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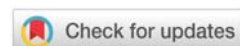
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## Review Article

# Negative effects of acid rains on agricultural areas

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## Abstract

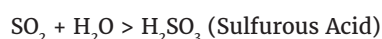
Due to the atmospheric pollution loads that started with the industrial revolution and have increased exponentially in the process that has come to the present day, the natural components of the atmosphere have been damaged and changed. One of the negative return points of this human-made degradation in the natural order is acid rain. Acid rains harm people directly and/or indirectly. One of the indirect effects is the negative effects on the food chain. Acid rains affect agricultural products, however, they affect the products from the soil. As a result, agricultural fields and agricultural products are damaged. The decreasing resources (water, etc.) with global warming and climate change also increase the negative impact on agricultural products. In this study, the negative effects of acid rain on agricultural areas were investigated and it was aimed to put forward the measures to reduce these negative effects.

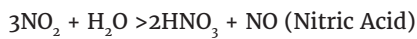
## Introduction

Throughout history, human beings have constantly engaged in activities based on increasing the comfort of life. With the effect of geographical discoveries and revolutions, human beings have also constantly developed and their needs have varied. The increase in population and consumption, especially in the process that started with the industrial revolution, has increased the use of natural resources and environmental pollution with a constantly increasing momentum.

In the world, which has become globalized with developments such as technology, population growth, and industrialization, human beings are ruthlessly destroying nature. The environmental problems that emerged as a result of this destruction have gained a global dimension to the same extent. Global warming and acid rain are just a few of the global environmental problems in question [1].

Unplanned urbanization due to rapid population growth, excessive use of fossil fuels for heating and energy purposes, emissions from heavy traffic, nitrogen oxides, sulfur dioxide, particulate matter and hydrocarbons formed as a result of volcanic activities and industrial activities, ammonia, chlorine, carbon dioxide, and methane gases, etc. used in industry other factors that can be considered pollute the air. Contaminants can remain suspended in the air for two days to seven days, react, and can be transported for kilometers under the influence of air movements. Harmful gases such as  $\text{SO}_x$  and  $\text{NO}_x$ , which emerge as the end product of combustion and mix into the air, combine with water molecules in the atmosphere and turn into sulfurous acid, sulfuric acid, and nitric acid. Rains containing these acids are called acid rains [2,3].





Acid rains falling on aquatic environments such as lakes, rivers, oceans, and terrestrial areas such as forests, settlements, and agricultural areas pollute the surface and groundwater, affect and even destroy many living species, and destroy agricultural areas, vegetation, and settlements [3].

The pH of normal rainwater varies between 5.5 and 5.6. The source of this pH value is the conversion of carbon dioxide in the atmosphere into carbonic acid by combining it with rainwater. Precipitation with an acidity value below the pH level of normal rainwater is acid rain [3,4].

When the reasons for the increase in acid rain are examined; It is seen that natural factors (Volcanic activities, oxygen-free decay in swamps, etc.) and human-induced factors (Ammonia resulting from the uncontrolled and excessive use of fertilizers to achieve high efficiency in agriculture,  $\text{SO}_x$  and  $\text{NO}_x$  resulting from the use of fossil fuels in industrial activities, thermal power plants and transportation) take place [4].

The biggest damage caused by acid rain to the soil is the solvent effect. Namely, with this effect, it dissolves and liberates the toxic substances in the soil and removes useful nutrients and minerals from the vegetation [4]. In this context, soil ecosystems and forests suffer greatly. It has been seen in a study on the damage done by acid rain to forests; The microbial activities of the soil, the fine roots of trees, and the rate of influence of the composition of forest species vary depending on the characteristics of the soil (Such as its capacity to bind acid) [5-7].

Depending on the nature of the soil, it can neutralize the acidity to a certain extent, but if it exceeds this capacity, the effectiveness of acid rain gains an increasing momentum [8].

The pH value of the soil is of vital importance in the nutrition of plants. At low pH, the transfer of some nutrients to the plant body increases so much that it leads to the poisoning of the plant. For example; As a result of the binding of aluminum ions, which are released by dissolving in the soil under the effect of acid rain, to the thin roots of the plants, the thin roots die by poisoning. Some nutrients such as calcium, magnesium, and potassium cannot be taken at low pH values, and this situation results in nutritional deficiencies in the plant [7].

We can collect acidic accumulation in the soil under 3 headings:

- **Wet Accumulation:** Transport by precipitation,
- **Dry Accumulation:** Transport of gases that cause acidity in the atmosphere to the soil by physical, chemical, and biological activities.
- **Hidden Accumulation:** Acidic water trapped in the clouds accumulates on the soil and vegetation as the cloud descends to the ground [9].

The effects of acid accumulation on agricultural products are not clearly known, but the impact of acid damage on forest

ecosystems is thought to be less serious. Lime and fertilizers used in agricultural activities generally reduce acid-induced effects on the soil [10].

Acid rains seriously damage the defense mechanisms of plant leaves, making plants vulnerable and directly suppressing leaf functions [11]. Acid rain damages the waxy cuticle membrane on both sides of the leaf, which ensures that the plant does not dry out as it provides water tightness and prevents evaporation [12].

Acid rains pass through the stomata of the leaves and cause an increase in the acidity of the cytoplasm, which maintains the water balance of the leaf. In trees and edible vegetables such as spinach and leek,  $\text{SO}_2$  closes the leaf surface and inhibits photosynthesis activity. As a result of this, the leaf that loses water dies in a short time [13]. Acid rains directly reduce the yield in agricultural activities and may even cause damage to the loss of the entire crop [14].

The effect of acid rain on leaves depends on two criteria: acid concentration and leaf exposure. In general, it is possible to physically detect the effect of acid rain on the leaves, such as brown spots in places and a change in the color of the leaf [14].

Acid rains negatively affect the chemical and morphological structure of the leaf, the pH balance of the cell, rubisco and nitrate reductase activity, carbon movements, chloroplast membrane, and conductivity in the stoma and mesophyll structure, resulting in decreased photosynthesis and thus yield and quality losses. Acids reaching the leaf surface of trees cause chlorosis and necrosis and adversely affect tree growth and development. As a result, bud growth decreases, leaves shrink, wither, and fall more quickly, the upper parts of the trees dry out and the age rings narrow [15,16].

When we look at the exposure rates to acid rain in the world, it is seen that China, North America, and Europe have the acid rain region in the first 3 places [17]. However, the country with the most scientific studies and publications on acid rain in China [16].

In many academic studies, the effect of acid rain on plants has generally been gathered under two main headings. While one of them is the investigation of the effects of acid rain on the leaf surfaces, the other is the structural deterioration/changes that occur in plants due to acid rains and the susceptibility of plants [16].

When we look at the research in general, it is seen that the researches on acid rain mostly focus on the effects of acid rain on water systems. In terms of the effects of acid rain on the terrestrial system, two more issues were focused on, namely agricultural products and forest ecosystems [18].

When evaluating the effect of acid rain on agricultural areas, it is necessary to look at both sides. Because pesticides used in agricultural areas and pollution loads spread through transportation activities are among the factors that cause acid rain [19].

Reducing the negative effects of acid rain on agricultural lands becomes possible with soils that are carefully cultivated from year to year (Such as supplementing with lime). Apart from this, acidity occurs in the soil exposed to acid rain in the long term, which reduces crop yield [18].

Considering the effects of air pollution on agricultural products, it can be concluded that ozone and  $\text{SO}_x$  are bigger problems for farmers than acid rain. Another approach is that acid rains can have a beneficial effect on some agricultural areas. As a justification for this view, it is seen that acid rains provide natural fertilizer and neutralize alkaline soil [18]. It has been seen in studies that acid rain can be said to be beneficial according to the pH value of the plant or the damage to the plant [20].

Although studies on the effects of acid rain on plants generally concentrate on tissue damage and physical effects, studies have also observed the relationship between acid rain and plant parasites [21].

Although the acid rain problem in Turkey is not experienced on a European scale, acid rain damages are encountered in the regions with significant sulfur dioxide emissions such as Murgul, Ergani, Yatağan, Elbistan, and especially in the northwestern parts, which are under the influence of precipitation from Europe. Turkey's rains are not as acidic as in Europe, and the geological structure is not sensitive to acid rain in most regions. In Turkey, calcareous soils that can neutralize the acid in the pouring rain are abundant [22].

Academic studies investigating the effects of acid rain on agricultural products have been compiled in the literature, and some noteworthy notes from these studies are given below.

In a study conducted on a number of different plants by exposure to simulated acid rain at different pH values (5.7, 3.4, 3.1, 2.9, 2.7, 2.5 and 2.3), it was determined that the most sensitive species in our country was the eagle fern (*Pteridium aquilinum*) has been done. When this plant was exposed to simulated acid rain for 10 days for 20 minutes a day at pH 2.5, approximately 10% of the leaf area was injured [23].

China is a largely agricultural country and rice production has an important place in Chinese agriculture [17]. Studies on acid rain in China seem to focus on rice.

It has been determined that some diseases that damage the product in rice production decrease in proportion to the acid rain index [17].

Again, in a study conducted in China; the changes in yield and product structure in corn production were investigated at different pH values caused by the cadmium ( $\text{Cd}^{2+}$ ) concentration in the soil and the effect of acid rain. With the effect of acid rain,  $\text{Cd}^{2+}$  is released into the soil and its density increases. In the results of working;

- It was observed that the germination percentage of corn seeds increased significantly and the plant root and height length increased when the  $\text{Cd}^{2+}$  concentration was between 0 mg/L - 10 mg/L.

- When the  $\text{Cd}^{2+}$  concentration is between 10 mg/L - 50 mg/L, the percentage of seed germination does not change significantly, but the root and height are significantly reduced, and the leaves are shorter and yellow [24].

In another study; it has been observed that silicon (Si) has a significant effect on reducing environmental stress in rice. It has been studied that silicon can reduce the stress caused by acid rain and the effect of rice in simulated acid rain at certain silicon concentrations and different pHs have been investigated. It has been determined that the use of low and medium-density silicon and the growth of rice roots increase at pH 4.0 and harmful effects are observed at high silicon concentration and pH 2.0 [25].

Again, a study on rice; showed that various lanthanum (LaIII) concentrations significantly improved the efficacy and retention of phytolith in germinated rice. While this adhesion is supported at pH 4.5, it has been determined that phytolith retention is inhibited at pH 3.5 with the effect of acid rain [26].

In a study on tomatoes; Physiological and biochemical changes in tomatoes due to acid rain; Loss of nutrients from the leaves, deterioration of the water balance of the plant, and changes in antioxidant enzymes. In this study, it was revealed that exogenous melatonin in tomatoes increased the tolerance against acid rain stress by reducing the destructive effect of acid rain [27,28].

Soy, alfalfa, and spinach have been shown to be more sensitive to the effects of acid rain than other crops. But crops like green peppers and onions grow better in acidic conditions [15,29].

## Discussions and conclusions

The primary way to reduce the effects of acid rain is to take measures to reduce the factors that cause acid rain. Some of these measures are:

1. Thermal power plants using fossil fuels should be as far from each other as possible and a desulphurization unit using the latest technology should be installed in their chimneys.
2. The amount of  $\text{SO}_2$  mixed into the atmosphere should be reduced by using fuels with low sulfur values.
3. Instead of fossil fuel energy sources, clean energy sources using wind and solar energy should be used.
4. The public should be encouraged to prefer public transportation instead of private vehicles in urban transportation.

In this study, the negative effects of acid rain on agricultural areas were investigated. In the literature review, it was seen that the studies focused on the effects of air pollution, which is the more general definition. There are not many studies on this subject in our country. Countries with a lot of studies stand out as countries with more exposure to acid rain, such as China and America.



Although we have geographical and topographic advantages as a country, it is considered that we should also focus on this issue in a world where the effects of global warming and climate change are increasing day by day.

From another point of view, it has been observed that there is almost no research in the literature on the direct damage of the acid effect on plants and soil by dew. It is considered that investigating the harm of acid effect by dew can be a good study subject.

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