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Pod quality, yields responses and water productivity of okra (*Abelmoschus esculentus* L.) as affected by plant growth regulators and deficit irrigation

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ABSTRACT

Water scarcity severely impacts agricultural productivity and quality in arid and semi-arid regions. Specific elicitors like plant growth regulators (PGRs) and bio-stimulants as well as deficit irrigation (DI) practices have been put forward to alleviate the effect of resultant water stress and enhance crop productivity. Hence, a field experiment was conducted for two years (2020–2022) to elucidate the effects of PGRs and bio-stimulants of organic and chemical origins under variable deficit irrigation levels on okra (*Abelmoschus esculentus* L.), a major crop grown in the semi-arid region of peninsular India. Treatments included combinations of the foliar sprays with PGRs i.e. irradiated chitosan (IC, 5 ml L^{-1}), sea weed extracts (SWE, 5 ml L^{-1}), thio-urea (TU, 600 ppm), salicylic acid (SA, 20 μM), bacterial biopolymer (BP, 5 ml L^{-1}) along with control (no PGR) and DI levels i.e. equalling 100 %, 75 %, 50 % and 25 % of the crop evapotranspiration (ETc). Irrigation levels were maintained using line source sprinkler (LSS) system. Reductions in pod yield (PY) and above ground biomass (AGB) ranged between 12 and 83 and 20–79 % with DI of 0.75–0.25 ETc. Exogenous foliar application of PGRs improved plant growth, physiological traits and thereby increased PY by 6.1–19.2 %. Beneficial role of PGRs for mitigating water stress was associated with cooler canopy temperatures, maintenance of higher leaf relative water content by modulating stomatal conductance, enhanced plant vigour and photosynthetically active surface. The lower values of yield response factors viz., K_{ywt} < 1 with SWE further indicated increased tolerance of okra to water stress. The maximum crop water productivity (CWP) was 3.43–3.79 kg m^{-3} with PGRs as compared with 3.32 kg m^{-3} without PGR. Especially PGRs of organic origin (SWE and IC) were more effective under medium to severe water stress conditions. The response to BP, bio-stimulant of bacterial origin was almost at par with SA. DI reduced physical quality attributes such as mean pod weight and pod length but firmness and seed/peel ratio got improved, the maximum being with 75 % ETc. Improved rehydration quality and higher accumulation of total soluble solids, dry matter, protein, total phenolics, and flavonoids that potentially affect enzymatic activity were monitored with PGRs. It is concluded that the exogenous foliar application of PGRs from organic origins such as SWE and IC in combination with low to moderate DI (50–75 % ETc) is optimal for improving production and post-harvest quality of okra grown in water-scarce areas of peninsular India.

1. Introduction

Okra (*Abelmoschus esculentus* L.) is an annual herb and a vital vegetable crop grown largely in tropical nations around the world, covering 2.5 million hectares and yielding 10.5 million tonnes each year (Food and Agriculture Organization of the United Nations, 2020). It is cultivated on a very large scale in India, which accounts for 60.4 % of global production. The coastal and central regions of the country, in particular, account for over 70 % of its production. Nevertheless commercial production of okra is concentrated in several pockets in central peninsular India, where it can be cultivated throughout the year and supplies can be tailored according to market demand. Here the crop is grown both during and post-monsoon seasons. Latter is often preferred for its superior export quality, which is rich in fibres and vitamins, uniform size and longevity for storage. Though having moderate tolerance to abiotic stress environments, okra productivity is often constrained by

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REVIEW ARTICLE

Role of chitosan nanoparticles in combating *Fusarium* wilt (*Fusarium oxysporum* f. sp. *ciceri*) of chickpea under changing climatic conditions

Bana Sravani, Sunil Dalvi, Tanaji Krishna Narute

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Studying the incidence and distribution of the grape powdery mildew disease in Maharashtra state's primary grape-growing regions

Shinde KR, Narute TK, Sonawane RB and Dalvi SG

Abstract
The Grapes powdery mildew disease was found prevalent during 2020-21 and 2021-22 in all five districts Nashik, Ahmednagar, Pune, Solapur, and Sangli, of Western Maharashtra's According to the survey data of the vineyards in these areas, the severity of the disease showed a nearly consistent pattern across the different surveyed districts. In Sangli district the highest disease severity was noticed 35.08% followed by Solapur 34.55%. Nashik district has the lowest disease severity upto 19.05%. In this Nashik district, the village of Khedgaon (15.20%) had the lowest disease severity. In Ahmednagar district the village of Belapur Tal Rahuri had the highest disease severity upto 33.10 percent, while Sonai village of the same tehsil had the lowest upto 27.42 percent. The disease severity in the Pune district ranged from 17.30 to 27.20% with an average of 21.09%. Kasegaon from tehsil Pandharpur had the lowest disease severity 33.00% and Tembhurni from Pandharpur tehsil had the highest i.e. 35.40%. The disease severity in Solapur ranged from 33.00% to 35.40%, with an average of 34. 50%. Manerajuri from Tasgaon tehsil 38.22% and Daphalapur from Jath tehsil 32.32% villages had the maximum and lowest disease severity, respectively. In Sangli district the severity of the disease varied among locations from 32.32 to 38.22 percent.

Keywords: Grape, powdery mildew, *Erysiphe necator*, survey

1. Introduction
Grapes (*Vitis vinifera* L.) is the most important temperate fruit crop that has acclimatized to the subtropical and tropical agro-climatic conditions. Grape is known for its cultural dualism between subsistence-oriented growers and export oriented large corporate growers in India. It has become the most remunerative commercial farming enterprise and as such, India exports a large quantity of fresh grapes The refreshing grape is high in sugars and vitamins, especially vitamin C. Grape is a deciduous crop that thrives in a temperate climate (Chadha, 2002) [2]. However, grapes are grown in India under two distinct climatic conditions, the sub-tropical climatic conditions of the north, where winter temperatures rarely reach freezing point and vines go dormant in the winter and the tropical climatic conditions of the peninsular India, where the winters are mild and vines do not go dormant and remain evergreen throughout the year. Grapes are commercially grown in 89 different nations throughout the world.
In Maharashtra, Nashik and Sangli districts are at forefront in the state. Apart from these, grapes are also grown in the district of Ahmednagar, Pune, Satara, Solapur and Osmanabad. However, Nashik and Sangli districts are ahead in the production of grapes in a scientific manner with advanced technologies. The important grapevine diseases are anthracnose, downy mildew, powdery mildew, dead arm, gray mold or bunch rot, black rot, crown gall and bacterial leaf spot. Different fungicides are used to manage diseases of grapevine. Powdery mildew, caused by the pathogenic parasite *Uncinula necator* (Schw.) Burr. is one of the most

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Survey for occurrence and distribution of downy mildew disease of grape in major grape growing areas of Maharashtra state

Khatal MP, Narute TK, Sonawane RB and Dalvi SG

Abstract
Survey is an exercise implemented for the collection of information, data and interpretation of research. The main objectives of disease survey is to know about disease status through disease monitoring and observation of disease symptoms in particular areas. Survey provides the information of current status of that particular disease as well as occurrence of newly disease in selected targeted area. Downy mildew disease is a major constraint and causes huge losses of grape crop all over the world in every year. Accordingly the roving survey on downy mildew disease of grape in grape growing regions of Maharashtra State were carried out during October pruning 2020 and 2021 in five district of Maharashtra State viz., Nashik, Pune, Ahmednagar, Sangli and Solapur. During survey time GPS location of surveyed areas were captured and downy mildew disease samples were collected for further studies. Survey interpretation is illustrated and described in detail as below. During year 2020-21 maximum disease intensity was observed in Sangli district (24.50%) followed by Solapur district (15.66%) and minimum in Pune district (14.35%) followed by Ahmednagar district (14.43%) and Nashik district (15.47%). On the other hand, during year 2021-22 highest disease intensity was found in Sangli district (25.92%) followed by Nashik district (17.39%) and minimum in Ahmednagar district (16.16%) followed by Pune district (16.34%) and Solapur district (17.15%).

Keywords: Grape, downy mildew, *Plasmopara viticola*, survey

1. Introduction
Grapes (*Vitis vinifera* L.) are a pleasant fruit that are high in carbohydrates and vitamins, particularly vitamin C. It is abundant in glucose, protein, vitamins, amino acids, lecithin, and minerals, as well as flavonoids, which act as antioxidants, neutralise free radicals, and slow the ageing process (Choudhary *et al.*, 2014) [1]. Grape is a deciduous crop that grows well in a temperate climate (Chadha, 2002) [2]. Among the all biotic and abiotic stresses downy mildew disease of grape caused by *P. viticola* is one of the most vulnerable one which reducing the yield of grape and possess a serious threat in grape farming.
Downy mildew is one of the most harmful diseases to grapevines in India's wine-growing regions. During damp and warm weather, the disease affects flower buds, young shoots, leaves, and berries. If rainfall happens throughout the early growth to fruit set stages of the fruiting season, crop losses can range from 30% to 100%. Infections on clusters can arise even if there is no rain because dew forms at night (Sawant, S. D. and Sawant, I. S. 2010) [3]. When compared to other diseases, downy mildew causes the highest economic losses to vines, with cluster destruction and foliage loss ranging from 50 to 100 percent (Emmett *et al.* 1992) [4]. Considering the importance of downy mildew infection and their potentiality of being an epidemic pathogen, survey on occurrence of downy mildew disease of grape will be helpful in managing the disease. Hence, survey on occurrence of downy mildew disease of grape was

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S.I. : DIVERSIFICATION OF SUGAR CROPS FOR VALUE ADDITION

Bio-Circular Economy: an Opportunity for Diversification for Sugar Industries in Compressed Biogas (CBG) and Organic Fertilizer Production

Sanjay Patil[1] · Kakasaheb Konde[1] · Shuvashish Behera[1]

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Abstract Press mud cake (PMC) is one of the world's most abundant sugarcane-based wastes, and in an Indian context, 8–10 million tonnes per annum is produced. The current use of PMC is restricted to use as filler material in bio-composting process or directly as fertilizer to improve soil fertility without any previous recovery of value-added products. However, considering its potential, only fertilizer use is not the best valorization route. Due to lack of transportation, press mud is unused and left in piles in most sugar mills, leading to blockage of drains and becoming a cause of water pollution. At the same time, increasing consumption of fossil fuels and environmental concern has led to increased use of compressed natural gas (CNG) in the transportation sector. Keeping in view limited resources of CNG, biogas is advised as potential fuel to provide continuous supply of CNG in the form of bio-CNG or Compressed Biogas (CBG). Therefore, to decrease the imports of crude oil and natural gas requirement and to increase the economic sustainability of sugar mills, utilization of wastes (spent wash and PMC)for biogas production through anaerobic digestion (AD) and further purification to produce CBG (a purified form of Biogas) will definitely generate additional revenue for sugar mills in India. This paper aims to produce a strong outlook on the importance of CBG production through anaerobic digestion and its purification. Further, an out sketch of five models has been designed showing the possibility to produce maximum CBG using existing biogas plant (sugar mill complex) with addition of a new biogas plant. Production of value-added CBG and recycle of digestate on organic fertilizer are perfect case of bio-circular economy.

Keywords Biofuels · Compressed biogas · Press mud cake · Bio-circular economy

Introduction

India has a total reserve of 763 Million Metric Tonne of crude oil and 1488 Billion Cubic Meter of natural gas (Ministry of Petroleum and Natural Gas, GoI). About 77% of its crude oil requirement and 50% of natural gas requirement is being imported in India. So, GoI has set a target of reducing this import by at least 10% by 2022 and it has also set a target of increasing the contribution of gas from existing 6.5% (global average is 23.5%) to 15% by 2022. Therefore, waste/biomass sources like agricultural residue (sugarcane trash), cattle dung, sugarcane press mud cake (PMC), municipal solid waste and sewage treatment plant waste, etc. are being targeted by GoI for production of biogas through the process of anaerobic digestion (Buraimoh et al. 2020; Sarker et al. 2017). The route for biomass to biogas and CBG production is shown in Fig. 1.

To reduce the import dependency in oil and gas sector, road map has been prepared by increasing domestic production adopting biofuels and demand substitution (Berndes and Hansson 2007). Standards for Compressed Biogas (CBG), Ethanol, and Flex-fuel Methanol combinations have been issued through various notifications. Renewable energy sources like CBG, ethanol, methanol will play an important role in country's energy requirement in future (Kaur et al. 2020).

Expression of interest has been invited by Oil Marketing Companies (OMCs) for the production and supply of CBG

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REVIEW ARTICLE

A Review on Opportunities and Limitations of Membrane Bioreactor Configuration in Biofuel Production

Shruti Garg[1,2] · Shuvashish Behera[1,3] · Hector A. Ruiz[4] · Sachin Kumar[1]

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Abstract
Biofuels are a clean and renewable source of energy that has gained more attention in recent years; however, high energy input and processing cost during the production and recovery process restricted its progress. Membrane technology offers a range of energy-saving separation for product recovery and purification in biorefining along with biofuel production processes. Membrane separation techniques in combination with different biological processes increase cell concentration in the bioreactor, reduce product inhibition, decrease chemical consumption, reduce energy requirements, and further increase product concentration and productivity. Certain membrane bioreactors have evolved with the ability to deal with different biological production and separation processes to make them cost-effective, but there are certain limitations. The present review describes the advantages and limitations of membrane bioreactors to produce different biofuels with the ability to simplify upstream and downstream processes in terms of sustainability and economics.

Keywords Biorefinery · Bioethanol · Biobutanol · Biodiesel · Biogas · Biohydrogen

Abbreviations

MBR	Membrane bioreactor
GHGs	Greenhouse gases
LPG	Liquefied petroleum gas
HF	Hollow fiber
FS	Flat sheet

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Passive immunization with equine RBD-specific Fab protects K18-hACE2-mice against Alpha or Beta variants of SARS-CoV-2

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Emergence of variants of concern (VOC) during the COVID-19 pandemic has contributed to the decreased efficacy of therapeutic monoclonal antibody treatments for severe cases of SARS-CoV-2 infection. In addition, the cost of creating these therapeutic treatments is high, making their implementation in low- to middle-income countries devastated by the pandemic very difficult. Here, we explored the use of polyclonal $EpF(ab')_2$ antibodies generated through the immunization of horses with SARS-CoV-2 WA-1 RBD conjugated to HBsAg nanoparticles as a low-cost therapeutic treatment for severe cases of disease. We determined that the equine $EpF(ab')_2$ bind RBD and neutralize ACE2 receptor binding by virus for all VOC strains tested except Omicron. Despite its relatively quick clearance from peripheral circulation, a 100μg dose of $EpF(ab')_2$ was able to fully protect mice against severe disease phenotypes following intranasal SARS-CoV-2 challenge with Alpha and Beta variants. $EpF(ab')_2$ administration increased survival while subsequently lowering disease scores and viral RNA burden in disease-relevant tissues. No significant improvement in survival outcomes or disease scores was observed in $EpF(ab')_2$-treated mice challenged using the Delta variant at 10μg or 100μg doses. Overall, the data presented here provide a proof of concept for the use of $EpF(ab')_2$ in the prevention of severe SARS-CoV-2 infections and underscore the need for either variant-specific treatments or variant-independent therapeutics for COVID-19.

frontiers | Frontiers in Genetics

REVIEW

Advances in Crop Breeding Through Precision Genome Editing

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The global climate change and unfavourable abiotic and biotic factors are limiting agricultural productivity and therefore intensifying the challenges for crop scientists to meet the rising demand for global food supply. The introduction of applied genetics to agriculture through plant breeding facilitated the development of hybrid varieties with improved crop productivity. However, the development of new varieties with the existing gene pools poses a challenge for crop breeders. Genetic engineering holds the potential to broaden genetic diversity by the introduction of new genes into crops. But the random insertion of foreign DNA into the plant's nuclear genome often leads to transgene silencing. Recent advances in the field of plant breeding include the development of a new breeding technique called genome editing. Genome editing technologies have emerged as powerful tools to precisely modify the crop genomes at specific sites in the genome, which has been the longstanding goal of plant breeders. The precise modification of the target genome, the absence of foreign DNA in the genome-edited plants, and the faster and cheaper method of genome modification are the remarkable features of the genome-editing technology that have resulted in its widespread application in crop breeding in less than a decade. This review focuses on the advances in crop breeding through precision genome editing. This review includes: an overview of the different breeding approaches for crop improvement; genome editing tools and their mechanism of action and application of the most widely used genome editing technology, CRISPR/Cas9, for crop improvement especially for agronomic traits such as disease resistance, abiotic stress tolerance, herbicide tolerance, yield and quality improvement, reduction of anti-nutrients, and improved shelf life; and an update on the regulatory approval of the genome-edited crops. This review also throws a light on development of high-yielding climate-resilient crops through precision genome editing.

Keywords: Genome editing, crop breeding, new breeding techniques, CRISPR, disease resistance, abiotic stress tolerance, biofortification, climate-resilient crops

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INTRODUCTION

The global climate change has a direct impact on the food security, agriculture, crop production and plant health (Tirado et al., 2010). According to the world population data sheet 2020, the world population is projected to increase from 7.8 billion in 2020 to 9.9 billion by 2050. Global cropland area per capita has decreased continuously from about 0.45 ha per capita in 1961 to 0.21 ha per capita in 2016 (https://www.fao.org). Further, the available area for cultivation is degraded due to various

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In vitro effect of chitosan nanoparticles on wilt disease resistance of chickpea by seedlings root feeding of *Fusarium oxysporum* f. sp. *ciceri*

Bana Sravani, Dr. TK Narute, Dr. SB Latake, Dr. Sunil Dalvi and Dr. SV Kolase

Abstract
Chickpea is widely consumed dietary legume contributing 18% of global pulse production. Standing third position after beans and peas, chickpea produces about 12.09 MT annually in the world. Unexpected climatic changes imposed several abiotic and biotic stresses on yield and productivity of chickpea. Among them, *Fusarium oxysporum* f. sp. *ciceris* (Foc) is a major soil born pathogen which causes 10-100% yield losses. In earlier studies chitosan and *Bacillus subtilis* sp were reported by many scientists as bioagents in management of diseases in crops. To overcome wilt problem in chickpea, attempts were made to identify the significant use of chitosan nanoparticles and *Bacillus* sp against wilt pathogen. In present experiment, root dip method demonstrated that chitosan and *Bacillus* sp treated gram seeds when fed with *Fusarium* spore suspension survived more days as compared to the untreated seeds. The seedlings with chitosan nanoparticles at 100 and 150 ppm and CNPs + bioagent at all concentrations survived for 22 days without displaying any symptoms of wilting. While in the case of negative and positive control, wilting started at 15 and 17 days of sowing respectively. Whereas, in the case of bioagent alone treated ones started wilting after 18 DAS. It is revealed that chitosan nanoparticles at 100 and 150 ppm when combined with *Bacillus subtilis* showed a synergistic effect of induced disease resistance in chickpea treatments at the early seedling stage for wilt resistance. Therefore, this is very simple and rapid method for screening induced resistance at early stage which will help for evaluation of bioagents for their use.

Keywords: Chitosan, nanoparticles, *Fusarium*, chickpea, root dip method, induced disease resistance

Introduction
Now a days chickpea production and productivity are largely limited due to various abiotic and biotic stresses. Fungal and viral diseases form a major part of biotic constraints in chickpea producing countries (Navas Cortes *et al*., 2008) [1]. Among them, *Fusarium oxysporum* f. sp.

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Review
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Biosurfactants' multifarious functional potential for sustainable agricultural practices

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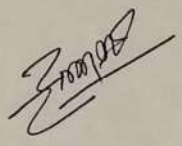
Increasing food demand by the ever-growing population imposes an extra burden on the agricultural and food industries. Chemical-based pesticides, fungicides, fertilizers, and high-breeding crop varieties are typically employed to enhance crop productivity. Overexploitation of chemicals and their persistence in the environment, however, has detrimental effects on soil, water, and air which consequently disturb the food chain and the ecosystem. The lower aqueous solubility and higher hydrophobicity of agrochemicals, pesticides, metals, and hydrocarbons allow them to adhere to soil particles and, therefore, continue in the environment. Chemical pesticides, viz., organophosphate, organochlorine, and carbamate, are used regularly to protect agriculture produce. Hydrophobic pollutants strongly adhered to soil particles can be solubilized or desorbed through the usage of biosurfactant/s (BSs) or BS-producing and pesticide-degrading



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ORIGINAL RESEARCH

Synergistic Activity of Rhamnolipid Biosurfactant and Nanoparticles Synthesized Using Fungal Origin Chitosan Against Phytopathogens

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Phytopathogens pose severe implications in the quantity and quality of food production by instigating several diseases. Biocontrol strategies comprising the application of biomaterials have offered endless opportunities for sustainable agriculture. We explored multifarious potentials of rhamnolipid-BS (RH-BS: commercial), fungal chitosan (FCH), and FCH-derived nanoparticles (FCHNPs). The high-quality FCH was extracted from *Cunninghamella echinulata* NCIM 691 followed by the synthesis of FCHNPs. Both, FCH and FCHNPs were characterized by UV-visible spectroscopy, DLS, zeta potential, FTIR, SEM, and Nanoparticle Tracking Analysis (NTA). The commercial chitosan (CH) and synthesized chitosan nanoparticles (CHNPs) were used along with test compounds (FCH and FCHNPs). SEM analysis revealed the spherical shape of the nanomaterials (CHNPs and FCHNPs). NTA provided high-resolution visual

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β-Glucan and its nanocomposites in sustainable agriculture and environment: an overview of mechanisms and applications

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Abstract

β-Glucan is an eco-friendly, biodegradable, and economical biopolymer with important roles for acquiring adaptations to mitigate climate change in crop plants. β-Glucan plays a crucial role in the activation of functional plant innate immune system by triggering the downward signaling cascade/s, resulting in the accumulation of different pathogenesis-related proteins (PR-proteins), reactive oxygen species (ROS), antioxidant defense enzymes, Ca^{2+}-influx as well as activation of mitogen-activated protein kinase (MAPK) pathway. Recent experimental studies have shown that β-glucan recognition is mediated by co-receptor LysMPRR (lysin motif pattern recognition receptor)-CERK1 (chitin elicitor receptor kinase 1), LYK4, and LYK5 (LysM-containing receptor-like kinase), as well as different receptor systems in plants that could be plant species-specific and/or age and/or tissue-dependent. Transgenic overexpression of β-glucanase, chitinase, and/or in combination with other PR-proteins like cationic peroxidase, AP24,thaumatin-likeprotein 1 (TLP-1) has also been achieved for improving plant disease resistance in crop plants, but the transgenic methods have some ethical and environmental concerns. In this regard, elicitation of plant immunity using biopolymer like β-glucan and chitosan offers an economical, safe, and publicly acceptable method. The β-glucan and chitosan nanocomposites have proven to be useful for the activation of plant defense pathways and to enhance plant response/systemic acquired resistance (SAR) against broad types of plant pathogens and mitigating multiple stresses under the changing climate conditions.

Keywords: MAP kinases; Plant innate immunity; Sustainable agriculture; WRKY transcription factors;