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Water Pollution: Water-Borne Plant Viruses

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virus, transmission, water-borne virus, water pollution

ABSTRACT
The water is the most critical factor for survival of all organisms. Vitality of plants depends on existence of water as it is the case for humans and animals. Cleanness and healthiness of water used for plants is as important as cleanness of water used for human health. Many microorganisms may be found in different water sources and cause microbial pollution. Viruses also important water polluting agents. However, when compared with human health, viruses causing infection in plants are of secondary importance and many different plant pathogenic viruses can be found in different water sources and may be carried by water. Therefore, water utilized for agricultural and irrigation purposes should be clean and and pathogen free. So, certain precautions are needed to be taken in order to eliminate infection sources of plant pathogenic viruses. This article discusses pollutions created by plant pathogenic viruses in different water sources, detection and identification of water-borne viruses, and hygienic characteristics of nutrient solutions used particularly for hydroponic culture and emphasizes control measures against possible infections.

Su Kirliliği: Su İle Taşınabilen Bitki Virüsleri

Anahtar Kelimeler
virüs, taşınma, su kaynaklı virüs, su kirliliği

ÖZET
Su, canlı yaşamının devamlılığı için vazgeçilmez ve en önemli unsurudur. İnsan ve hayvanlar kadar bitki canlılığı da suyun varlığına bağlıdır. İnsan sağlığında kullanılan suyun temizliği ne kadar önemliyse bitkiler içinde kullanılan suyun temiz ve sağlıklı olması son derece önem arz etmektedir. Farklı su kaynaklarında birçok mikroorganizma bulunabilmekte ve mikrobial kirliliğe yol açabilmektedir. Bunlar arasında virüsler önemli bir yer işgal etmektedir. Ancak, insan sağlığı ile kıyaslanınca, bitkilerde enfeksiyon yapan virüsler ikinci planda kalmakla birlikte, çok sayıda bitki patojeni virüs farklı su kaynaklarında bulunmakta ve sulama suyu ile taşınabilmektedir. Bu nedenle tarımda, sulamada kullanılan suyun bitki patojenleri yönünden temiz ve kaliteli olması son derece önemlidir. Bunun için de bitki patojeni virüslerin enfeksiyon kaynaklarını ortadan kaldırıcı bazı ön tedbirlerin alınması gerekmektedir. Bu makalede, bitki patojeni virüslerin farklı su kaynaklarında oluşturduğu kirlilik, suda teşhis metodları ve tarımda kullanılması gereken sulama suyu ve özellikle hidroponic kültürde kullanılan besin solüsyonların hijyenik özellikleri tartışılmaktadır. Buna ilave olarak, insan sağlığında içme suyunda olduğu gibi, bitki virüslerinin enfeksiyon kaynaklarından birisini oluşturan sulama suyuna dikkat çekilerek, oluşabilecek enfeksiyonlara karşı önlem alınması gerektiği vurgulanmıştır.

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1. Introduction

Global warming, drought and water pollution are the most concentrated issues at water quality management. Studies implemented up to today mainly have been about issues that may impact human health and covered hygienic procedures in different water sources including particularly drinking water [1, 2, 3, 4, 5, 6, 7]. Water-borne human pathogenic viruses attracted attention of researchers and clinicians . Environmental virology has been initiated about 50 years ago through studies regarding identification of polioviruses being a member of enterovirus in sewages [8]. Studies have been implemented about microbial pollution i sea [9, 10], lake, river [10, 11, 13, 13], source [14, 15] and drinking water [16, 17, 18, 19], marina [20, 21], swimming pools [22] in order to highlight water-borne diseases on human health. However, water-borne plant pathogenic microorganisms did not take that much attention. Factors, such as indirect impact of plant pathogens on human health or their insignificant impact and nonexistence of sensitive diagnosis methods cause lack of interest in this issue [23, 24, 25]. However, some studies have been carried out about impacts of plant pathogenic viruses in environmental waters. Plant pathogen viruses have been detected in sea, lake, river, stream, irrigation and drainage waters, underground water and spring waters [26].

Existence of viruses in environmental waters is important for causing water pollution and dissemination of viruses among agricultural areas [27, 28, 29, 30]. Accurate and precise controls should be applied on field and greenhouse irrigation water [31] and waters utilized soilless agriculture and nutrient solutions used in hydroponic systems [25, 32]. Otherwise, contaminated waters could be a source of infection for plant diseases and cause yield loss. In case of existence of a virus in waters, it infects plant through root system of plant as a result of which disease symptoms occurs. In addition, some viruses can pass to drainage water and accordingly, cause diseases in other crops [23, 29, 31]. Viruses can be carried to distant areas by means of rivers and streams [23, 24, 27, 33, 34, 35, 36] and even drinking waters can be contaminated by viruses. Rapid, accurate and precise diagnostic methods should be used to identify and detect plant viruses in waters.

This article highlights the importance and detection of water-borne plant pathogenic viruses that has not been emphasized as much as other water pollutants, and their transmission by irrigation water, drainage water and particularly, nutrient solutions used in hydroponic culture.

2. Transmission of Plant Viruses by Means of Water

When compared with other pathogens, transmission of plant viruses by water and their existence within water have not been considered and studies regarding this issue have been applied in limited number. However, some studies have been applied regarding this issue, since detection of many plant pathogen viruses exist in waters. For example, 26 plant viruses have been detected within 47 water samples collected from environment in a study applied in Hungary [24]. Studies put forth existence of plant pathogen viruses in seas [37, 38], rivers and streams [35], lakes [27, 36, 39, 40], irrigation waters [39, 41, 42, 43] and drainage waters [23, 31, 44], underground waters, well and spring waters [26].

Many human activities play essential role in dissemination of plant viral factors and creation of problems by diseases. Other factor being important in dissemination of diseases is utilization of inappropriate water during irrigation [26]. Water used during plant growing should be clean and in good quality. Particularly, important problems may be caused when pathogen contaminated water is used as circular in greenhouses [45]. Different researchers have identified that viruses are transmitted to agricultural areas by means of water in different countries. *Tobacco mosaic virus* (TMV) and *Cucumber mosaic virus* (CMV) have been identified in water samples collected from rivers used as irrigation water in agricultural areas of Yugoslavia [35] and Italy [39]. Another study established for identification of *Tobacco mosaic virus* (TMV) and *Tomato mosaic virus* (ToMV) in water samples taken both from irrigation channels and streams [42, 43]. *Carnation ringspot virus* (CRV) was identified in water channels [41], whereas *Tobacco necrosis virus* (TNV) and *Tomato bushy stunt virus* (TBSV) were determined in river water [33]. It has been reported that existence of many plant pathogenic viruses is possible in waters reused in agricultural areas, such as *Arabis mosaic virus* (ArMV), *Cucumber green mild mottle virus* (CGMMV), *Pelargonium leaf curl virus* (PLCV), *Tomato spotted wilt virus* (TSWV) TMV, ToMV, TNV and CMV [46]. In a study, samples

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have been collected from different water sources in Ankara. Existence of *Alfalfa mosaic virus* (AMV), *Tomato black ring virus* (TBRV), *Watermelon mosaic virus-2* (WMV-2), *Zucchini yellow mosaic virus* (ZYMV), CMV has been detected in collected samples [27]. In another study, water samples have been collected from gravel pits being close to rivers, agricultural areas and water tanks of ToMV-infested greenhouses and contaminated greenhouse soils in Slovenia between 2004 and 2006. ToMV detected by using many different methods . Double antibody sandwich- enzyme-linked immunosorbent assay **(**DAS-ELISA**),** electron microscopy and real-time polymerase chain reaction (PCR) have been applied on collected water samples. In addition, concentration of ToMV in plants watered with clean water was lower than plants watered with wastewater [30].

Transmission of viruses by means of water and especially plant viruses carried with soil-borne fungus are frequently observed mainly in hydroponic culture [29]. To illustrate, it is reported that *Melon necrotic spot virus* (MNSV) is transmitted through irrigation water and nutrient solutions in hydroponic culture [25, 32]. As MNSV is carried with aquatic zoospores of *Olpidium bornovanus*, it is observed in higher amounts within plant growing systems in water. MNSV particles are stable; can remain in soils and infected plant wastes for many years and can pass to soil as a result of normal irrigation water or floods occurring due to hard rainfalls and can pollute other areas. Being soil-borne virus and transmitted by same fungus species (*O. bornovanus*), *Cucumber leaf spot virus* (CLSV) is also detected in drainage water of cucumber greenhouses. This was the first study proving that CLSV is a water-borne virus and can disseminate with irrigation system in greenhouses. Water circulation in greenhouses causes rapid dissemination of these viruses [29].

Some viruses can pass into drainage waters through plant roots. For instance, TMV and TNV viruses can pass into water in case of injury, decay or drying in roots. In addition, some viruses such as *Cucumber necrosis virus* (CNV), *Southern bean mosaic virus* (SBMV), *Petunia asteroid mosaic* (PetAMV), *Carnation ringspot virus* (CRV), TBSV and TNV have been detected within drainage waters [23, 44]. Particularly, many plant pathogenic viruses, such as TBSV [34, 36], CRV [48], *Grapevine Algerian latent virus* (GALV) [49], *Pelargonium leaf curl virus* (PLCV) [46], *Lettuce necrotic stunt virus* (LNSV) [50], PetAMV and *Cymbidium ringspot virus* (CymRSV) [28] included within Tombusvirus group have been isolated from water sources.

Plant viruses can disseminate with water directly or by transmission of soil-borne vectors with water accompanied with viruses indirectly. For example, a study applied in Amasya region of Turkey exhibited that regions being rich in terms of river, stream and water channels including branches of Yesilirmak River contains higher rates of *Beet necrotic yellow vein virus* (BNYVV) that can be carried by means of soil-borne fungal vector (*Polymyxa betae*) [51].. Virus contamination rate was also found to be higher in soil samples in regions having intense river, stream and water channels when compared to other regions [51]. It is reported that surface flows occurring due to hard rainfalls and flooding method may cause easier dissemination of vector fungus and accordingly viruses [31].

Requirement regarding more effective utilization of water sources has been well understood. One of these approaches is re-usage of wastewaters for agricultural purposes [52]. However, this approach provides advantage in terms re-valuation of these scarce sources, but brings many adverse conditions. Usage of wastewater for irrigation purposes may compromise human and plant health against virus, bacteria and other pathogenic infections. Diseases to be occurred due to transmission of pathogens with water can affect farmers as a result of direct physical contact and may occur as a result of consumption of crops watered with wastewaters or contamination of underground and surface waters with pathogens [53, 54]. It is important to use clean irrigation water that does not contain microorganism especially for vegetables consumed raw and particularly when leaves are consumed. Therefore, measures preventing pathogen contamination of vegetables watered with drainage water and water contaminated with wastes should be taken [55, 56].

Studies highlighted that virus concentration is extremely low in water samples [23, 25]. However, possibility of viruses to cause infection is high and concentration is increased by reproduction of viruses in infected plants as plants can remain within waters contaminated with viruses during a few months in accordance with their developmental period. Some problems arise in terms of diagnosis methods when concentration of viruses is low in water samples.

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Therefore, precise, effective and rapid methods should be used to detect plant pathogenic viruses in these samples [25, 30].

3. Detection Methods of Viruses in Water

While DAS-ELISA method has widespread application area regarding diagnosis of plant viruses in the past years [57], more precise methods that can identify viruses in quantity have been developed in recent years. In order to determine some plant viruses having low concentration in environmental waters, specific real-time PCR has been developed. Real-time PCR method has been utilized to identify enterovirus in sewages [1], asteroviruses in drainages [58] and adenovirus in rivers and seawaters [10, 11, 12, 13, 59], swimming pools [22] and drinking water supplies [18, 19]. Besides, real-time PCR method has been developed to identify many plant viruses such as *Potato mop-top virus, Tobacco rattle virus* [60], *Tomato spotted wilt virus* [61], *Barley yellow mosaic virus* [62], *Cauliflower mosaic virus* [63], *Cucumber vein yellowing virus* [64], *Plum pox virus* [65, 66, 67, 68] and *Cucumber green mottle mosaic virus* [69] in different parts of plants.

RT real-time PCR is used to identify many plant viruses, as well as determination of ToMV that can be carried with irrigation water. Real-time PCR is five times more sensitive than serological tests to detect ToMV which is in low concentration, [30]. Compared to ELISA, PCR method is found to be more sensitive, for detection of viruses [62, 66]. Water samples used for irrigation purposes can be analyzed and active viruses can be detected. In addition to application of this method to detect plant viruses in various water sources, utilization of this method as a a model system for detection of other human and animal viruses is also highlighted.

Low concentration is the prioritized problem for identification of viruses. Concentration of viruses in waters may be extremely low [25]. However, low concentration viruses have the capability to infect plants [23, 24, 70]. Certain procedures have been developed to detect low concentration viruses in waters. Different researchers have utilized PEG precipitation, Pro-cipitate precipitation, spin column chromatography and ultra filtration procedures to detect low concentrated viruses in waters [57].

Mainly diagnosis methods based on PEG application [71] which is used for detection of enteric viruses in waters have been adopted to detect viruses in nutrient solutions used as circular in hydroponic culture [25]. Diagnosis can be applied to detect plant viruses existing in highly diluted conditions in water samples by precipitation provided through ultracentrifuge [29] or PEG after appropriate virus concentration is obtained [58].

A new chromatographical media called as Convective Interaction Media (CIM) disk monolithic columns is developed for detection of plant viruses which is able to increase concentration to achieve detection. Concentration of ToMV has been increased by means of this newly developed CIM monolithic chromatographic media and it has been set forth that CIM-ELISA method could be successfully applied to identify ToMV in irrigation samples. Besides, it has been emphasized that CIM disk monolithic columns could be used effectively to increase concentration of other plant pathogenic viruses [57]

4. Conclusion

Requirements regarding effective usage of water sources being scare in today's world are better understood. One of the most important requirements for effective utilization of water is displaying same sensitiveness for plant health as done for human health. Studies have been implemented worldwide by different researchers about microbial pollution issues created due to viruses in different water sources (see, lake, river, stream, source, underground, drinking, irrigation and drainage). Both human and plant pathogenic viruses have been detected in different water sources.

Challenging to plant virus diseases is extremely difficult. Therefore, precautions are required particularly regarding prevention of virus diseases at agricultural areas. This may be achieved by elimination of viruses, and environmental factors that possibly cause infection. One of the most widespread infection sources of viruses is utilization of contaminated irrigation water some precautions are required to be taken to prevent transmission of plant viruses by water. Irrigation water should be clean and healthy in order to get healthy growing plants, . Particularly, pathogen contaminated water may create serious problems, if used as circular in greenhouses.

Certain precautions may be taken into consideration in production areas such as drip irrigation method is used instead of flooding method or irrigation of furrows independently or cleanness of water tank and water reservoirs used for irrigation purposes. Some studies proved that application of hypochlorite to the water used as circular at greenhouses could minimize dissemination of some viruses. Particularly, irrigation water and nutrient solutions used at hydroponic culture systems should be clean. Therefore, effective diagnostic methods should be used that may detect plant viruses in water sources.

Many plant pathogenic viruses can be conveyed by irrigation water without vector and infect roots. Despite their limited number, they can create epidemics through root infections.. As a result, laboratory analysis should be implemented regarding existence of dangerous microorganisms that may be found in the waters utilized as circular at greenhouses and conveyance by means of irrigation water should be considered during epidemiological studies.

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