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Review

Current Situation of *Tetranychus urticae* (Acari: Tetranychidae) in Northern Africa: The Sustainable Control Methods and Priorities for Future Research

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Abstract: In North Africa, *Tetranychus urticae* Koch, 1836 represents one of the most destructive generalists among mite herbivores. Unfortunately, it is a source of important annual casualties in crop production. It is a phytophagous mite that can feed on hundreds of host plants and produces significant damage. The control of *T. urticae* in North Africa has been principally based on acaricide sprays. However, new alternative methods have shown effective results, such as artificial ultraviolet-B, natural enemies, and the introduction of new genetic methods. This review aims to present a synthesis of information surrounding control methods of *T. urticae* in North Africa. We highlight the principal findings of previous studies. Then, we discuss current control methods and propose new innovative research and sustainable approaches to controlling this pest. The control method can potentially extrapolate in North African regions due to its positive ecological results. Further, studies proved the use of natural enemies, myco-metabolites, bacteria metabolites, and the introduction of a genetic method in an integrated long-term sustainable program that can successfully defeat the populations of *T. urticae*. We also discuss high-priority research guidelines to investigate new sustainable management strategies. Setting up an integrated long-term ecological monitoring program in different Northwest African countries and incorporating new technologies into monitoring programs is an urgent need to fight this devastating pest.

Keywords: *Tetranychus urticae*; propagation; environment; crop protection; acaricide; biological control; integrated; management

1. Introduction

Maghreb countries share most of the phytosanitary problems [1]. North Africa's agricultural productivity is harshly restricted by multiple constraints. These constraints

include lack of manpower, maturity of orchards, biotic, and abiotic constraints. The negative impact caused by pests reduces the quantity and quality of production. Indeed, spider mites, aphids, medflies, and diaspine scales are pests of primary economic importance [2]. When conditions are favorable and in the absence of adequate methods of control, significant damage is often observed on fruits, twigs, leaves, and young shoots [1]. The effective control of insects in food products has long been the object of producers and the industry sector [3]. Its pests are resistant to most groups of acaricides [4].

Tetranychus urticae Koch, 1836 (Acari: Tetranychidae) is one of the most important pest species that is widely distributed globally; it is a phytophagous mite from the family of *Tetranychidae*. This species is a highly polyphagous herbivore and a major agricultural pest worldwide that causes hard damages to economics. It is a cosmopolitan species [2]. It presents a notable pest of field crops, ornamentals, and annual and perennial plants [5,6]; it attacks (i) fruit species, including citrus, apple, pear shrubs, and raspberry [7], (ii) vegetables, including eggplant, cucumber, bean, okra, and tomato [8–11], (iii) ornamentals, especially dahlia, rose, gerbera, zinnia, and ganda [12]; and medicinal plants, such as moringa (*Moringa oleifera*), metel (*Datura metel*), Alfalfa (*Medicago sativa*), Peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), and common vervain (*Verbena officinalis*) [13,14].

In Egypt, *T. urticae* causes principal damage, such as defoliation, leaf yellowing, and leaf burning [14,15], plus the indirect damage by diminishing photosynthesis, transpiration, and a significant decline in yield productivity [6,16]. In Morocco, *T. urticae* is undoubtedly remembered for its significant damages in agriculture and its redoubtable capacity to elaborate resistance to pesticides [17]; it causes qualitative and quantitative yield losses every agricultural season. All mobile stages of this mite preferentially feed on the lower surface of the leaf and extract the contents of mesophyll cells [14,18]. This pest attacks the cells of the parenchyma of which they absorb the contents with their cheliceral stylets, and provokes the appearance of yellow-greenish patches on the upper face of the leaves, thus producing the destruction of the foliage and the reduction of the period of filing of the ear [19]. Moreover, *T. urticae* causes severe damages in the Tunisian territory, particularly prevalent in the majority of orchards. During mid-March to June and from September to December; the citrus species of orange, lemon, tangerine, and pomelo are most susceptible [20].

Between mites' pests, *T. urticae* has the most significant proportion of pesticide resistance. In conventional chemical control management of *T. urticae*, broad-spectrum acaricides are often sprayed to diminish population levels. Nevertheless, they can additionally eliminate natural enemies, including auxiliary fauna [21]. Furthermore, multiple features of the spider mite biology, including incredibly high fecundity, rapid development, and haplodiploid sex determination, seem to facilitate the development of pesticide resistance [22]. The control of multi-resistant mites has become frequently difficult in North Africa [23]. This review aims to summarize North Africa's diverse current and prospective methods used to control *T. urticae* populations and motivate implementation of an integrated management strategy based on environmentally friendly practices, such as developing new biopesticides, physical control, or the use of a genetic approach. The goal of this study, on the one hand, is to describe the various control methods available for *T. urticae* in North African countries. On the other hand, it highlights the key findings from previous studies and overviews current and sustainable approaches used to manage this pest.

2. *Tetranychus urticae* in North Africa

Tetranychus urticae is a problematic pest of several global crops [24,25]. It is a generalist species that can feed on hundreds of host plants and produces significant damage to the field, greenhouse, and horticultural crops, as well as ornamental and fruit-bearing trees [26–29]. It can produce silk threads to protect itself from predators or to disperse from plant to plant. In Egypt, the generations of *T. urticae* follow one another at a rapid pace (approximately 27 generations per year) [30], *T. urticae* on Hood pear variety; the

highest mean number of eggs laid by a female was 143.6 eggs/female with a daily rate of 16.7 eggs/female/day at 30 °C [31]. In Moroccan conditions, this pest presents an optimal development at temperatures of 30 °C. The female can generate a high number of eggs in a short time; for instance, on clementine, they can lay about 34 eggs in a period of 17 days (the biological cycle takes from 8 to 12 days in optimal condition) [32,33]. The drying up of leaves due to *T. urticae*, can negatively affect the crop's green matter (GM) yield. However, a reduction in potassium, nitrogen, and phosphorus has been detected on *Chrysanthemum* infested by *T. urticae*. Additionally, [19] observed a reduction in amylase activity and proteolytic enzyme, and reduced the total amount of proteins. In Tunisia, the economic importance of this mite has expanded on many crops, principally because of its resistance to acaricides [34]. *Tetranychus urticae* in citrus orchards are mainly active during summer and autumn. The highest population density is recorded in July and August. On lemon, the attack can be observed throughout the year if the winter is mild. The varieties of the clementine groups are the joint susceptible to mite attacks causing significant defoliation. In Algeria, *T. urticae* is listed as one of the most dangerous pests that cause immense damage to vegetable plants [35].

3. Levels of Infestation and Severity of Spread

Tetranychus urticae is a cosmopolitan pest. It occurs in most parts of the world; in Europe, Asia, Africa, Australasia, Caribbean islands, and North America [36]. Further, this pest is adapted to different climatic conditions. In North Africa, especially in Morocco, *T. urticae* is one of the most recorded pests on various crops, including fruit trees (apple and citrus) and spontaneous plants [37,38]. Similar results were cited in Algeria and Tunisia, which are under the same climatic conditions as Morocco [39]. In Egypt, spider mite was found in fruit trees and ornamental vegetation, causing serious damage, according to the infestation rates on these plants [40,41]. The differences in infestation rates can be attributed to the variation of environmental conditions, planting dates, and age of plantation [42].

Tetranychus populations multiply fast in the weeds and orchards surrounding vegetation and migrate to occupy the fruit trees [43]. This spread is not always passive but often takes place under the action of various stimuli counting temperature, wind, rainfall, and farming practices [44,45]. On clementine, a study was conducted in the Gharb region of Morocco, in which the orchards were isolated for three cropping annuals and without practice of acaricide treatments, in order to know the severity of infestation rate by *T. urticae*. This study showed that the infestation degree of the trees was 10% in mid-April, to increase rapidly to 87% in July. According to this study, the spread occurs when the climatic conditions and the phenological development of the tree are favorable for the deployment of the mite [37]. *T. urticae* have been studied in Moroccan orchards over a period of ten weeks (from 25 March to 2 June 2002) on herbaceous strata and on two different varieties of apple trees ("Golden" and "Anna"). Adventitious plants such as *Cuscuta epithymum*, *Malva neglecta*, *Sonchus asper*, *Convolvulus arvensis*, and *Urtica urens* (and, to a lesser extent, *Mentha pulegium*, *Sonchus oleraceus*, *Papaver rhoeas*, and *Sinapis arvensis*) appear to be the most favorable host plants to *T. urticae*. Hence, they must be considered as potential sources of infestation for the fruit trees. In the North African countries, therefore, we suggest conducting this kind of research to estimate the infestation rates and propagation ways [46].

4. Kind of Hosts

Tetranychus urticae represents one of the most destructive generalists among mite herbivores [33]. It is considered a major pest decreasing plant growth and yield on different crops [47]. Among these, in North Africa, it attacks flowering plants and fruit crops, such as apricot, cherry (*Prunus* sp.), apple (*Malus domestica*), *Citrus* sp., strawberry (*Fragaria ananassa*), blackcurrant (*Ribes nigrum*), quince (*Cydonia oblonga*), plums (*Prunus domestica*), pear (*Pyrus communis*), cotton (*Gossypium hirsutum*), clover (*Trifolium* sp.), sunflower (*Helianthus* sp.), grapevine, eggplant (*Solanum melongena*), moringa (*Moringa oleifera*), melons,

watermelons (*Citrullus* sp.), baby marrow (*Zucchini* sp.), cucumber (*Cucumis sativus*), green beans (*Phaseolus vulgaris*), carrots (*Daucus carota*), peanut (*Arachis hypogaea*), bindweed (*Convolvulus arvensis*), metel (*Datura metel*), alfalfa (*Medicago sativa*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), common vervain (*Verbena officinalis*), and (*Rosa* sp.) have been recorded [31,48,49].

5. Control Methods

5.1. Chemical Control

In the commercial orchards of Northern Africa, the protection against pests is currently assured by preventive and intensive chemical control. Despite benefits such as rapid action in the reduction of pests numbers and their easy use when compared to natural extracts from plants [50], this strategy has many limitations; the examination of the action spectrum of the active components used throughout the world reveals that 46% of acaricides, 72% of insecticides, and 28% of fungicides are globally toxic towards auxiliary arthropods and public health [51]. Additionally, spider mites have developed resistances to more than 80 acaricides in more than 60 countries [34]. Particularly, *Tetranychus urticae* has developed resistances to more than 30 organophosphates and carbamates in 40 countries, this resistance is due to mutations in the mitochondrial cytochrome b protein of this pest [52]. Besides, a non-rational application of benomyl [methyl 1-(butylcarbamoyl) benzimidazole-2-ylcarbamate] and other pesticides killed all noticeable predators of the pest [53]. Therefore, the absence of control by natural enemies due to their death by pesticides can cause a considerable increase in *T. urticae* populations [54].

In Morocco, the Spirodiclofen (240 g/L), Malathion (440 g/L), Abamectine (18 g/L), Bifenazate (480 g/L), Fenpyroximate (51,2 g/L), Fenazaquin (200 g/L), Tébufenpyrad (20%), Propargite (57%), Milbémectine (1%), Bifenthrine (100 g/L), Clofentézine (500 g/L), Pyridabène (100 g/L), Maltodextrine (27%), and Dicofol (18,5%) are the most acaricides used to control the tetranychid mites in greenhouses and orchards [55]. In the Loukkos Morocco area, to prevent the *T. urticae*, the majority of strawberry plants are treated with Abamectin [2,54]. In Tunisia, the main acaricides used to fight *T. urticae* on diverse crops are Hexythiazox 10% WP, Fenpyroximate 50 g/L SC, Abamectin 18 g/L EC, and Pyrethrin 40 g/L EC [56]. In Egypt, the use of the Abamectin revealed excellent results and important toxicity on *T. urticae* [57]. However, the intensive Abamectin applications have diminished the efficacy and shortened their effect, indicating a potential resistance development problem [57,58]. The effects of acaricides on *T. urticae* are extensively studied [59,60]. The intensive and abusive use of acaricides to control this mite has driven an increasingly important resistance against carbamates, cyclodiene organochlorine, organophosphates pyrethroids, organotin miticides, benzoylureas, organochlorines, hydrazine carbazate, macrocyclic lactones, and other chemical products [61]. Other effects have been noticed, such as alterations in the physiology and biology of living organisms and modification of fecundity and behavior [62]. To overcome this difficulty, the experts are constantly exploring new products based on biological control, particularly biopesticides [23,63].

5.2. Biological Control

Biological control agents such as bacteria, predatory insects, or fungi can be used as alternative approaches for control [64]. Bacterial organisms, such as *Yersinia entomophaga*, *Xenorhabdus* spp. *Pseudomonas entomophila*, *Burkholderia* spp. *Chromobacterium* spp. *Streptomyces* spp. *Saccharopolyspora* spp., and *Bacillus* spp. have all recently gained commercial interest for the production of diverse metabolites that act as effective insecticides [65]. Secondary metabolites of fungi, such as *Aspergillus melleus*, *Emericella nidulans* G. Winter, 1884, *Alternaria terreus*, *Chaetomium globosum*, *Trichoderma viridae*, and *Eurotium eurotiorum* are a promising source of control against various agricultural pests [66].

The most important predators that have significantly managed *T. urticae* and other spider mites are *Amblyseius swirskii* (Athias-Henriot, 1962), *Typhlodromus rhenanoides* (Athias Henriot, 1960), *Phytoseiulus persimilis* (Athias-Henriot, 1957), *Typhlodromus phialatus* (Athias

Henriot, 1960), *Neoseiulus cucumeris* (Oudemans, 1930), *Neoseiulus stolidus* (Chaudhri, 1968), *Feltiella acarisuga* (Vallot, 1827), *Scolothrips longicornis* (Priesner, 1926), *Euseius scutalis* (Athias Henriot, 1958), *Euseius stipulatus* (Athias Henriot, 1960), and *Stethorus punctillum* (Julius Weise, 1891) [5,59].

5.2.1. Myco-Metabolites

The fungal isolates of *Aspergillus melleus*, *Emericella nidulans*, *Chaetomium globosum*, and *Aspergillus terreus* presented practical control activities against females and eggs of two-spotted spider mite [66]. The effect of culture filtrates of fungal isolates showed mortality rates of 52.4%, 52.4%, 48.4%, and 50.4%, exhibited by *Alternaria terreus*, *A. alternata*, *Trichoderma viridae*, and *Eurotium eurotiorum*, respectively [67]. Further, the laboratory evaluation showed these secondary metabolites of *A. melleus*; (nodulisporic acid, melleamide; ochratoxin C, 7-oxocurvularin, 6-(4'-hydroxy-2'-methyl phenoxy)-(-)-(3R)-mellein and 7-oxocurvularin can be used as biopesticides in the biological control of *T. urticae* [66]. Similarly, the *Azadirachta indica* (neem oil) extract registered that the mortality proportion of adults was 100% at all tested concentrations after 72 h of application [68]. In Spain, *Beauveria bassiana* gave impressive results in the control of *T. urticae*, and therefore is a candidate to be included in integrated pest management programs with triflumuron against *T. urticae* [69].

5.2.2. Bacterial Metabolite

The essential secondary metabolites implicated in biocontrol by fluorescent pseudomonads are pyoluteorin (PLT), phenazines (PHZ), 2, 4-diacetylphloroglucinol (DAPG), cyclic lipopeptides (CLPs), pyrrolnitrin (PRN), and volatile natural composites (VOCs) such as hydrogen cyanide (HCN). These metabolites are recognized for antibacterial, antifungal, antiviral, antitumor, and antinematicidal properties [63]. A study in Morocco at the laboratory showed that all three fluorescent pseudomonas isolates Q110B, Q036B, and Q172B from tomato rhizospheric soil were potential biological control agents for *T. urticae*. In particular, *Pseudomonas fluorescens* isolate Q036B was the most promising applicant for biological control of *T. urticae* with a mortality rate of approximately 99% 72 h after application. For the other two strains (Q172B and Q110B), the mortality rates were similar 72 h after application and varied from 54 to 89% [23]. Besides, the *P. fluorescens* produces bacterial chitinases, which are efficient in controlling the mites by hydrolyzing their chitinous exoskeleton, the culture with cent percent of *P. fluorescens* produced 100% mortality of spider mite in 24 h after application, whereas 75% culture yielded 100% mortality in 72 h, when 48 h, 50% culture was found to be least effective [70]. In Turkey, under laboratory conditions, *Pseudomonas putida* isolated from tomato soils produced high mortality rates of *T. urticae*. This bacterial application significantly diminished the total number of eggs and egg hatch compared to the control [71]. Thus, multiple *Agrobacterium* strains, *Streptomyces*, *Bacillus*, *Pseudomonas*, *Alcaligenes*, and others have been notified as help bacterial control agents. To fight against pests, they employ many biotechniques, for example competition, parasitism, antibiosis, and cross-protection [72,73].

5.2.3. Protectants Plant-Incorporated (PIP)

The extracts of plants are remarkably rich in toxins and inhibitors and can be the source of many insecticidal and acaricidal substances exploitable in the control of pests [74,75]. Black soap, brown in color, is biodegradable, non-polluting, and an excellent insecticide. This product is active on some insects such as mealy bugs, aphids, whiteflies, thrips, mites, etc. Through simple contact, it asphyxiates them while blocking the respiratory pores. Besides, it does not produce toxic residues and does not affect natural predators. These products are authorized by the specifications of organic agriculture (EEC regulation 2092/91) [76,77]. A study conducted in the Saïs region of Morocco showed that black soap was effective against several pest populations on the bell pepper crop compared to the control block [77].

The utilization of Sulfur on tomato leaves diminished *T. urticae* from 31.5 ± 6.5 individuals/15 leaves before treatment to 4 ± 0.3 [78]. This reinforces the results observed on the grapevine [79], according to which sulfur can be used to control mites while presenting low toxicity to predators. Another study under laboratory conditions confirms that sulfur is toxic against eggs of *T. urticae* [80]. In the field, the lime sulfur reduced *T. urticae* fecundity and fertility. It showed selectivity against naturally occurring predatory mites, which increases its potential as a mechanism for integrated mite management [78].

The pesticide effects of the diverse specific components of *Achillea millefolium* essential oil have been assessed in recent studies. Piperitone [81], cymene, borneol [82], bornyl acetate [83], 1,8-cineole, α -pinene [84], α -terpinolene [85], camphene [86], α -terpinene [87], and carvacrol [88] revealed prospective pesticidal effects. Besides, the susceptibility of *T. urticae* to some monoterpenes has been reported [82,84,86,89]. According to the apparent results in the laboratory condition, it can be concluded that the major component of essential oil of *A. millefolium* is responsible for the acaricidal action against *T. urticae* and may be useful in the exploration of the effective natural products such as acaricide [90]. *Mentha* sp. essential oils can be used in sustainable pest control. In Egypt, under greenhouse conditions, *Mentha longifolia* showed 100% toxicity to *T. urticae* [91]. In Algeria, the essential oils obtained from *Mentha spicata* presented a better insecticidal impact against most pests [92]. The sesquiterpenoids isofuranodiene and germacrone from the crucial oil of *Smyrniolum olusatrum* (Apiaceae) recorded significant oviposition inhibition, and they can be used to produce adequate acaricides [93]. In Tunisia, field experiments, the extracts of three plant species (*Allium sativum*, *Allium cepa*, and *Deverra scoparia*) produced an effective control of *T. urticae* population more than 15 days compared with the untreated control and with classical synthetic acaricides (spirodiclofen and fenbutatin oxide) [75,94]. Besides, the tests have revealed that the extract of *A. sativum* was efficient on the population of *T. urticae* was diminished to 1.7 mites per leaf for more than 21 days after treatment compared with the untreated control at 3.7 mites per leaf [50].

The laboratory tests showed that the fumigant toxicity of 24 essential oils from lemon eucalyptus was effective against females of *T. urticae* menthol being the maximum toxic compound, followed by citronellyl acetate [95]. The two eucalyptus essential oils, specifically *Eucalyptus lehmani* and *Eucalyptus astringens*, showed a positive effect against strains from Tunisia and Algeria of three stocked beetles: *Rhyzopertha dominica*, *Callosobruchus maculatus*, and *Tribolium castaneum* [96]. In Tunisia, the ten principal constituents of *Deverra scoparia* oil were individually tested against *T. urticae* females. The greatest toxicity was found with α -pinene, 3-carene, and terpinen-4-ol. pinene. The presence of all elements together in the artificial mixture caused a notable reduction in the number of eggs laid by females of *T. urticae*. The essential oil of *D. scoparia* showed that female mortality increased with growing oil concentrations, and a decline in fecundity had been observed. *Deverra scoparia* might add to the arsenal of programs for controlling mites in open field and in greenhouses. However, further studies are needed to evaluate the cost, efficiency, and safety of the oil, besides knowing each constituent's role in the toxicity and effects on fecundity [97]. In laboratories growing wild in the Mediterranean area, the mortality rates of 95–100% were observed at all the sage oil dosages and when rosemary emulsions contained at least 0.20% essential oils [98]. In the laboratory sage, the essential oil had raised mortality (toxicity to adult females of *T. urticae*) and diminished fecundity (production and viability of eggs) [98]. The essential oils lose their force against environmental conditions. Nanoformulation is a method that may preserve the pesticide performance of plant essential oils. The Chitosan nanocapsules loaded with the essential oil of *Achillea millefolium* against adult *T. urticae* showed a beneficial effect [99].

5.2.4. Control with Predators

The main predators encountered in North Africa are *Typhlodromus rhenanoides*, *Phytoseiulus persimilis* (Athias-Henriot), 1957, *Typhlodromus phialatus*, *Neoseiulus cuc-*

umeris, *Neoseiulus stolidus*, *Feltiella acarisuga*, *Scolothrips longicornis*, *Euseius scutalis*, and *Euseius stipulatus*.

Phytoseiulus persimilis (Athias-Henriot, 1957)

Phytoseiulus persimilis (Acari: Phytoseiidae) is a specialist predator that feeds particularly on *Tetranychus* species and whose survival depends on the presence and quality of its prey [50]. In Morocco, *P. persimilis* is the principal predators of *T. urticae* in the open field and in greenhouses [100], according to faunal estimations performed in 2009–2010 on strawberry plants in the Loukkos region which revealed that the mite pest *T. urticae* and its natural enemy, the predatory mite *P. persimilis*, are habitually encountered [2]. In Egypt, this predator is one of the most significant biological control agents against the two-spotted spider mite. This predator can control *T. urticae* on different crops when it releases at low infestation [6]. In Turkey, the greenhouse tests were conducted to discover the efficiency of single and combined releases of two predatory, *P. persimilis* and *Neoseiulus californicus* (McGregor, 1954) to control the *T. urticae* on the Soybean plant; the authors concluded that releasing of *P. persimilis* was the best control method among the other combined releases tested to control spider mites. The similar results were found [101] in Spain, the release of *P. persimilis* alone was better than combined releases. Generally, *P. persimilis* is an efficient natural enemy in the Mediterranean greenhouse crops to the mite *T. urticae* [102].

Neoseiulus californicus McGregor, 1954

The *Neoseiulus californicus* (Acari: Phytoseiidae) is a cosmopolitan species of Mediterranean climates that tolerate the higher temperatures of semi-arid to arid areas [103,104]. In Egypt, the *N. californicus* is the natural enemies associated with *T. urticae* [57]. In Morocco, the predatory mite *N. californicus* feeds on all stages of the weaver mite *T. urticae* on citrus crops [105]. In Tunisia, the *N. californicus* is a predatory Phytoseiidae widely utilized in integrated pest management programs to control the tetranychid mites in citrus, apple, fruit, and vegetable crops [106]. This predator plays a key role in the regulation of *T. urticae* in Spanish citrus orchards [107].

Euseius stipulates Athias-Henriot, 1960

This species was described from North Africa in Algeria, Morocco, Tunisia [108]. It feeds on the red spider and eriophyid mites and consumes pollen [108]. In Tunisia, *E. stipulatus* was the most abundant species found on citrus trees (82%) [20]. Generally, this species is well represented in Mediterranean citrus orchards [109].

Combined Releases

In Egypt, the releasing of predators *Chrysoperla carnea* (Steph, 1836), *Orius albidipennis* (Reuter, 1884), and *P. persimilis* showed significant control of *T. urticae*, and it also assured increased crop yield as compared to pesticide application [110]. In Morocco, the new introduction in citrus orchards, such as the predators *Neoseiulus californicus* and *Amblyseius swirskii* against *Eutetranychus orientalis* (Klein, 1936) and *T. urticae* have produced good results [111]. Similarly, in Spain, the control of *T. urticae* through releases of the predatory mites *Phytoseiulus persimilis*, *Neoseiulus californicus*, *Amblyseius swirskii*, and *Orius laevigatus* Fieber, 1860 (Hemiptera: Anthocoridae) showed significant results. Besides, the combined release of *O. laevigatus* with *A. swirskii* gave efficient control of sweet pepper principal pests [112]. The use of *F. acarisuga* (Diptera: Cecidomyiidae) and *S. longicornis* (Thysanoptera: Thripidae) play an important role in the control of spider mites populations in different crops [113]. In Spain, *Stethorus punctillum* (Weise, 1891) is an important predator of spider mites, especially *Panonychus citri* (McGregor, 1916) and *T. urticae* in citrus orchards [114]. *Amblyseius andersoni* (Acari: Phytoseiidae) is an important predator species found in multiple crops. The nymphs and adults of *A. andersoni* are predaceous, feeding on different spider mite species [115]. A study confirmed that the use of this predator alone or in combination with other phytosides mites provides better control of spider mites [116].

5.3. Physical Control

Integrated pest management should rely on an array of tactics. In reality, the use of physical control methods must be part of an integrated pest management approach. Physical controls can be classified as passive (e.g., fences, organic mulch, trenches, particle films, inert dust, and oils), active (e.g., thermal shocks, electromagnetic radiation, mechanical shocks, and pneumatic control), and miscellaneous (e.g., cold storage, heated air, flaming, hot-water immersion) [117]. Some physical methods such as oils have been used successfully for preharvest treatments for decades [118]. Another recently invented method for preharvest situations is particle films [119]. As we move from production to the consumer, legal constraints restrict the number of alternatives available. Consequently, several physical control methods are used in postharvest situations. Two notable examples are the entoleter, an impacting machine used to crush all insect stages in flour [120], and hot-water immersion, used to kill tephritid fruit flies [121].

Over the past decade, UV Perspective, the solar and artificial ultraviolet-B (UVB) radiation, has frequently been shown to exert deleterious impacts on the survival and egg production of mites [122]. The eggs and larvae of *T. urticae* are more vulnerable to UVB radiation than adult females, and mortality is directly proportional to the cumulative UVB irradiance [123]. Additionally, using the ultraviolet-B method control of spider mites showed excellent results, especially for greenhouse horticultural crops such as strawberries; performing it is a favorable IPM strategy [124]. Conversely, the enhanced UV-B radiation increases the deleterious effects on insect behavior and health and affects their interactions with plants via induction of defensive material products and photomorphogenic variations. Insect suction devices, insect glue, and electromagnetic energy suppress insect populations. Generally, the physical control methods are environmentally safe, fit well into IPM strategies, and significantly reduce chemical control [125]. These methods are not yet explored in North Africa, but with the similarity of Mediterranean context recorded, we suppose that the good results documented in South Europe could be extrapolated to North Africa.

5.4. Genetic Control

Genetic control is one of the methods that can replace the application of insecticides [126]. The examination of the sequenced genome of *T. urticae* will reveal the resistance mechanisms used by the mites. Moreover, the complete sequencing revealed that this genome, considered small with its 90 million bases, includes unique genes that have not yet been identified in other arthropods [17]. The researchers also identified numerous genes implicated in detoxification and digestion of toxins, which help explain the mite's unparalleled resistance to toxic compounds produced by certain plants to defend themselves, opening up the prospect of developing naturally resistant plants [127].

5.5. Integrated Pest Management of *Tetranychus Urticae*

Integrated pest management through predator and a compatible synthetic acaricide may provide an alternative strategy to chemical control of the pest [128]. Experiments were conducted on greenhouse roses to evaluate the efficacy of the nC24 petroleum spray oil (PSO), D-C-Tron in combination with *Phytoseiulus persimilis* (Acarina: Phytoseiidae) against *Tetranychus urticae* in the context of developing an integrated management program. Results showed that 0.5% PSO applied fortnightly to roses provided excellent protection against *T. urticae* infestation and did not affect the population density of *P. persimilis* in the upper and lower foliage [129]. In Brazil, on strawberry crops, control of *T. urticae* in the program based on release of *Neoseiulus californicus* (McGregor) and reduction of the frequency of acaricide applications (IPM) was effective in maintaining a significantly lower level of pest infestation, resulting in a six-fold reduction in the frequency of acaricide applications and, consequently, a reduction in selection pressure for acaricide resistance [130]. Another field experiment in hops using b-acid sprays with a release of the predatory mite *P. persimilis* ensured significant control of *T. urticae* [131].

6. Conclusions

This review highlights the current knowledge and prospects of sustainable control approaches against *T. urticae* used in North Africa, to clarify the current situation of this pest and inspire specialists in other countries to control it. In addition, it serves as a roadmap for scientists to expand their research. In terms of plant protection, it is clear from the discussions, developed in our study, that integrated pest management remains the most appropriate sustainable method for better crop protection. Practiced by the majority of Maghrebian countries, chemical control is the most widely used method in commercial agriculture. This is essentially due to economic and technical reasons. Henceforth, the control methods must be based on the use of biopesticides, genetic control, and physical control in an integrated long-term sustainable program. The development of physical control provides interesting opportunities as mechanical control, thermal control, electromagnetic control, and pneumatic controls. Their inclusion in an integrated pest management program can contribute greatly to the achievement of the pesticide reduction objectives set by several countries and organizations. In this context, responsible agricultural organizations should actively support the development and implementation of physical control methods in integrated pest and plant protection management programs. Genetic modifications of plants and mites could be performed to improve the molecular mechanisms that control the plant–mite interplay. An advanced understanding of the mite–plant interaction will be an effective tool for protection. The advances are also expected in light of pest control due to these technological developments in lighting. Finally, the current trend is to combine all these methods in an integrated pest management strategy. These programs must take into account the climate conditions, phenology of pests, infestation rates, and propagation speed of pests in each North African country. All these elements are suggested to control pests, respect the environment and public health.

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