AN OVERVIEW OF THE MEANS TO ENHANCE TOMATO SEED PHYSIOLOGICAL QUALITY IN THE CONTEXT OF SUSTAINABLE HORTICULTURE

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Abstract

The tomato (Solanum lycopersicum L.) is one of the most cultivated vegetable species worldwide, both in protected areas, as well as in open - field conditions, due to the preferences of consumers for this vegetable, its nutritive and nutraceutical value, also its multiple processing possibilities. At the same time, tomatoes are model plants for studies on fruit growth, development and ripening. Along with many other common factors that influence the quality of tomatoes (variety, cultural practices, timing and method of harvesting, handling, transport and storage) and taking into account the various growing conditions and possible exposure to the action of various stress factors, the primary condition for good growth and development of plants (including for promoting yield, fruit quality value, as well as technological properties) is the use of a seed characterized by a high physiological quality. In this context, the different seed priming techniques have proved effective both in favor of the germination process and increasing the vigor of the seedlings, as well as in terms of enhancing the crop productivity within the different cultivation systems. Besides these, the quality of the fruits at the time of harvest, as well as their behavior in the post-harvest period proved to be beneficially influenced by the treatments applied to the seeds. This short overview presents some noteworthy research results obtained in the last decade for tomatoes, which have proven to be of interest from the economical, environmental protection and human health viewpoint in the context of increasing sustainability.

Key words**:** *Solanum lycopersicum* L., *seed germination, seedling vigor, stress, priming*

INTRODUCTION

The seed represents the connection between the past and the future, as Bareke [6] mentioned.

A fast germination of the seeds and an early stabilization of the seedlings are absolutely necessary characteristics for the production of seedlings, in favorable, but especially in unfavorable environmental conditions. Therefore, the physiological quality of the seed is a basic precondition in order to obtain a uniform crop, a large and quality harvest, both in terms of nutritional and / or nutraceutical quality, maintaining post-harvest quality, including extending fruits shelf life, and obtaining of a good quality product after processing [45], [29]. Additionally, quality seeds provide a substantial profit for farmers who produce seed material, as well as for seed dealers [76].

The tomato (*Solanum lycopersicum* L.) is one of the most cultivated vegetable species worldwide, considering the possibilities of cultivation throughout the year, regardless of the season, both in protected areas (greenhouses, solariums), as well as in open - field conditions, due to the preferences of consumers for this vegetable, given its nutritive and nutraceutical value [24],[17], [54], also its multiple processing possibilities and tomato based products [68]. At the same time, tomatoes are model plants for studies on fruit growth, development, and ripening [31]; [73], and last but not least for the study of plant-microbe interactions [46].

Especially in the last decade, the exploitation of beneficial microorganisms present in the rhizobiome of tomatoes (but also at the level of phyloplane), whether we are talking about species of bacteria that promote growth, mycorrhizal and/or antagonistic fungi, or various microorganisms that have been shown to produce different hormones has become of interest. Their research in the view of recommending as possible bio stimulants for plant nutrition (in other words bio fertilizers), as bio control agents of some biotic stress agents, or simple promoters of seed germination and increasing seedling vigor and last but not least, as increasing agents of plant productivity, have become major topics in multidisciplinary research. All these conducted studies, as well as those that will be done will assure notable results for the practice of sustainable horticulture.

Given that conventional agriculture involves the use of phytopharmaceuticals to control diseases and pests and to achieve high production and has effects of deteriorating soil health and negative impact on human safety, the practice of biological solutions alternatives (as for instance bacterial endophytes) becomes to be taken into account, in the general context of environmental benefits [23], [21].

There are also recent promising results of Giuliani et al. [32] studies, that lay the foundations of a bio-economic analysis to support policy makers in charge of promoting the sustainability of the tomato growing systems.

Considering the above mentioned, in this mini review there are included some results obtained in the last decade, in connection with the need of use of a quality seed when setting up a tomato crop, as well as the practicing of the procedures that enhance the germination capacity of the seeds and early seedling growth, tolerance to the action of stresses and not finally obtaining a large crops with high nutritional and functional quality, objectives that are in the current and future attention of researchers and farmers.

MATERIALS AND METHODS

This bibliographic synthesis was prepared based on the results of research conducted in the last decade and published in prestigious journals, indexed in internationally recognized databases. Only the scientific articles were considered and the results of interest, in accordance with the theme of the paper were systematized and discussed. The importance of the new measures for the practice of a sustainable system for tomato cultivation is highlighted, in the context of constrains caused by different stress factors, without neglecting the possible undesirable effects that such practices may have.

RESULTS AND DISCUSSIONS

Obtaining, characterizing and preserving the tomato seed physiological quality

Over time, the connection between the morpho-anatomical characteristics of seeds and their germination has been demonstrated. The attention in the research was focused on the good development during embryogenesis and the profound transformations that take place during this process [71].

The techniques of investigation of some seeds morphological characters have been perfected in the last years and in tomatoes. Thus, the study of embryo morphology and the presence of free spaces through X-rays image analysis can be an alternative method for characterizing the physiological maturity and selection of high tomato quality seeds [10].In this regard, Gargiulo et al. [30] carried out a three-dimensional study of the seeds and the results proved to be predictive regarding the germination, although the authors recommend caution when using X-ray micro-tomography (micro-CT) in order to develop industrial systems for testing or sorting tomato seeds. In-depth studies on germination speed, based on quantitative trait locus (QTL) analysis have highlighted the involvement of QTL chromosome 1 and its usefulness for breeding cultivars capable of germinating at low temperatures [53].

During the development period of the seeds, numerous metabolites are biosynthesized and the metabolic profile together with the specific genetic variability can have marked effects in the regulation of the metabolism and the behavior of the seeds. Therefore, the analysis of the metabolome in combination with genetic resources can lead to the development of comprehensive strategies to improve crop quality, to characterize unknown genetic functions and to faster screen metabolic phenotypes [42].

Besides the conditions for achieving embryogenesis and respectively the actual characteristics of the seed, the way of their storage will influence their physiological quality. So, the extension of the time storage period is a desideratum that must be taken into account. As studies by Jacob et al. [38] have shown, the use of a hydrophilic polymer (Disco Clear) film coating can have practical applicability as an alternative to save seed storage. Such a treatment has been shown to ensure tomato seed quality maintenance for a longer period of time, as compared to untreated seeds. In addition, after exposure to freely available water, the presence of the polymer facilitated a faster and more controlled seed imbibition, which had the effect of reducing the average germination time.

Accelerated aging of seeds can also contribute to lowering their quality. In this regard, studies conducted by Nigam et al. [55] have highlighted the involvement of mitogen activated proteins kinases (MAPK) pathways in achieving physiological (germination percentage, seedling vigor, vigor index) and biochemical changes (reducing sugar, soluble proteins, lipids peroxidation, enzymatic antioxidant system) in tomato seeds.

Moreover, in addition to the modern methods used today in the breeding process, must not be forgotten the use of local tomato varieties (e.g. tomato germplasm preserved ex-situ in Gene Banks) as a way to consider the breeding programs [60].

Directing atention to understanding the quality of seeds during development and maturation, dormancy, germination process, and their longevity during storage leads to the successful operation of seed genebanks and respectively to ensure efficient conservation of plant genetic resources [75].

Enhancing tomato seed physiological quality by biological means

Increasing the physiological quality of the seeds and improving tolerance to stresses can be achieved by "seed priming" using conventional and advanced methods [74]. Seed priming is a technique with favorable effects on metabolic processes involved in achieving a uniform and rapid germination [19], thanks to the reduction of imbibition period, activation of enzymes involved in biodegradation of reserve substances and biosynthesis of new metabolites, DNA repair and regulation of water absorption by osmosis [58].The agricultural systems that counteract the negative impact of climatic change must be in the attention of practitioners [20] and priming beneficial effects seem to be due to what is called "priming memory", fixed during the priming procedure and manifested later, when the seeds are exposed to stresses that occur during germination [14].

In the context of the need to practice a sustainable horticulture and the implementation of low cost, safe and environmentally friendly cultivation technologies, many recent studies are focused on enhancing the physiological quality of seeds by bio priming (or some combined seed treatments), in order to promote plant growth and productivity under conditions of abiotic and biotic stress [56].Various microorganisms from the categories of plant growth promoting bacteria and plant growth promoting fungi (PGPB and PGPF) are exploited and recommended by the researchers. Such microorganisms have proven to be effective in favoring the activity of absorption of water and mineral nutrients from the soil, the production of hormones, but also concerning the changes they induce in the sense of activating systemic resistance mechanisms against the attack of biotic stresses.

The rhizobiome (or in other words, the root associated microbiome) of tomatoes is a potential source of beneficial microorganisms, including some that are capable of producing indole acetic acid (IAA), the main growth stimulant phytohormone. For example, Rushabh et al. [65] researches led to the selection of a bacterial isolate (7MM11) identified as *Providencia* sp., which was subsequently studied *in vitro* to ensure optimal culture conditions for the production of IAA (a high production of 89.22 μg/mL, in a period of 24 h incubation period). *In vivo* studies have highlighted the bacterium's ability to improve germination, increase seedling vigor, and promote plant growth. Rocha et al. [64] studied the antagonistic activity against the fungus *Fusarium oxysporum* f. sp. *lycopersici* (*Fol*), of bacteria of the genus *Bacillus* that colonize tomato plants and highlighted the control provided by *B. cereus* against *Fol* race 1, *B. magaterium* controlled 100% the *Fol* race 2 and *B. toyonensis* controlled 100% of disease caused by *Fol* race 2 and race 3 isolates. At the same time, the functional activity they have on plant growth was highlighted.

The use of plant growth promoting rhizobacteria (PGPR) based elicitors suppress plant disease by ensured a deterioration of the cell wall of *Alternaria solani* fungus, an inhibition of colony development, also enhanced the plant growth.It was registered an induced systemic resistance (ISR) based on different metabolic indicators, such as total phenols, free proline, peroxidase and polyphenoloxidase activities increase, also increasing the contents of IAA, abscisic acid (ABA), salicylic acid (SA) and jasmonic acid (JA)[4]. Karthika et al. [41] emphasised the eficacity of the PGPR, the isolate KTMA4 (*Bacillus cereus* - MG547975) against *F.oxysporum* (66%) and *A. solani* (54%) after seven days of incubation.*In vitro* studies highlighted its capacity to produce IAA, ammonia, catalase, siderophore and 1-aminocyclopropane-1-carboxylate (ACC) deaminase. Moreover, it has nitrogen biological fixation ability, besides to the production of lytic enzymes (amylase, cellulase, xylanase, lipase, and protease).Further, the bacterium *B. cereus* KTMA4 effectively produced biofilm, biosurfactants and salt-tolerant (5% NaCl).Beneficial effects have been noticed also *in vivo*, as regard as seed germination and seedling vigor improving. So, this new isolated rhizosphere bacterial strain can be used as a posible biocontrol agent against different pathogens, as well as a biofertilizer inoculant for tomato cultivation.

Furthermore, research conducted in laboratory conditions, but also in the greenhouse by Gowtham et al. [34] demonstrated the possibility of using of ACC deaminase produced by *Bacillus subtilis* Rhizo SF 48 isolate, as a bio inoculant for sustainable production of tomatoes in water deficit conditions, as is the case in arid and semi-arid areas.

Promising beneficial effects were also obtained by Shrivastava et al. [72] who used a combination treatment consisting of *Pseudomonas* (a PGPR), the antagonist fungus *Trichoderma harzianum* and the arbuscular michorizal fungus (AMF) *Glomus intraradices* against the same fungus. Seed priming with *T. harzianum* and *Pseudomonas* increased seed germination and reduced average germination time, while the combined treatment with the three factors provided a disease reduction by 81% and 74% in pots and field culture, while production yield increased by 33%.

If we refer to mycorrhizal fungi, besides their known beneficial effects on water and mineral nutrients at the root level, Sanmartin et al. [66] also emphasizes the positive responses induced at the level of the above-ground part, by the *Rhizophagus irregularis*, through what is called Mycorrhiza-Induced Resistance (MIR). The proof are the results of metabolomics analyzes that revealed an increase in the content of lignans, oxocarboxylic acids, the metabolism of amino acids and phytohormones in the mycorrhizal roots, also the signaling assured by oxylipins between the accumulation of yatein in roots and leaves during MIR. The lignan yatein had *in vitro* antimicrobial activity against the *Botrytis cinerea* fungus, as well as a protective function in the case of tomato plants.

Panda et al. [57] demonstrated too, the beneficial effects of colonizing tomato roots with mycorrhizal fungus *Piriformospora indica*, in terms of promoting growth, but also inducing systemic defense against the pathogen *A. solani*. A systemic modulation of some key components of the signaling cascade was found to regulate transcription, namely CBL-interacting protein kinases

(CIPK), mitogen activated protein kinases (MPKs), lipid transfer proteins (LTPs), WRKY1, ethylene responsive transcription factors (ERF) and jasmonate zim domain 1 (JAZ1), a negative regulator of jasmonic acid (JA), demonstrating the potential ability of colonization with *P. indica* in providing durable basal defense against pathogens.

Also, Bona et al. [7], [8] emphasized that the use of *Pseudomonas* sp. 19Fv1T or *P. fluorescens* C7, as a treatment applied to tomato plants has reduced fertilization, while the amount of fruit obtained has been higher and their nutritional value (e.g.soluble sugars, organic acids, carotenoids and ascorbate) has also been shown to be improved.

In addition to the known beneficial effects on metabolism and the induction of tolerance mechanisms against biotic stresses, Brilli et al. [11] demonstrated experimentally that *Pseudomonas chlororaphis* (a PGPB) also improves the tolerance of tomatoes to water stress. Its effects are multiple: it stimulates antioxidant activity, limits the accumulation of reactive oxigen species (ROS) in leaves, increases the content of proline and abscisic acid (ABA), which results in better control of stomatal movement. Thus, it ensures better water use efficiency (WUE) and not in lastly, an increase in biomass accumulation.

One of the possibilities to mitigate the effects of abiotic stress (such as drought) is the expolatation of the microbiome of arid zone plants. In this regard, Eke et al. [26] studied 191 endophytic bacteria (13-genera and 18-species) isolated from wild cactus and demonstrated that in the case of tomato seeds bacterization (especialy with the endophytic strain *B. amyloliquefaciens* - CBa_RA37) the seeds germination, also seedlings growth have been promoted. So, the species has been characterized as a possible bio-inoculant, in a low-cost, efficient and environmentally friendly technology, in order to counteract the effects of drought in arid areas.

As Singh et al. [69] emphasised, the application of an integrated seed priming treatment (with ascorbic acid - AA, *Trichoderma asperellum* BHU P-1 and *Ochrobactrum* sp. BHU PB-1) ensured an improvement of the physiological parameters related to germination (higher germination with 80% at a low concentration of AA - 1 pM) and also activated the defense response against the attack of the pathogenic *F.oxysporum* f. sp. *lycopersici* fungus, that causes tomato wilting (disease incidence reduction to 28% in tomato plants at 10 days). From a biochemical point of view, there was registered an increase in the total phenol content and in the activity of some enzymes activated in plant as a defense response against to the pathogen atack (phenylammonia lyase, peroxidase, chitinase and polyphenol oxidase), while the production of ROS represented by hydrogen peroxide was reduced, compared to the untreated control.

Studies have also shown the possibility of using beneficial microorganisms isolated from other plant species, or some active plant tissues/plant extracts. Thus, the application as a fertilizer of the halotolerant actinomycete *Streptomyces* sp. KLBMP5084 obtained from the root of the halophyte *Limonium sinense* has been shown to have antifungal activity against the fungus *A.solani*, *in vitro* and also had the effect of promoting seedling growth under conditions of salt stress [33].

On the other hand, Abdel-Motaal et al. [1] demonstrated the role of *Aspergillus flavus* (isolated from the medicinal plant *Euphorbia geniculata*) in improving tomato plant growth, as well as in increasing the content in secondary metabolites, which enhanced the plant's resistance to the attack of pathogen *Alternaria phragmospora*, that causes early blight disease.

Along with a quality seed, the nutritive substrate has a major influence on the seeds germination and growth of the seedlings. In this context, Kadoglidou et al. [40] studied the possibilities of improving soil properties and growing tomato seedlings by incorporating aromatic plant tissues (such as dried spearmint -*Mentha spicata* and sage - *Salvia fruticosa*) into the seedbeds. The results highlighted the favorable effects of *M. spicata*, whose presence increased microbial populations and the decomposition of organic matter at the substrate level, while the pH of the soil remained within the optimal limits, specific to tomato cultivation.

Enhancing the physiological quality of tomato seed by other modern means

Hormonal treatments and beyond

Hormones produced by plants, but also those produced by microorganisms have a great influence on plant metabolism, including effects on seeds germination [47] and inducing mechanisms of tolerance to stresses [25].

Effects of interest were also highlighted in the case of the of different secondary metabolites, which normally occur in plant metabolism, which perform specific functions, but whose biosynthesis and involvement in signaling defense responses under stress is evident [37], as well as to use nanomaterials with a view to adaptation of cultivated plants in stressful conditions [59].

Jasmonic acid is one of the hormones with a major impact on plant tolerance to biotic and abiotic stress. Bali et al. [5] studies showed that tomato seed treatment with JA (100 nM) reduced the heavy metal phytotoxicity of lead (Pb) by stimulating the biosynthesis of assimilatory pigments, secondary metabolites, osmotically active substances, compounds that chelating heavy metals, organic acids, and polyamines in tomato seedlings. The obtained results suggested that JA mitigated the oxidative damage by lowering the expression of the *RBO* and P-type ATPase transporter genes and by modulating antioxidative defense system activity.

On the other hand, Król et al. [43] emphasised that the application of methyl jasmonate (MeJA) at a dose of 0.1 mM for 1 h, as a seed priming procedure ensured a significant increase in the resistance of tomato seedlings to the soil borne fungus pathogen *F.oxysporum* f.sp. *lycopersici* (4 weeks after inoculation). Due to the treatment, there were registered high levels of phenolic (such as salicylic acid) and flavonols compounds (e.g. quercetin and kaempferol).

Madamy et al. [44] highlights for the first time the potential of hormonal treatment of seeds with IAA (0.09 mM) or salycilic acid (SA - 1 mM) in terms of mitigating the negative effect of stress caused by the parasitic weeds *Orobanche ramosa*, especialy by increasing the antioxidant defence markers metabolites and enzymes.

The involvement of the phytohormones abscisic acid (ABA) and gibberellic acid (GA) in the control of the germination process is known, and the studies carried out by Yang et al. [77] led to the identification of a tomato mutant, salt tolerant cultivar (LA2711), whose germination was fast in such stressful conditions. It has been shown experimentally that the *SICY707A2* gene encoding the enzyme involved in ABA catabolism has a high level of expression and may play a decisive role in ensuring rapid germination.

As Moles et al. [51] noticed, natrium chloride (NaCl) treatments have been shown to promote the germination process by activating the hydrolysis of galacto mannans (endo-β-mannanase, β-mannosidase and α-galactosidase) as well as the biodegradation of starch, counteracting oxidative stress.These processes have determined the increase of the content of total soluble carbohydrates and at the same time the amount of metabolic energy necessary for organogenesis and the counteracting of oxidative stress was ensured.

Regarding the mechanism of the action of seed priming with 300 mM NaCl, Nakaune et al. [52] highlighted the major bioactive role of gibberellic acid (GA_4), materialized by activating the genes involved in its biosynthesis, while the effects on ABA degradation were minor during germination. The genes involved in endosperm cap weakening were overexpressed by priming.

Cold plasma seed priming modulates the seed coat and has a beneficial effect on germination. Moreover, it induces a certain potential for drought tolerance of seedlings by promoting growth, activating the antioxidant system, phytohormones, and the expression of defense genes, which causes a series of signalings cascades at the cell level and changes in biochemical and physiological parameters [2].

Shikimic acid treatment (60 ppm) for seeds soaking has been shown to marked increase of plant growth, fruit productivity and quality of tomatoes plants grown in field conditions. Thus, there were registered an increase of total leaf conductivity, transpiration rate and photosynthetic pigments (Chl. a, chl. b and carotenoids) of tomato plants. Also, there was noticed a significantly increased of nitrogen, phosphorus and potassium concentration in tomato leaves, as compared to control (non-treated tomato plants) [3].

Qiao et al. [61] conducted *in vitro*, greenhouse and field studies on the effects of carvacrol treatments, applied to seed, foliar alone or in combination with copper, to reduce the severity of bacterial spot ot tomato (BST) produced by *Xanthomonas perforans*. The results showed that a dose of 32 mg L^{-1} promoted germination and improved seedling vigor. The combined foliar treatment (at 32 mg L^{-1} + copper at 76.8 mg L^{-1}) was more effective in reducing the severity of BST. In addition, carvacrol increased the effectiveness of copper against *X. perforans* copper resistance. So, the authors indicated a posible sustainable way of control the BST. Promising results as regard as activation of defence genes were also obtained by Chandrashekar and Umesha [12] by seeds priming with 1.0 mM 2,6-dichloroisonicotinic acid (INA) as an abiotic inducer of resistance to *X. perforans*.

The use of economical, renewable, efficient and environmentally friendly fertilization methods are primary conditions for promoting sustainable agriculture, so the exploitation of natural resources as organic fertilizers is a current concern. Thus, Chanthini et al. [13] analyzed the potential to stimulate seed germination and tomato plant growth of the liquid extract of green seaweed *Chaetomorpha antennina* (CA-LSE). Its effects on the biochemical profile of plants were also demonstrated and it was established which are the main mineral elements (oxigen - O, natrium - Na, magnesium - Mg, sulphur - S, chlorine - Cl and calcium - Ca) that provided the potential for biostimulation.

Additionally, the use of a water-soluble vitamin K3 derivative, respectively menadione sodium bisulphite (MSB) for the treatment of the root system under saline stress conditions has been shown to have a positive effect on photosynthesis, regulating stomatal movement and maintaining optimal water balance. At the same time, the treatment favored the accumulation of proline, the maintenance of cellular homeostasis by activating the expression of genes that control ion transporters, as well as the antioxidant activity at the cellular level [39] .

Selim and El-Nady [67] demonstrated the protective effect against the water deficit of seed treatment with magnetized water and irrigation with magnetized water (especially at levels of 60% and 40% of field capacity). The positive effects were manifested in connection with the growth characteristics, water relationship, proline content and assimilatory pigments, as well as the anatomical structure of some plant organs.

Use of nanotechnology

Another proof of the concerns in the field of agrotechnology is the promising results presented by Colman et al. [16] with reference to the commercial potential of chitosan microparticles (CS-MP) and their possible introduction as input into the sustainable tomato production system. The application of the treatment to the seeds ensured a better germination, as well as an index of vigor with high values before transplanting, both regarding the root system and the stem. The explanations were easy to specify given the low level of ROS, the marked antioxidant activity and the modulation of defense marker proteins, including the participation of cytokinin and auxin signaling pathways during root formation.

Favoring plant growth, but also marked protection (72.9 %) against the attack of the fungus *Phytopthora infestans* which produces the late blight of tomato were recorded if seed was primed with mycogenic selenium nanoparticles (SeNPs).It has been shown that this treatment has resulted in the obvious accumulation of compounds involved in cellular defense processes, such as lignin, callose and hydrogen peroxide. The activity of some enzymes (lipoxygenase - LOX); phenylalanine lyase - PAL; β-1,3-glucanase - GLU; superoxide dismutase - SOD)) has also been intensified in treated plants with this nano-biostimulat fungicide [36]. At the same time, the results obtained by Chun and Chandrasekaran [15] confirmed that chitosan

(CS) and chitosan nanoparticles (CNPs) induced the expression of pathogenesis-related (PR) proteins genes: (PR-1; PR-2 - β-1,3-glucanase; PR-8-chitinase and PR-10) in the case of tomato - *Fusarium andiyazi* system, with an up-regulation of PR-proteins and antioxidant genes, also.

On the same note, studies carried out by Cumplido-Nájera et al. [18] emphasised that the simultaneous application of copper and silicon nanoparticles has been shown to induce tomato tolerance to *Clavibacter michiganensis*.The explanation given was that the treatment positively modified the enzymatic activity (SOD, PAL, glutathione peroxidases - GPX and ascorbate peroxidase - APX), reduced glutathione concentration and the phenol content in the leaves.

The use of eco-friendly nano-fungicides has also been shown to be effective in controlling the fungus *Alternaria alternata* [27]. Thus, after the biosynthesis of titanium dioxide nanoparticles (TiO_2NPs) and silver nanoparticles (AgNPs), by *Aspergillus versicolor* KY509550 through surface resonance peaks at 340 and 400 nm, respectively, and testing them, the expression of an antifungal activity of 100% inhibition in the laboratory trials was obtained in the case of TiO_2NPs. In greenhouse and field conditions, the significant effect of reducing the severity of the disease was also recorded at TiO_2NPs, while AgNPs showed a moderat effect.

Comparative studies conducted by Derbalah et al. [22] in the greenhouse on the antifungal effects against *A. solani* fungus of mesoporous silica nanoparticles (MSNs) as compared with metalaxyl (a recommended fungicide) have also led to promising results in terms of an effective and save alternative control of this disease. Furthermore, Hajiahmadi et al. [35] transformed tomatoes with MSNs containing pPZP122: 35S: GUS (pDNA-MSNs) and then transferred the *cryIAb* gene through pPZP122:35S:*cryIAb*-MSNs into tomatoes for *Tuta absoluta* control. The obtained results were successfully, so the system was characterised as a new and more efficient technique in crop genetic engineering.

For an overview of the advantages and doubts about the possible environmental and human risks of nanotechnologies applied in horticulture, it is recommended to consult the synthesis paper of Feregrino-Perez et al. [28]. A strong regulatory system regarding the use of nanoparticles is necessary [48].

Use of agrohomeopathy

In recent years, one of the newest approaches in agricultural research is agrohomeopathy. The scientific studies have shown the ability of the potentised homeopathic medicines to modify the physiological processes in plants and to provide some degree of resistance to the attack of biotic / abiotic stresses.

The use of four homeopathic medicines for human in two centesimal dynamizations (7CH and 13CH) [(*Silicea Terra* (SiT), *Natrum muriaticum* (NaM), *Zincum phosphoricum* (ZiP) and *Phosphoricum acidum* (PhA)], specifically improved tomato development depending on the dynamization or power used and the development stage [9].

Also, high dilution preparations of *Arsenicum album*, *Nitricum acidum* and *Staphysagria* at 6, 12, 25, 30, 50, 60, 80 and 100 CH (centesimal Hahnemannian dilution scale) were studied in vitro as a treatment against *A. solani*.

The dilution preparations have different effects on mycelium growth, according to the dynamization level.A decrease of *A. solani* colonies diameter was determined by *A. album* 80 CH, by *N. acidum* 80 and 100 CH, and by *Staphysagria* 6, 30 and 60 CH compared with the control, when applied over potato dextrose agar (PDA) medium [50].

Generaly spaking, applications of the homeopathy to seed invigoration [63], as well as a viable alternative to the use of agrochemicals [62], including on replacing pesticides in organic tomato production system [49] will be of interest in the future [70], after the better knowing of the action mechanisms of such eco-friendly treatments [9].

CONCLUSIONS

The tomato (*Solanum lycopersicum* L.) is one of the most cultivated vegetable species worldwide, both in protected areas (greenhouses, solariums), as well as in open - field conditions.

The use of seeds with high physiological quality for the establishment of crops, as well as for a better plants growth and productivity is a precondition for successfully overcoming the constraints caused by abiotic and biotic stress factors to which tomato plants can be exposed.

In the last decade, besides some well-known common priming techniques, researches have been focused on procedures for enhancing the tomatoes seeds physiological quality mainly based on the rhizobiome microorganisms exploatation as a sourse of bio priming agents, as well as modern novel emerging technologies (such as nanotechnology and agrohomeopathy), that have proven to be of interest from the economical, environmental protection and human health viewpoint in the context of increasing sustainability.

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