10 times more than air injection and after 10 minutes it reduced to one-tenth of it in irrigation water.

H_2O_2 decomposition in soil

The decomposition of H_2O_2 in soil takes place by Catalase reaction or Haber Weiss reaction

Catalase

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Haber Weiss reaction – in presence of metal oxides

$$O_2^- + H_2O_2 \rightarrow OH\bullet + OH^- + O_2$$

6. Effects of aerogation

6.1. Soil respiration

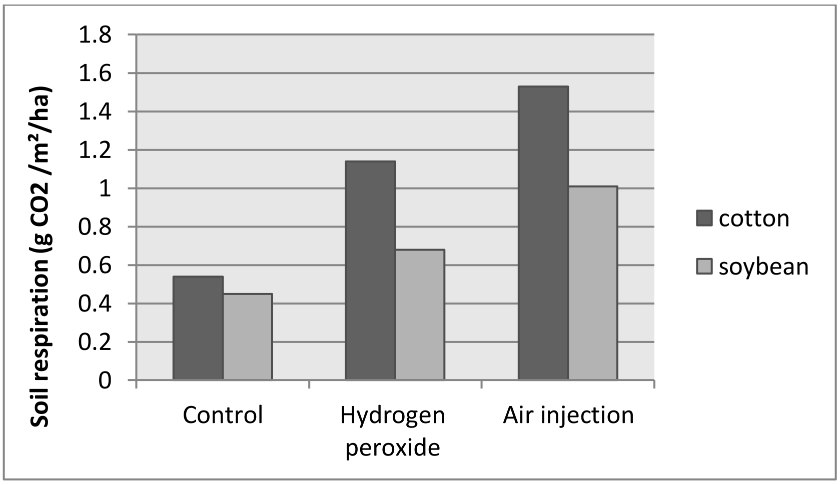
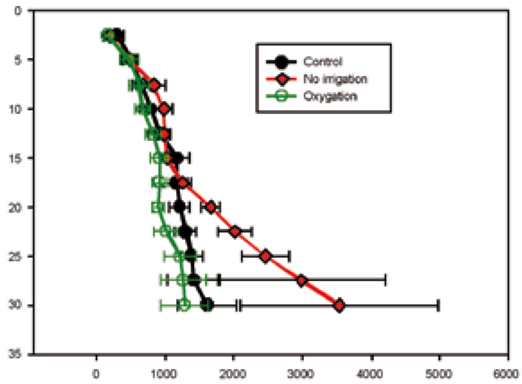


Figure 3. Effect on soil respiration in cotton and soybean

Soil respiration is the carbondioxide produced by the biological activity of soil organisms including plant roots and microbes. Also, soil respiration is affected by moisture and level of oxygen in the soil. In this study, there were three treatments and greater soil respiration was observed in aerated treatment compared to the control in both the crops. This could be due to the more availability of oxygen for respiration (Bhattarai *et al*., 2004).

6.2. Soil compaction



Soil resistance (Kpa)

Figure 4. Effect on soil compaction in pineapple

Soil compaction is the process in which when any stress is applied to a soil causes densification as air is displaced from the pores between the soil. The main negative effects to plants are reduced root growth and nutrient uptake. So by aerogation when we are supplying air it improves the air exchange, water infiltration and nutrient penetration.

In this experiment there were three treatments and the aerogation treatment reported lower soil penetration resistance down the soil profile which means aerogation has role in reducing soil resistance and thereby compaction (Dhungel *et al*.,2012)

6.3. Denitrification

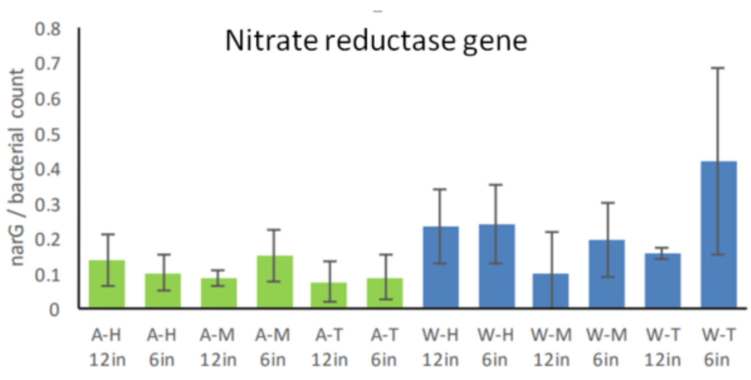


Figure 5. Quantification of *Nitrate reductase* gene

This experiment was conducted in a farmer's field which follows aerogation in the field for past five years and a field which was supplied only with water. Soil samples were collected from three different locations at two different depths. Then they quantified the genes encoding for the enzymes involved in denitrification. The result was that in the aerogated fields the amount of gene was less which indicates less loss of nitrogen through denitrification (Adrian *et al.,* 2016).

6.4. Effect on bulk density, root density and phytophthora incidence in pineapple

Treatment	Bulk density(g/m³)	Root density(kg/m³)	Phytophthora incidence (% plants)
Control	1.68	6.32	4.9
Aerogation	1.61	7.50	3.0

Table 1. Effect of bulk density, root density and phytophthora incidence in pineapple

Dhungel *et al*. (2012) reported that bulk density is slightly reduced in aerogation treatment although it was not significant but the rrot density was significantly higher and phytophthora incidence was also less in aerogation treatment. This phytophthora is a soil borne pathogen which refers damp conditions so due to aerogation the disease occurrence was less.

6.5. Root growth and function

In SDI root mass is concentrated in small volume compared to surface irrigation so any depletion in oxygen will adversely affect root growth and function. During oxygen availability there will be high root respiration, increased water and mineral absorption. The plants grown in well aerated soils have long fibrous and profusely branched with many root hairs (Abuarab *et al.*, 2012)

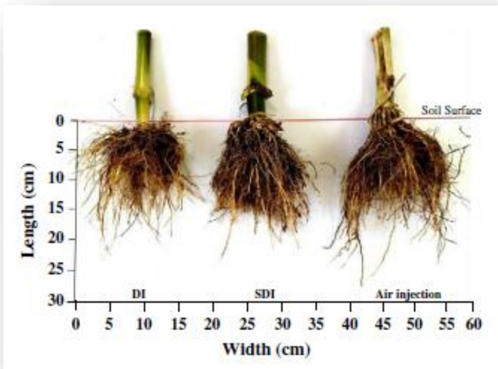


Figure 6. Root of maize

6.6. Water Use Efficiency

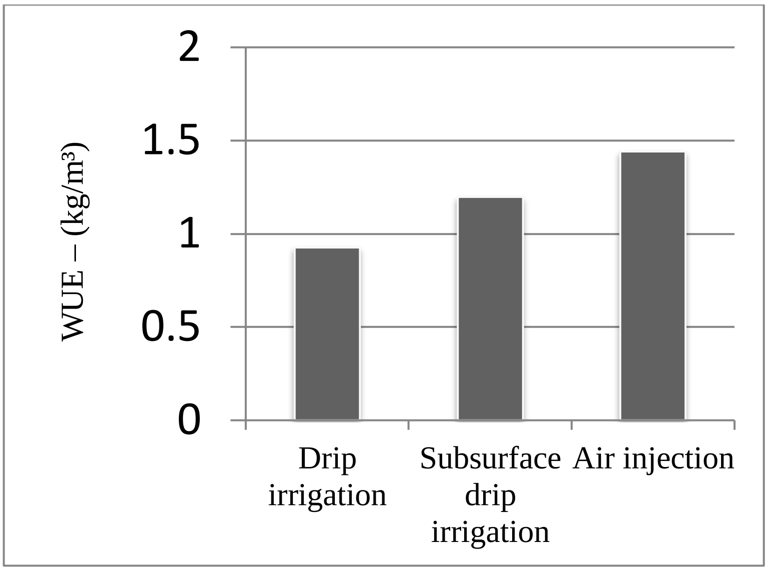


Figure 7. Effect on WUE in maize

Abuarab *et al.*(2012) reported highest WUE for the treatment SDI with air injection. This could be due to the more root growth and function and also the yield was also highest in the same.

6.7. Yield

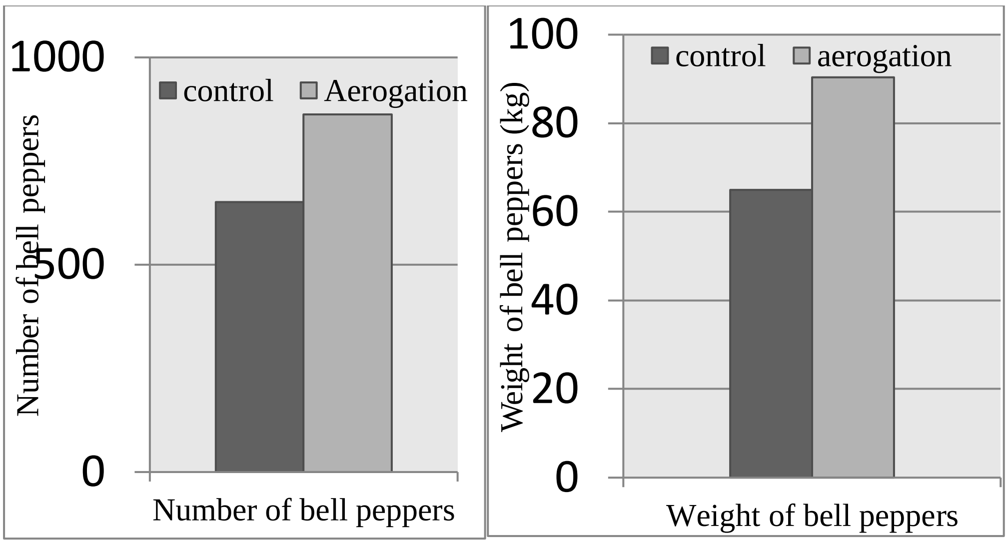


Figure 8. Effect on yield of bell pepper

Goorahoo *etal*. (2002) reported highest yield (both number and weight) of bell pepper in aerogation treatment compared to the control. This is due to more root growth and higher WUE.

6.7. Effect on photosynthesis

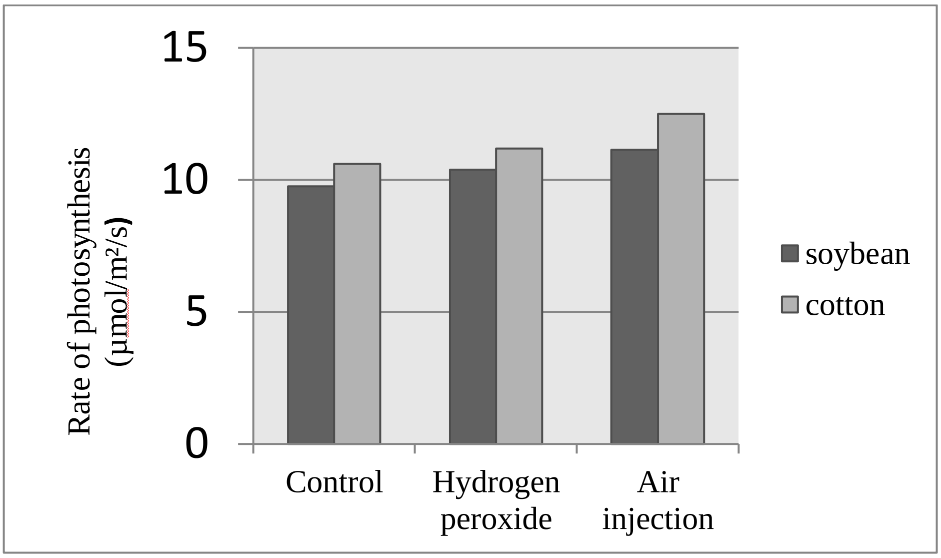


Figure 9. Effect on photosynthesis in cotton and soybean

Bhattarai *et al.*(2004) reported higher rate of photosynthesis for aerated plots when compared to the control plot. This is due to high WUE in aerated plots.

7. Applications of Aerogation

7.1. Saline/ Sodic soils

Saline soils are rich in chlorides and sulphates of . Due to the presence of salts in soil solution it reduces the ability of plant to take up water. When the aerated water is used for irrigation when it exerts pressure on the soil it enhances flushing of soil. Also enriches oxygen content in rhizosphere and thus plant tolerance to salt is enhanced.

7.2. Saline irrigation water

Saline irrigation water has electrical conductivity >0.7 dS/m. As plants extract the water salt will be deposited in the root zone. In aerogation, due to high efficiency SDI the volume of water used is less so the salt load is also less. Also in poor aeration condition there will be change in root membrane permeability and more uptake of Na+ and Cl^{-} will be there rather than K+ uptake. It causes harm to plants. If there is good aeration root membrane only allows K+ uptake and excludes Na+ and Cl¯ thus enhances tolerance to salt.

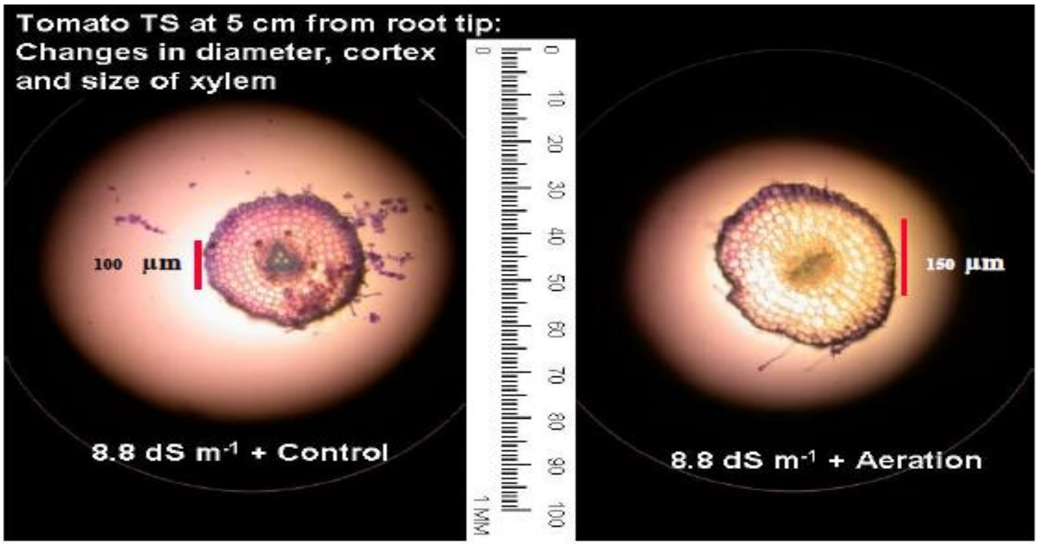


Figure 10. Transverse section of tomato root tip

8. Ways for improving aerogation efficiency

8.1. Irrigation types

Aerogation uses SDI for the delivery of aerated (venturi) or oxygenated (HP) water directly to the root zone. Root systems of crops irrigated with SDI are unique in that they concentrate around the emitter and differ markedly from the pattern of spread characteristic to furrow and other irrigation practices. As most of the root mass in SDI is close to emitters, and that root zone is temporally saturated, the benefits of aerogation are evident.

8.2. Soil type and line depth

Some large-scale irrigation installations have drip lines up to 800 m in length and uniform distribution of aerated water to the extremities could present a problem, as air may tend to escape from the emitters close to the source(Lamm *et al*., 1995).

8.3. Row length

Aerogation is effective in heavy clay soils. The depth of laterals depends on soil type and crop to be grown.

9. Conclusion

Root respiration is the driving force for most of the root metabolic activities that also directly control the aboveground crop performance. However, the supply of oxygen to ensure adequate root respiration is dependent upon the oxygen diffusion processes in the rhizosphere. Low oxygen concentrations in the root zone associated with salinity ,compaction, sodicity and irrigation in different soil types have been recognized as major bottlenecks for achievement of yield potential.To enhance crop yields in the future, limitations imposed on crops by the soil surface and profile that are associated with suboptimal supply of soil oxygen must be overcome before full advantage is taken of the inputs applied in the root zone.

10. References

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11. Discussion

1. What is the minimum pressure differential required for the suction of air through the suction port of the air injector?

The minimum pressure differential required for its operation is 15-20 Kpa

2. What is the relationship between soil penetration resistance and soil compaction?

Soil penetration resistance is a soil attribute that allows to identify areas with restrictions due to compaction, which results in mechanical impedence for root growth and crop yield. As soil compaction increases soil penetration resistance also increases.

3. Whether the same venturi injector can be used for fertiliser injection?

Yes, same can be used for fertiliser injection

4. What are the disadvantages of aerogation?

Aerogation is possible only in case of subsurface drip irrigation. But in case of subsurface drip irrigation it is difficult to take out the drip lines after each and every crop and lay back again.

5. Is there any harmful effects for plants while using hydrogen peroxide as a source of oxygen for plants?

No, till now no negative effects have been reported. The concentration used is 1ml/L of irrigation water

12. Abstract

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Agron. 591: Masters Seminar

Name : Minu Mariya Issac — Venue : Seminar Hall
Admission No: 2018-11- 061 — Date : 05-12-2019
Major advisor : Dr. Mini Abraham — Time : 10:45 am

Aerogation – An emerging technique

Abstract

Crop yield depends on a balanced combination of genotype, aerial environment, production inputs such as fertilizer and water, and the rhizosphere environment. Soil is a dynamic, three-phase (solid, liquid, gas) system. Effective soil aeration ensures sufficient oxygen diffusion into the root zone for optimal crop function. Low oxygen concentrations in the root zone associated with salinity/sodicity and compaction have been recognized as major bottlenecks for achievement of yield potential.

To overcome such problems, aerogation is emerging as an attractive alternate method. Aerogation is the process of aerating irrigation water and employing subsurface drip irrigation (SDI) to deliver water directly beneath the root zone. Hyper aerating irrigation water to increase the oxygen concentration is accomplished by either mixing air (12% by volume of irrigation water) or by mixing chemicals such as hydrogen peroxide with irrigation water before it is distributed through the irrigation lines (Bhattarai *et al*., 2005).

In soybean and cotton experiment in heavy clay soil, hydrogen peroxide (50% v/v) was mixed in the irrigation water at the rate of 1ml/L of irrigation water. This showed consistent yield benefits for both the crops (Bhattarai *et al*., 2004).

The positive effects of aerogation include increased root growth, soil respiration, photosynthesis, yield, water use efficiency, crop health and decreased soil compaction. Abuarab *et al.* (2013) reported higher yield and water use efficiency of corn in aerogation when compared to conventional drip irrigation and SDI. The negative impact of compaction, flooding and salinity/sodicity which reduce soil porosity and oxygen supply to the roots could

be offset by the use of aerogation. Dhungel *et al*. (2012) reported less soil compaction in the aerogation treatment compared to the control due to lower soil resistance recorded down the soil profile. Some of the ways to improve the aerogation efficiency include choosing suitable irrigation type, optimum row length and line depth.

Goorahoo *et al*. (2002) found that the concept of aerating the irrigation water increased the potential for air to travel with water movement within the root zone. Generally, the incorporation of aerogation in SDI system increased root zone aeration and could add value to grower investments.

To enhance crop yields in the future, limitations imposed on crops by the soil surface and profile that are associated with suboptimal supply of soil oxygen must be overcome before full advantage is taken of the inputs applied in the root zone.

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Abuarab, M., Mostafa, E., and Ibrahim, M. 2013. Effect of air injection under subsurface dripirrigation on yield and water use efficiency of corn in a sandy clay loam soil. *J.Adv.Res*. 4:493-499.

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