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REVIEW PAPER

Mitigation of pest pressure in crops by the foliar application of vegetable extract and cultivation of marigold as a companion crop: A review

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Abstract

Tomato cultivation in Pakistan, particularly in Punjab region, faces challenges due to extreme weather conditions and pest attacks, impacting growth and production. This review explores strategies to mitigate pest pressure in tomato crops including allelopathy, botanical sprays, and companion planting with marigold. Companion planting with marigold effectively controls fruit borers and manages *Meloidogyne incongnita*, a root-knot nematode. The article also discusses challenges in the Capsicum genus due to pests like whiteflies, thrips, and jassid. Botanical extracts, such as ginger, have proven effective in managing jassid infestations. Additionally, companion cropping with marigold has shown to bolster tomato production by diminishing pest attacks on the roots and exhibiting positive effects on - crops such as cabbage and chili. However, when chili was cultivated alongside maize and sweet potato, it causes reduction in the production of chili. These insights underscore the significance of innovative approaches, such as companion planting, for sustainable pest management, while aiming to augment crop yields. The article provides an extensive overview of various botanical extracts and synthetic insecticides tested in pest management. These include Eucalyptus, Bakayan (*Melia azedarach*), Chilli (*Capsicum annum*), Thyme (*Thymus volgaris*), Onion (*Allium cepa*), and Steward 150 EC (Indoxicarb). The efficacy of these botanical extracts in controlling pests in crops like tomato, marigold, basil, and celery is evaluated, emphasizing the potential of certain botanical extracts, such as marigold, owing to their allelopathic properties. Additionally, the practice of companion cropping with mint, okra, and leek is highlighted as an effective strategy in curbing whitefly infestations in tomatoes. The current manuscript also examines the use of botanical fungicides like cinnamon and clove extracts to combat plant diseases. Conclusively, the botanical extracts including onion, bakayan, and chilli, hold promise as substitutes for synthetic insecticides due to their accessibility, safety, and their minimal adverse effects on natural enemies and non-target species.

Keywords: Allelopathy, Botanical spray, Companion crop, Marigold, Pest pressure, Tomato

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Introduction

Tomato is being grown on all over Pakistan mainly in Punjab during the month of November to December. Extreme summer of Punjab compel tomatoes to be grown on high altitudes. Tomato is unable to produce flower below 15 °C because it is very sensitive to frost. It also does not grow well over 35 °C because it is sensitive to extreme heat. It grows well between temperatures 21 to 24 °C. Tomato is most susceptible to diseases, weeds and pests in May and July-August (Pakistan Agricultural Research Council [PARC], 2007). Fresh tomatoes annual production of world is almost 159 million tonnes. Although, processing industry covers more than half of this 159 million tonnes of tomatoes, which make tomatoes world's largest vegetable to be processed. Tomatoes are planted on vast area of 63602 hectares as in year 2017-18 annual yield of Pakistan was about 601098 tonnes (Faostat, 2017). In Pakistan 35.6 kg per capita is average vegetable use.

World Health Organization (WHO) recommended 73 kg of vegetable consumption on per capita. Fruit of tomato is used as a fresh vegetable and being processed in different products (Lal & Lal, 1996; Hussain & Bilal, 2007). No cooking preparation is complete without tomato. Tomato is very famous around the world due to its high usage. Among top 15 vegetables listed by FAO, tomato ranks 6th in total annual production of world. Tomato is among 40 types of vegetables that could be grown in Pakistan (Ishtiaq & Panhwar, 2017). Tomato contains potassium, vitamin C, vitamin A and other elements like fiber. Tomatoes can thrive in a variety of environments, whether they are cultivated with the support of modern agricultural practices or grown under sub-optimal conditions through subsistence farming. Biological pest control methods offer a more balanced and environmentally responsible approach to managing pests in tomato cultivation. They reduce the harm to non-target species and decrease the

risk of pesticide resistance development. These methods promote healthier ecosystems and contribute to the long-term sustainability of tomato farming while minimizing the impact on the environment (Adedipe, 2018).

Many alternative techniques which are eco-friendly are assessed as companion cropping which ultimately put a break on aphid population and reduce their damage to low level (Dahlin et al., 2015). A specific kind of poly culture when two plants are planted together because it is supposed to have a useful, synergistic enhancement on the growth of both plants is called companion cropping. It should not be confused with intercropping, which is the efficient use of area by growing vegetables near to each another or in close arrangement (Kourik, 2005). Companion planting is a technique which includes growing different type of crops to getting better biodiversity, use space economically, getting mutual benefits to achieve a balance of nutrition and management of site to increase number of friendly natural predators for getting higher yield and managing other biological hazard as nematodes, weeds, disease causing pathogens and insect pests. It could give lots of benefits as giving shade to those plants which loves to grow in shade, to repel damaging insects, to attract crop friendly insects, or to provide other important soil supplies to those planted in this system. Companion plants could easily repel pests, increase nitrogen fixation, deter adult pests, attract beneficial insects, destroy weeds, prevent and eradicate root nematodes, conserve and protect soil moisture, used in trap cropping to trap insects, and plant roots to prevent from soil-borne insects and other pathogens (Reddy, 2017). It could be a pest management technique to intercrop companions with horticultural crops. Aphid infestation could be reduced by organic volatile compounds emitted by companion plants (Dardouri et al., 2017). Intercropping is a proven approach for getting higher amount of sustainability in vegetable growing. So this system helps in reducing diseased pests, and weeds also (Galea et al., 2017). Diversification may help to expand the abundance of helpful insects due to giving expanded botanical flora, substitute prey and hosts, also more and best suited sites for hibernation, mating and oviposit ion to counter natural enemies of crop pests (Alignier et al., 2014). When, we plant it in a correct method, many plant species have the power of producing mutualistic association in which every species get benefits (Kourik, 2005).

Marigolds are successfully used as a trap crop to combat fruit borers in tomato plants (Srinivasan et al., 1994). Marigolds effectively dominate soil-dwelling pathogenic nematodes, specifically Meloidogyne and Pratylenchus penetrans, owing to their abundance of heterocyclic sulfur compounds called thiophenes (Topp et al., 1998). Fruit worms and their adult counterparts prefer laying eggs on young marigold flowers over tomato fruits, resulting in reduced *H. armigera* infestations in tomatoes (Srinivasan et al., 1994). While chemical fertilizers may boost yield, they lack the natural support that organic fertilizers provide. Compost, on the other hand, can offer this natural support and stimulate root growth (Jesikha, 2013). Chemical control methods are widely employed to combat aphids, effectively reducing their numbers. However, they come with environmental risks and increased costs due to repeated use of synthetic aphicides (Foster et al., 2002). The extensive use of synthetic chemicals also leads to pesticide residue buildup and resistance among pests. Hence, there is a growing trend towards more eco-friendly techniques, such as trap cropping management (Fitt, 1989; Mehrotra, 1989). The heavy reliance on chemical methods for pest control has led to a decline in the effectiveness of certain insecticides, especially synthetic pyrethroids (Dilbagh & Narang, 1990). Whitefly infestations can cause extensive damage, including up to 100% crop loss, and can transmit the Tomato Yellow Leaf Curl Virus. To combat whitefly infestations, a variety of insecticides, including carbamates, organophosphates, and organochlorines, are commonly used in many crop management systems. However, these insecticides can harm fruits and foliage by leaving toxic residues (Gupta & Dikshit, 2010). Growers heavily rely on chemical solutions for effective pest control, but the declining effectiveness of certain insecticides and the environmental impact of these chemicals call for a shift towards more sustainable and eco-friendly pest management methods.

Enhancing tomato yield and quality through eco-friendly pest management strategies

Pests that commonly infest tomatoes include thrips and aphids, leading to yield losses ranging from 5% to 80% (Dong & Zhang, 2011). The application of vegetable extracts on various crops has shown promising results. Modern scientists favor biopesticides due to their advantages over chemical alternatives. The annual global production of biopesticides has reached 3,000 tonnes, with a continuous upward trend (Gupta & Dikshit, 2010). The use of plant extracts for pest management is gaining prominence, and there is a growing need to shift towards eco-friendly methods for safeguarding plant growth against pests and diseases (Zarins et al., 2009). Many plant species contain natural compounds, such as allelochemicals, that can attract or repel pests and beneficial insects. Some plants enhance the growth of companion plants, thereby improving overall fruit quality and yield (Tringovska, 2015). Research has shown that plant-derived chemicals are specific in their action, environmentally friendly, and ideal for integrated pest management (IPM). Approximately 2,000 medicinal plants and herbs possess insecticidal properties (Ghosh, 2013). Traditional insecticides are facing resistance from insect pests worldwide (Cahill et al., 1996). To enhance the abundance of beneficial insects, herbal extracts have been incorporated into pesticides, offering a safer alternative (Hanssen et al., 2010). Plant extracts are used as antifeedants, repellents, insecticides, acaricides, and oviposition deterrents. These natural sources do not contain toxic materials and decompose rapidly, making them a sustainable alternative to synthetic pesticides (Garcia et al., 2004).

Tomato (*Solanum lycopersicum*), a member of the Solanaceae family, originated in western South America and was initially known as "Tomati" in Mexico (Kimura & Sinha, 2008). Whiteflies are also major pests, causing damage by feeding on various parts of the tomato plant (Mutisya et al., 2016). While chemical control is effective for aphids (Ben-Issa et al., 2017), natural pesticides are gaining popularity due to their environmental friendliness and rapid degradation (Kumar, 2012). Mealybugs, another significant pest of the Solanaceae family, can weaken and even kill tomato plants through defoliation. They secrete honeydew, which can lead to secondary diseases like sooty mold (Ibrahim et al., 2015). Mealybugs are known to infest around 200 different plant types, causing economic losses (Gebregergis, 2018). Various strategies, including biological control, are employed to manage mealybugs (Canario et al., 2017).

Companion planting with marigold for sustainable agriculture

Modern agriculture relies on chemical insecticides to combat pests, harming the environment (Galanihe et al., 2017). Intercropping, a long-standing agricultural practice boosts yields and reduces diseases (Boudreau, 2013). Planting companions offer numerous benefits, including pest control, nitrogen fixation, improved nutrient uptake, water conservation, and enhanced biodiversity (Bowen et al., 2016). Marigolds like *Tagetes patula* are excellent for companion planting as they release pest-repelling a-terthienyl from their roots (Gommers & Bakker, 1988; Hooks et al., 2010). Integrated Pest Management (IPM) methods produce vegetables with minimal pesticide residues (<0.01 ppm), surpassing conventional methods (Sharma et al., 2009). IPM ensures chemical-free vegetables with higher productivity (Osee Muyima et al., 2004). Companion planting optimizes space, nutrition, habitat management, and pest control. Companion plants reduce pests, attract beneficial insects, fix nitrogen, eliminate weeds, deter root nematodes, conserve soil moisture, and repel soil pathogens through root exudates (Reddy, 2017). The ideal companion plant directly benefits the farmer and target crop (Parker et al., 2013). Marigolds have variable effects when intercropped with cash crops (Hooks et al., 2010). Vermicompost benefits tomato and pot marigold growth and pest control (El-Salam et al., 2015). Intercropping with French marigold enhances celery growth and yield (Galea et al., 2017). Marigold is highly effective in reducing whitefly infestation in tomatoes (Adedipe, 2018). Planting marigolds with tomatoes reduces whitefly infestation, with limonene from marigolds being a key factor (McDaniel, 2017; Conboy et al., 2019). Companion crops like mint, okra, and leek decrease whitefly infestation in tomatoes, while carrots protect against virus diseases (Galanihe & Madugalle, 2017).

Harnessing marigold's allelopathic powers for pest control in tomato farming

Wild marigold possesses natural pest control abilities through allelopathy, with its root exudates containing toxic compounds that exhibit nematicidal, insecticidal, fungicidal, antiviral, and cytotoxic properties (Bhattacharyya, 2017). Integrating marigold plants into tomato fields not only manages pests effectively but also increases tomato crop profits by PKR. 63,780 per hectare. Utilizing marigold as a companion plant for tomatoes proves highly successful in controlling fruit borer, such as *Helicoverpa armigera* (Hubner) (Singh & Tripathi, 2017). In addition, the widespread issue of early blight in tomatoes, caused by *Alternaria solani*, can be mitigated by using marigold as a trap crop. Early infestations can damage tomato leaves, and later stages result in fruit damage, causing significant yield losses (Gomez-Rodrıguez et al., 2003). The most effective approach involves a 3: 1 ratio of tomato to marigold transplantation, reducing larval infestation and fruit loss. Interplanting with specific crop spacing can enhance pest control. High-density planting with basil, tomato, and brussels sprout demonstrates beneficial outcomes. While companion planting with basil offers advantages for brussels sprout crops, growing tomatoes and brussels sprouts together does not yield the same benefits (Bomford, 2004). Intercropping can lead to better growth and quality of crops, as seen in celery intercropped with cauliflower, which results in longer stalks and more stalks per plant (Galea et al., 2017). Botanical fungicides, such as cinnamon and clove extracts, exhibit potent antifungal properties and can match the effectiveness of chemical fungicides when used in combination. Methanol extract of clove (S. aromaticum) shows the highest inhibition zone compared to other extracts (Yeole et al., 2016). Plant-based products like chinaberry, marigold, and neem tree extracts are widely utilized in the production of eco-friendly bio-pesticides. These bio-pesticides are effective against insects and fungi without harming the environment. Extracts like neem oil demonstrate superior results in maintaining biochemical characteristics in citrus fruits (acidity pectin, ascorbic acid, and TSS) (Khursheed et al., 2022).

Botanical extracts as effective pest control solutions for crop protection

Tagetes erecta extracts (20% w/v, 100 ml each) from pre- and post-blooming stem and root portions were tested for their effectiveness in controlling M. incognita in infected soil (10 kg) with defenseless *Lycopersicon esculentum*. The results showed that *T. erecta* extracts significantly increased plant height and leaf number compared to those grown in naturally infected soil (Anjum et al., 2016). Aqueous extracts of marigold demonstrated efficacy against bacterial speck in tomatoes by inducing the expression of genes PPO, PAL, and POX, making marigold extracts effective as bio-pesticides (Goel et al., 2017).

Cucumber extracts, when combined with other species, reduced insect pests, with onion and garlic extracts prepared using the citrate-buffered QuEChERS method proving effective. The combination of extracts further reduced pesticide residues, with most combinations showing minimal residues (Chen et al., 2017). Bitter gourd and round gourd extracts effectively reduced the population of fruit flies, especially in female fruit flies, without affecting plant yield. These extracts were recommended for integrated pest management (IPM) programs (Ullah et al., 2015). Aromatic plants intercropped with tomatoes demonstrated effectiveness in reducing infestations of *Bemisia tabaci* in field conditions and in greenhouse experiments, making them a valuable addition to integrated pest management (Carvalho et al., 2017).

Conclusion

Marigold as a companion crop with tomatoes increases production by up to 50% while reducing root pests, especially Marigold Single Gold, which effectively controls pests and nematodes, similar to the effects of CH3I foliar application. Intercropping maize with peppers significantly reduces Aphis spp. populations. The largest aphid numbers were in control plots, with fewer in the pepper-maize intercropped plots ($P<0.01$). Pepper-maize intercropping also boosts marketable and total pepper yields. However, intercropping chili with maize and sweet potato reduces chili yields by 13% and 14% compared to controls. Marigold flower extract significantly improves the growth and disease resistance (canker, early blight, wilt, fruit spot, blossom end rot, sun scald) compared to controls in tomato plants. Similarly, Cabbage crop also get benefits from companion planting with tall marigold and pot marigold, which reduced pest attacks, butterfly egg laying, and white butterfly populations. It's particularly effective against cabbage moth and diamond back moth. Plant extracts and oils act as natural insect repellents and insecticides, reducing pest populations and supporting natural enemies. They produce fumigants, toxins, and repellents, making them a valuable pest control method for both commercial and household use. Garlic extract, rich in volatile sulfur compounds, proteins, vitamins, minerals, and flavonoids, possesses potent antimicrobial properties and plays a vital role in fruiting processes of various fruit crops. Diversified cropping systems are found to be more effective in controlling pests and minimizing yield losses compared to mono-cropping.

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