Current Trends in Natural Sciences
Vol. 14, Issue 28, pp. 80-88, 2025
https://doi.org/10.47068/ctns.2025.v14i28.007
Current Trends in Natural Sciences (on-line)
ISSN: 2284-953X
ISSN-L: 2284-9521
Current Trends in Natural Sciences (CD-Rom)
ISSN: 2284-9521
ISSN-L: 2284-9521

PLANT ACTIVATORS AND SUSTAINABILITY OF FIELD CROPS

Onur Okumuş [1], Neslihan Doruk Kahraman [2], Ali Kahraman [2,*]

[1] Erciyes University, Faculty of Agriculture, Department of Field Crops, Kayseri, Turkiye
[2] Selcuk University, Faculty of Agriculture, Department of Field Crops, Konya, Turkiye

Abstract
Human existence depends on a healthy environment and food. Today, agricultural production models based on sustainability have gained importance due to the gradual decrease in resources, the extinction of some living beings, inadequate and unbalanced nutrition, and the emergence of hunger problems. Agricultural control methods are used to protect products from damage that diseases and pests may cause. In this context, agricultural control is a kind of insurance for agricultural areas. Producers and consumers who are aware of sustainable life in a balanced ecosystem have started to prefer the produce and consuming of agricultural based products which are produced with the methods no destroying of nature besides no toxic effects on humans. Based on the sustainability goal, the introduction of biologically sourced plant activators in plant production systems is important in terms of creating an alternative for using of the chemicals inputs in agricultural production. In today's conditions, where environmentally friendly applications are needed more, comprehensive research is needed in line with the principles of sustainability by focusing on studies conducted with plant activators. In this study prepared with these basic justifications, studies conducted on plant activators are examined and the basic concept of sustainability is emphasized.

Keywords: Field crops, sustainability agriculture, PGPR.

1. INTRODUCTION

Despite this increase in agriculture, the problem of hunger continues today. This problem is caused by the imbalance in food distribution rather than the lack of production in the world. Input use in agricultural production today is the cornerstone of increasing unit area productivity. One of the most important of these inputs is pesticides used in chemical control. One of the most important factors that jeopardize food safety is the chemicals used against plant diseases and pests that reduce yield and quality during production. Thanks to the substances presented under the name of "Plant activators", which is a new approach in plant protection and cultivation, it is aimed to strengthen the plant defense mechanism and grow plants healthily from planting to harvest.
It is expected that plants will need more water as the average temperature increases in the coming decades due to changing climate factors (Grant et al., 2012; Feng and Fu, 2013; Klamkowski et al., 2015). Unconscious and excessive use of chemicals for sufficient food production due to population growth causes water and air pollution, decrease in soil fertility and harm to health (Hossain et al., 2003). Plants are constantly stimulated by biotic and abiotic factors locally and systemically in the environments they are located in (Dangl and Jones, 2001). All technologies developed for

*Corresponding author, E-mail address: kahramanali@selcuk.edu.tr

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agricultural production should be economically feasible, ecologically harmless, environmentally safe and socially acceptable (Huang and Hsu, 2003).
Substances that activate the natural defense system and provide stimulation when applied externally are called plant activators and were first introduced in the early 19th century (Vallad and Goodman, 2004). The unconscious use of chemical substances in agricultural production can directly affect human health, as well as the leakage of these chemicals into water resources and their accumulation in the soil, negatively affecting all living things and disrupting the ecological balance (FAO, 2019). Activators activate the SAR (Systemic Acquired Resistance) mechanism as a defense mechanism against pathogen attack in the plant. The activation of this mechanism was first reported in tobacco and *Arabidopsis thaliana* plants (Yasuda, 2008). On the other hand, phytoalexins are not the only defense mechanism that plants have. Plants use the spreading microorganisms, lignin-type compounds, callose, silicon, cellulose, and proteins formed due to pathogens as protection mechanisms (Lagrimni et al., 1993).
Plant activators can be defined as substances that contain microorganisms such as plant growth promoting root bacteria (PGPR; *Azospirillum, Pseudomonas striata*, *Azotobacter*, *Bacillus firmus*, *Bacillus subtilis*, etc.), and also the mycorrhiza (*Glomus aggregatum*, *Glomus intraradices*, *Glomus fasciculatum* etc.), microalgae (*Spirulina platensis*), alone and/or in combinations with those microorganisms such as mineral based substances, vitamins, plant based extracts etc. (Anonymous, 2002). Plant activators are one of the applications whose use for sustainable agriculture is becoming more and more widespread day by day. In addition, these materials; They are natural, environmentally friendly, non-toxic preparations that increase plant development by positively affecting the physiological and morphological characteristics of plants, strengthen the natural defense systems of plants, promote more nutrient and water uptake, increase the tolerance of plants to abiotic and biotic stresses, and help increase yield and fruit quality (Kunichi et al., 2010; Bulgari et al., 2015). The most important of the defense responses is the perception of avr (avirulence) proteins found in the pathogen by the R genes (resistance genes) found in the plant (Lehmann, 2002).
In order to achieve high yields in agricultural practices, excessive amounts of chemical fertilizers are applied. Detailed studies are being carried out to eliminate the negative effects of such practices. It is expected that global warming will have an effect, especially in the form of temperature increase, and the secondary effects that will emerge in parallel with this, such as changes in precipitation regime, rising water levels, and the spread of stress factors, will deeply affect agricultural production carried out depending on the climate. In this study prepared for these reasons, literature information on the subject were investigated and studies were made on sustainability in field crop production with plant activators.

2. PLANT ACTIVATORS AND SUSTAINABILITY OF FIELD CROPS

A main issue that has been discussed in recent years is the decrease in food security despite the increase in agricultural products. Food security, one of the most important elements in human nutrition, is frequently on the agenda, especially in countries where the quality of life is high. In this section, the findings of research conducted on plant activators worldwide and the potential of plant activators are examined.
Plant activators enable the plants to show resistance to diseases through the mechanisms of systemic acquired resistance (SAR) and induced systemic resistance (ISR). In the SAR mechanism, the pathogen stimulates the plant to produce hormones (jasmonic acid and salicylic acid) and PR

*Corresponding author, E-mail address: kahramanali@selcuk.edu.tr

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protein; in ISR mechanism, a non-pathogenic stimulant stimulates the plant to produce phytoalexins, plant cell enhancers, etc. to neutralize pathogens (Sequeira, 1983). Despite the indisputable benefits of pesticide use, its uncontrolled and excessive application negatively affects the environment, health, agricultural product exports, and therefore the economy (Çömelekoğlu and Mazmancı, 2000).

In addition to a major factor such as water deficiency, which causes restrictions on plant development and production, problems related to mineral nutrition are also expected to emerge (Silva et al., 2011). In the recent decades, the use of pesticides against pests and diseases has decreased, and the introduction of more effective, biologically based products on target organisms provides alternative opportunities. These biologically based products are plant activators (Copping and Menn, 2000).

The structures of pathogens that cause the immune system to emerge against disease agents in plants are called Pathogen Associated Molecular Patterns (PAMPs) (Zipfel, 2008). One of the periods when the most quality losses occur in plant products is the post-harvest period. Therefore, subjecting the product coming from the garden to some applications before storage can significantly reduce quality losses during storage (Terry and Joyce, 2004). They are sources of plant activators, plant growth regulators, organic osmolytes, amino acids, macro and micronutrient elements, and vitamins (Jameson, 1993; Spinelli et al., 2010; Sharma et al., 2014). The natural resistance mechanism is effective against a very wide group of pathogens (Strobel et al., 1996).

Nowadays, studies on inducing resistance in plants have gained more importance for controlling of soil-borne diseases to planta. Resistance mechanism is based on the activation of defense reactions in the host before pathogen infection by biotic and abiotic stimulants (Jarvis, 1992). It has been determined that chemicals such as polyacrylic acid, acetyl salicylic acid and salicylic acid applied externally induce the resistance mechanism in plants (Ryals et al., 1992; Yasuda, 2007).

When the plant activator activates the plant defense mechanism, the plant begins to be successfully protected against pathogen attacks. However, it has no direct effect against fungi and bacteria. The application time is very important. Approximately 7 days after usage of the plant activators, entire defense mechanism is fully activated (Anonymous, 1999). Using of the plant activators within the concept of integrated control of plant diseases by spraying natural compounds on the leaves of the plants or by injection into the plant body has an important place in research all over the world and successful results are obtained as a result of these methods (Benhamou, 1996). For example, the method of planting the seed by surface drying without completely drying it after harvest is called "on-farm seed priming" (Harris et al., 1999). On the other hand, in the fight against some diseases that cannot be controlled with existing control methods, the activation of the natural defense system in the plant before the disease agent infects the plant, in other words, the activation of SAR (Systemic Acquired Resistance), has been a revolutionary development in the elimination of diseases (Oostendorp et al., 2001). Seeds that remains of soil with longer times without germination are subjected to the danger of diseases and pests. Pre-planting seed applications, generally called "priming", reduce the negative effects of environmental conditions (Heydecker and Coolbaer, 1977).

The development of agricultural economy based on chemical pesticides and fertilizers has caused many environmental problems and brought with it questions that still await solutions (Huang and Wu, 2009). One of the purposes of plant activators is to increase the effectiveness of fungicides. For this purpose, plant activators and/or their use together with fungicides in agricultural production are used successfully in the fight against some diseases.

*Corresponding author, E-mail address: kahramanali@selcuk.edu.tr

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There are many scientific studies on the effects of plant activators on yield and resistance (Hodge, 2000). Harpin is a naturally occurring bacterial proteins. The Harpin, that activates natural typed plant defensive mechanisms, was isolated by the bacterial based pathogen called as *Erwinia amylovora*, which causes fire blight disease in apple and pear. It is classified as a biochemical pesticide (Wei et al., 1992). Messenger (Harpin P.) is a patented plant activator containing the naturally occurring protein Harpin protein (Harpin P.) (Anonymous, 2011a). The rate of phytoalexin accumulation during ripening and storage caused a decrease in antifungal compounds (Prusky, 1997). Salicylic acid is defined as a chemical that activates defense genes in plants through the signal transduction pathway it mediates (Vidyashekaran, 2004). Grain-set (LF+Ba+Ms/G) is applied in wheat, barley, corn, sunflower, rice, chickpea, lentil fields and provides an increase in product yield, formation of large and quality grains and provides high resistance to disease resistance and stress conditions such as drought (Anonymous, 2011b).

Unlike agricultural drugs such as classic pesticides, fungicides, and insecticides, plant activators do not directly affect the disease agent. It has been determined that plant activators are effective in increasing resistance in many plants and that they do this by stimulating resistance-increasing genes in the applied plant (Vallad and Goodman, 2004). In another previously realized study (Jablonskytė-Raščė et al., 2012), it was revealed that Biokal 01 used as a plant activator increased the content of protein by 2.1% ratio besides the content of gluten 2.6% ratio in the *Triticum aestivum* L. species. Another research result showed that the application of plant activator increased the gluten content by 15.4% in *Triticum spelta* L., a winter wheat species. In a study investigating the effectiveness of A-S-M, which creates induced resistance by increasing coumarin on the leaf surface, on sunflower rust (Prats et al., 2002), the application of A-S-M, which provides induced resistance to rust infection in sunflower, was characterized by a reduced infection frequency. Studies have shown that phytoalexins inhibit mycelial growth in fungi and have a toxic effect on other pathogens such as other bacteria and nematodes (Borad and Sriram, 2008). In a study conducted on tomato plants infected with bacterial spot, it was determined that harpin applications gave quite good results (Obradovic et al., 2004).

Unlike pesticides, plant activators do not directly affect the pathogen; they provide resistance by stimulating genes that activate the plant resistance mechanism (Vallad and Goodman, 2004). For example, peroxidase provides suberization of cell walls and accumulation of phenolic polymers (Sherf et al., 1993). Using bioactive based products, in other words, plant activators, activates of systemic acquired resistance (SAR) on the plant and limits the entry of many pathogens (Louws et al., 2001). Lignin is one of the main components of cell wall, it provides mechanical support to plant tissues, and is also found in the xylem and plays an essential role for protection of plants against pathogen attacks (Lagrimni et al., 1993). In their study where they applied Messenger Gold containing harpin as a bioactivator by spraying it on tomato plant leaves (Chuang et al., 2010), they determined that some genes thought to be involved in the formation of biotic and abiotic stress response were activated. In their studies conducted in different years and locations (Perez et al., 2003), they set up experiments to determine the role of A-S-M in the operation of the SAR mechanism against *Peronospora hyoscyami*, the causative agent of blue mold disease in black tobacco. In this study, they stated that A-S-M plays a type of SAR. When plants encounter a biotic or/and abiotic based factors of stress, some biochemical and physiological responses occur and different chemical compounds are synthesized as a result of the stimulation of different metabolic pathways, salicylic acid (SA), jasmonic acid (JA), ethylene, etc. (Creelman and Mullet, 1997). In another research conducted in Poland (Koziara et al., 2006), a field study was conducted to see the

*Corresponding author, E-mail address: kahramanali@selcuk.edu.tr

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effects of different bioactivators and nitrogen fertilizers against disease formation in wheat. They applied A-S-M (Acibenzolar-S-methyl) and algin+cytokinin+gibberellin bioactivators and different doses of nitrogen fertilizer (0, 30, 60 and 90 kg/ha). In the laboratory, it was determined that Harpin P. stimulated germination and plant growth in corn, cotton and soybean plants when applied to seeds and plants. The results obtained in a study conducted on sugar beet (Artyszak et al., 2016) showed that it may be possible to decrease the mineral nitrogen by applying about 30% ratio without a reduce in the biologic and pure based sugar yield by using Penergetic (K + P) and Azote growth activators containing *Azospirillum brasilense*, *Azotobacter chroococcum* and *Bacillus megaterium* bacteria. Another study (Whan et al., 2008), they examined the effectiveness of A-S-M activator against *Fusarium oxysporum* f. sp. *vasinfectum* (Fov), which causes disease in cotton plants. When they compared the plants applied with A-S-M alone with the control groups that were only irrigated, they stated that there was no significant increase in enzyme activities. When they looked at the plants applied with only A-S-M or Fov, they concluded that there was an increase in Polyphenol oxidase activities three days after inoculation.

In a study conducted with plant activator and fungicide, it was reported that 60% protection was provided when plant activator was applied alone at 30 g ha^{-1}, 80% in plant activator and fenpropidin (375 g ha^{-1}) applications and 82% in plant activator + cyprodinil applications (Quimette, 2012). In studies conducted on wheat (Prifti and Maçi, 2015), it was stated that Herbagreen application contributed to the yield and increased the productivity of the plants by approximately 30% compared to "classic" fertilization. In a study conducted on A-S-M cotton (Mondal et al., 2005), it was concluded that it might be suitable to use as a component of integrated management methods against black root rot disease. The Hm1 gene found in the corn plant prevents disease by converting NADPH, which forms the HC toxin in the fungus, into NADH with its reductase and dehydrogenase enzymes (Ilag et al., 2000). In order to control diseases in fruits and vegetables, increasing the natural disease resistance of the product is a preferred strategy compared to other methods (Terry and Joyce, 2004). In a study (Faessel et al., 2008) investigating the effects of plant defense stimulants against damping-off disease in soybean welded by the *Rhizoctonia solani* AG-4, it was seen that AS-M showed activity in the form of reduced mycelial growth depending on an antifungal dose. Auxigro, a plant activator produced with GABA technology, which has recently been used, was applied to potato tuber leaves by creating specific application groups and it was determined that there was an increase in yield in each group (Pavlista, 2011). In a study where rice straw was used in compost production (Barus, 2012), 3 different plant activators (Promi, EM 4, BeKa) containing different microorganisms were added to this compost and it was determined that the Promo application increased grain yield and weight. In a study (Aminuzzaman and Hossain, 2007), they applied the plant activator Bion 50 WG commercially, Tilt 250 EC and Amistar commercially named fungicides alone and in combination against leaf blight disease in wheat, and it was determined that the disease agent was significantly reduced in all applications compared to plants without application. Another previous study they conducted with durum wheat (De Giorgio et al., 2008), they used mycorrhiza, azosprillium and both in combination as plant activators. As a result, they reported that mycorrhiza application in particular decreased the fiber content while increasing the cellulose content. A study was conducted in nine different regions in Switzerland with different potato varieties (Nicola, Urgenta, Bintje, Agria), and LF+Ba+Ms/C was applied by a ratio of 600 ml ha^{-1} when the tubers were 1-2 cm long. Total yield increased by 8% in the plots where LF+Ba+Ms/C was applied, and a 6% increase in the number of potatoes harvested was observed (Anonymous, 2008).

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According to various findings, it has been reported that in some cases plant activators do not have an effect or may have an effect when used together with another application. In their study (Bishnoi and Pavyavula, 2004), they investigated the effects of harpin and acibenzolar-S-methyl on yield and disease resistance in tomato and canola plants. As a result of the application, they observed an 8-12% decrease in severity of the early leaf blight based diseases in tomato and a 10-13% increase in yield. In canola plants, they reported that black spot disease did not change at any rate, but there was an increase in plant height in harpin application, and Acibenzolar-Smethyl application increased the number of carob by 7.2% and 8.6%, and yield by 9.7% and 7.2%. In the study, harpin protein was applied to cotton plants, but it was determined that harpin had no effect on yield and quality (Bednarz et al., 2002). In another study, Chitosan oligomers were not successful in stimulating enzymatic activity in bean plants (Shalom et al., 2002).
Consumers believe that organically produced products are healthier, higher quality and have higher nutritional content than conventionally produced products. Since they do not have plant activators, pesticide or antibiotic activities, the negative impacts to health of human besides the environment are minimum (Sreeja, 2014). For this reason, organic production is encouraged in most developed countries and the amount of organic production is increasing in parallel (Watanabe et al., 2015).
Studies are ongoing to prevent product losses caused by diseases caused by various bacteria, viruses and fungi in most plants of economic importance thanks to the use of these natural and harmless products. Another important factor threatening agricultural production is the widespread use of synthetic chemicals by producers in order to increase yield and quality. There is an increasing demand for different techniques and applications that can be an alternative to excessive chemical use, which has reached dimensions that threaten living and environmental health.

3. CONCLUSIONS
Today, parallel to the population growth, people are trying to obtain more products from the resources they have in the face of increasing needs. As a result of the effort to obtain more yield from the unit area, different agricultural techniques have begun to be applied. These agricultural techniques are essentially the improvement of the quality of production inputs and the selection of those suitable for a sustainable environment. The rapid increase in the effects of many negative factors such as global warming due to the deterioration of the environmental order, the changes seen in water, soil and climate in general bring problems in all product groups. The ease of use of plant activators in practice and the most important fact that they do not have a clearly known negatively effects to human health also increase their preferability. Thanks to the use of these completely natural preparations, it has been possible to prevent product losses in most plants with economic importance. Thus, the safety of food resources and the sustainability of food supply can be ensured. In this regard, in order to ensure sustainability, especially health and food safety in the production of the field crops, more detailed research should be conducted on quality components as well as yield parameters.

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*Corresponding author, E-mail address: kahramanali@selcuk.edu.tr

Current Trends in Natural Sciences
Vol. 14, Issue 28, pp. 80-88, 2025
https://doi.org/10.47068/ctns.2025.v14i28.007
Current Trends in Natural Sciences (on-line)
ISSN: 2284-953X
ISSN-L: 2284-9521
Current Trends in Natural Sciences (CD-Rom)
ISSN: 2284-9521
ISSN-L: 2284-9521

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*Corresponding author, E-mail address: kahramanali@selcuk.edu.tr