INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
24–0410/2025/33:330304
http://www.fspublishers.org

Full Length Article

Assessing the Role of Compost Tea and Potassium-based Inorganic Salts in Managing Anthracnose in Chili Plants

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Received 05 September 2024; Accepted 15 November 2024; Published online 24 December 2024

Editor: Arshad Javaid

Abstract

Anthracnose, caused by *Colletotrichum capsici*, is a major disease impacting chili plants (*Capsicum annum* L.) and resulting in significant yield losses globally. This study was aimed at evaluating the *in vitro* antifungal activity of compost tea, inorganic salts (potassium phosphate and potassium bicarbonate), and their combinations against *C. capsici*, as well as their practical application under field conditions. Compost tea was prepared at different ratios (1:5, 1:10, 1:15 and 1:20), and their colony-forming units (CFU) were determined. The *in vitro* antifungal activity of compost tea, inorganic salts and their combinations were assessed using the poison food technique. The potential of the applied treatments to reduce disease severity on inoculated chili leaves was also evaluated. The results showed that compost tea at all the tested ratios contained CFU counts ranging from 7.17×10^{10} to 2.22×10^{11} and completely inhibited *C. capsici in vitro*. Potassium phosphate at concentrations of 0.5 to 1.5% achieved 74.07 to 74.44% fungal inhibitions, while potassium bicarbonate at concentrations of 0.5 to 1.5% showed 70.28 to 77.41% fungal inhibition. Combinations of compost tea with 1.5% inorganic salts exhibited fungal inhibition ranging from 66.30 to 100%. At field, compost tea demonstrated significantly lowest disease severity, 0 to 2.44% on inoculated chili leaves. Inorganic salts provided moderate control, 22.44 to 34.44% disease severity, and combinations of compost tea with inorganic salts showed varied effectiveness, 12.89 to 50.67% disease severity. The study concludes that compost tea and inorganic salts are effective in managing anthracnose which highlights their potential in sustainable plant disease management strategies.

Keywords: Compost tea; Fungal inhibition; Inorganic salts; Plant disease

Introduction

Anthracnose, primarily caused by the fungal pathogen *Colletotrichum capsici*, is one of the most destructive diseases affecting chili plants. This disease leads to significant losses in yield and quality which pose a severe threat to chili production worldwide. Symptoms of anthracnose include sunken lesions on fruits, stems, and leaves, which can lead to defoliation, fruit rot, and ultimately, plant death (Lubbe *et al*. 2006; Saxena *et al*. 2016). Traditional management strategies for anthracnose have relied heavily on chemical fungicides, which later on raised concerns regarding environmental impact, human health and the development of pathogen resistance (Finger *et al*. 2024).

In recent years, there has been a growing interest in sustainable and environment friendly disease management practices (Khan *et al.* 2021; Rafiq *et al.* 2024; Zohaib *et al.* 2024). Among these, the use of compost tea and inorganic salts has gained attention due to their antifungal properties and benefits to plant health. Compost tea is a fermented watery extracts or leachate produced from degradation of agriculture waste and mixed with water under controlled conditions. It contains a diversity of beneficial microbes which could be used in crop production for control of plant pathogens and enhance growth of host plant (Al-Mughrabi *et al*. 2008). Their suppressive antagonistic properties in the compost tea present an intriguing alternative as a plant disease management agent (Kone *et al.* 2010; Siddiqui *et al.* 2011). Several studies have reported the ability of compost tea to inhibit the growth of soil- and air-borne phytopathogens (Sang *et al*. 2010; Dionne *et al.* 2012; Martin *et al*. 2012). Furthermore, application of compost tea as foliar sprays or as soil drenched frequently help to reduce plant disease (Dukare *et al*. 2011; Naidu *et al.* 2013). However, the efficacy of compost tea varies and is attributed to different procedures of preparation, its source, composition, quality and maturity (Weltzien 1991).

To cite this paper: Ibrahim NF, MAAM Harisi, S Lob, NC Soh, IHM Nawi (2025). Assessing the role of compost tea and potassium-based inorganic salts in managing anthracnose in chili plants. *Intl J Agric Biol* 33:330304 https://doi.org/10.17957/IJAB/15.2280

Inorganic salts such as potassium phosphate and potassium bicarbonate are known for their direct antifungal activity and have been used as alternative treatments to synthetic fungicides. Some inorganic salts are known to possess a strong inhibitory influence on a variety of fungal pathogens and less prone to external factors than other potential protection methods, such as biocontrol agents, which can make them useful in the effective and reliable monitoring of plant pathogens (Avis *et al*. 2008). Arslan (2015) stated that potassium phosphates can offer a suitable way as synthetic fungicides, currently used to prevent plant diseases. Most research is using potassium salts because it presented the following mechanisms to describe the disease-suppressing action such as it showed direct effects on pathogen proliferation, growth and survival, plant synthesis, plant defense reactions and stomata function. According to Deliopoulos *et al*. (2010), phosphates salts express antifungal activity through the induction of acquired systemic resistance (SAR).

Despite the promising potential of compost tea and inorganic salts, there is limited research evaluating their role in managing anthracnose in chili plants. This study was aimed at to fill this gap by conducting a comprehensive analysis on the efficacy of compost tea and inorganic salt treatments in inhibiting *C. capsici* and reducing disease severity in chili plants. The objective of this study was to assess the *in vitro* antifungal activity of compost tea and inorganic salt treatments against *C. capsici*, and their practical application under field conditions.

Materials and Methods

Preparation of compost tea

Agriculture wastes at ratio 1:1:1 (spinach, banana and pineapple) was collected from supermarkets around Kuala Nerus, Terengganu. Then, the agricultural wastes were chopped and layered in a 13 L compost bin with biocatalyst, before incubated for 7-days. The resulting compost tea was diluted with the sterile distilled water at four different concentrations, 1:5, 1:10, 1:15 and 1:20. The acidity of the compost tea was adjusted to pH-6 to 6.5 according to Mistry and Mukherjee (2015) before further used.

Determination of colony forming units (CFU)

Compost tea samples at each concentration were serially diluted to 10^{-7}, 10^{-8} and 10^{-9}, and only 0.1 mL was spread uniformly on surface of potato dextrose agar (PDA). After 24 h of incubation, fungal colonies were counted and converted to CFU mL^{-1} using the following formula, then log transformed for analysis.

$$\text{CFU/mL} = \frac{\text{number of colonies}}{\text{volume of culture plate}} \times \text{dilution factor}$$

Preparation of treatments

Twenty treatments were used in this study including compost tea, inorganic salts, compost tea enriched with 1.5% inorganic salts, fungicide (Kencozeb M45) as positive control and PDA only as negative control (Table 1). The fungicide was prepared according to the standard procedure.

Preparation of fungal pathogen, *C. capsici*

A 7-day-old culture of *C. capsici* (UMT19A) which recorded 100% pathogenic on chili plant was used for *in vitro* and *in vivo* study. For this purpose, the isolate was subculture onto the PDA and incubated at 27 ± 2°C.

Fungal inhibition test (*in vitro* study)

For this purpose, a sterile PDA was cooled at 45°C before mixed with the selected treatments as mentioned in Table 1. This method was followed as per Dianez *et al*. (2006) with some modification. After solidifying, a 5 mm agar plug of *C. capsici* was placed at the center before incubated for 6–7 days in the dark at 27 ± 2°C. Then, the mycelial growth was measured. This experiment was conducted according to a completely randomized design with four repetitions. Percentage of fungal inhibition was calculated as follow:

$$\text{Percentage of fungal inhibition}(\%) = \frac{x - y}{x} \times 100$$

Where,

X = mycelium growth diameter on control plate.

Y = mycelium growth diameter on treated plate.

Determination of disease severity (*In vivo* study)

Six-week-old plants planted in the cocopeats, fertilized with AB fertilizer were used in this study. One healthy leaf was selected, tagged and sterilized using 3% sodium hypochlorite, before injected with *C. capsici* spore suspension (1×10^5 spore mL^{-1}). Control leaves were injected with sterile distilled water. After 4 days, treatments were applied every 3 days for 4 weeks. There were five replicates for each treatment, which arranged in completely randomized block design. Percentage of disease severity (DS) was calculated based on 0 to 5 scale before converted into percentage of disease severity (DS) formula:

$$\text{Disease severity } (\%) = \frac{\sum n \times \text{disease scale}}{\text{dmax} \times \sum n} \times 100$$

Where;

n = number of replicates.

Dmax = maximum scale.

Data analysis

Data for CFU, fungal inhibition and disease severity were analyzed using Analysis of variance (ANOVA) and Tukey's test ($P < 0.05$) by using SPSS version 20.

Table 1: Treatments used in this study

No.	Treatment
1	CT (1:5 v/v)
2	CT (1:10 v/v)
3	CT (1:15 v/v)
4	CT (1:20 v/v)
5	0.5% PP
6	1.0% PP
7	1.5% PP
8	0.5% PB
9	1.0% PB
10	1.5% PB
11	CT 1:5 + 1.5% PP
12	CT 10 + 1.5% PP
13	CT 1:15 + 1.5% PP
14	CT 1:20 + 1.5% PP
15	CT 1:5 + 1.5% PB
16	CT 10 + 1.5% PB
17	CT 1:15 + 1.5% PB
18	CT 1:20 + 1.5% PB
19	Kencozeb M45 (Positive control)
20	PDA only (Negative control)

Note: CT: compost tea; PP: potassium phosphate; PB: potassium bicarbonate

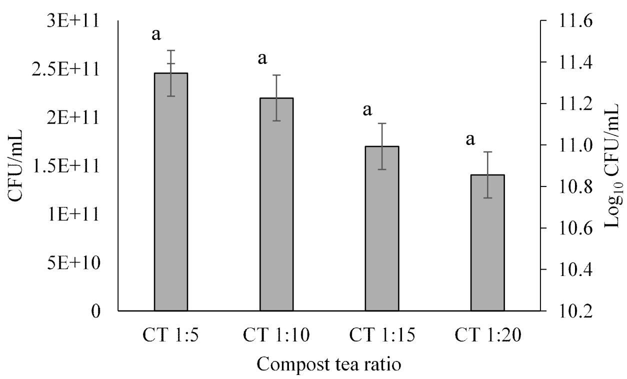

Fig. 1: Colony Forming Unit (CFU) mL^{-1} for compost tea at ratio 1:5, 1:10, 1:15 and 1:20. Different letters denote statistical significance ($P \leq 0.05$) derived from Tukey's HSD post-hoc test analysis

Results

Colony forming unit (CFU)

The CFU count for compost tea at concentration 1:5 to 1:20 ranged from 7.17×10^{10} to 2.22×10^{11} CFU mL^{-1} corresponding to log values between 10.9 to 11.3 (Fig. 1). Compost tea at 1:5 ratios exhibited the highest CFU count, followed by 1:10, 1:15 and 1:20. This suggests that higher compost tea concentrations support greater microbial activity, although statistical analysis indicated no significant differences in CFU counts across concentrations.

Fungal inhibition (*in vitro* study)

In vitro tests revealed complete inhibition of *C. capsici* growth by compost tea at all concentrations (1:5, 1:10, 1:15 and 1:20) (Fig. 2). This antifungal effect was statistically significant compared to all other treatments except for compost tea (1:5 and 1:20) enriched with 1.5% potassium phosphate, suggesting robust antifungal activity in compost tea. The fungicide, Kencozeb M45 also inhibited *C. capsici* but was slightly less effective (87.65% inhibition) than compost tea. Potassium phosphate and potassium bicarbonate treatments showed moderate inhibition (70.28 to 77.41%) but were significantly different with negative control and less effective than compost tea and Kencozeb M45. Enriching compost tea with potassium phosphate increased inhibition (up to 100% in some cases), particularly in compost tea at ratios of 1:5 and 1:20 with 1.5% potassium phosphate, which showed superior inhibition to Kencozeb M45.

Disease severity (*in vivo* study)

Based on *in vivo* study, foliar application of compost tea at concentrations (1:5, 1:10, 1:15 and 1:20) on *C. capsici*-inoculated chili leaves resulted in significantly reduced disease severity compared to other treatments, except Kencozeb M45 and compost tea (1:5) enriched with 1.5% potassium phosphate (Fig. 3). Potassium phosphate and potassium bicarbonate sprays provided moderate disease control but were less effective than compost tea alone (22.44 –34.44% disease severity). When compost tea was enriched with potassium phosphate or potassium bicarbonate, disease severity varied (12.89 to 50.67%) but generally exceeded that of compost tea alone.

Discussion

This study highlights the high CFU count in compost tea prepared with agricultural waste, which were comparable to prior findings on compost made from vegetable waste (Varma and Kalamdhad 2014). The composting process facilitated the proliferation of mesophilic microbes, enhancing microbial activity and nutrient cycling. This aligns with Ingham (2005) that recommended an optimal compost tea containing 10^8 to 10^9 bacteria mL^{-1}, while Ngampimol and Kunathigan (2008) noted that plant-based compost teas can reach microbial populations up to 10^8 CFU mL^{-1}. The enriched CFU mL^{-1} in compost tea for this study could be due to the accelerated decomposition achieved through biocatalyst addition. Variations in microbial diversity are also influenced by initial organic content, oxygen levels, and moisture (Leow *et al.* 2018), which collectively affect compost quality and pathogen suppressive abilities (Scheuerell and Mahaffee 2004).

The strong antifungal activity in compost tea inhibiting *C. capsici* in this study aligns with previous findings on the efficacy of compost teas against pathogens such as *Botrytis cinerea* and *Fusarium oxysporum* (Martin 2015). Studies by Islam *et al.* (2019) and Boiu-Sicuia *et al.* (2021) confirm that compost teas at ratio 1:4 and 1:5 (w/v) can inhibit fungal pathogens effectively, with inhibition often exceeding 50%. The results of this study corroborate the

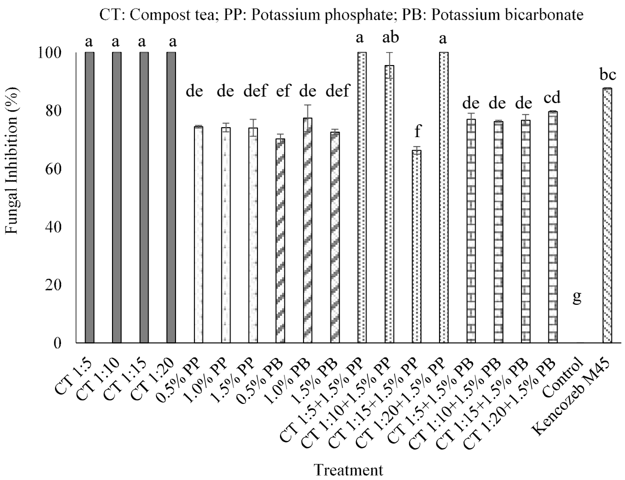

Fig. 2: Percentage fungal inhibition in compost tea, potassium phosphate, potassium bicarbonate, compost tea enriched with 1.5% inorganic salts, Kencozeb M45 (fungicide) and control (PDA only) through *in vitro* study. Different letters denote statistical significance ($P \leq 0.05$) derived from Tukey's HSD post-hoc test analysis

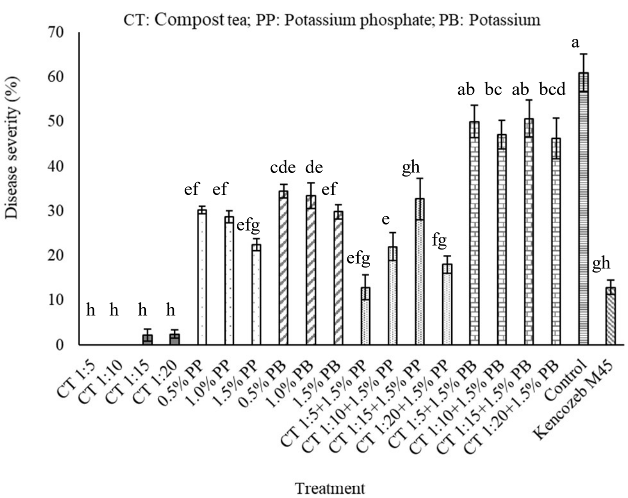

Fig. 3: Percentage of disease severity on inoculated chili leaves treated with compost tea, potassium phosphate, potassium bicarbonate, compost tea enriched with 1.5% inorganic salts, Kencozeb M45 (fungicide) and control (PDA only) through *in vivo* study. Different letters denote statistical significance ($P \leq 0.05$) derived from Tukey's HSD post-hoc test analysis

role of compost tea in suppressing *C. capsici*, possibly due to present of antagonistic microbial populations and bioactive compounds (Noble and Coventry 2005; El-Masry *et al*. 2002). These findings are consistent with reports that non-aerated compost teas are particularly effective in pathogen suppression (Scheuerell and Mahaffee 2006; Din *et al*. 2018).

The application of inorganic salts such as potassium phosphate and potassium bicarbonate showed moderate effectiveness in reducing *C. capsici* growth and disease severity. Potassium phosphate has previously demonstrated inhibitory effects on fungal pathogens, such as *Leveillula taurica* (Reuveni *et al.* 1998) and *Rhizoctonia solani* and *Uromyces appendiculatus* (Arslan 2015). Application of mono- and dipotassium phosphates can successfully treat anthracnose disease on cucumber, and powdery mildew on cucumber, pepper and tomato (Orober *et al.* 2002). This result suggests that potassium phosphate may enhance plant resistance by affecting pathogen survival and plant defence mechanisms (Perrenoud 1990). Percival *et al.* (2009) also reported that foliar treatment with potassium phosphate may protect against several plant diseases. Although potassium phosphate is a salt compound found in food additives, applying it as a foliar spray can improve a plant's disease resistance (Arslan 2015).

Potassium bicarbonate was less effective than potassium phosphate, yet still provided moderate antifungal action. These results were consistent with prior observations on *Sclerotinia sclerotiorum* and *B. cinerea* suppression at different dosages of potassium bicarbonate (Ordóñez-Valencia *et al*. 2009). An *in vivo* study by Türkkan *et al*. (2017) demonstrated that 1% (100 m*M*) potassium bicarbonate can inhibit certain fungal species. Ordóñez-Valencia *et al.* (2009) found that increased alkalinity due to rising bicarbonate concentration; can inhibit fungal growth on PDA media. Additionally, Bombelli and Wright (2006) reported that a 2% potassium bicarbonate treatment applied over two weeks can effectively prevent fungal attacks. However, concentrations greater than 2% have been shown to be phytotoxic, negatively affecting fruit quality in crops like melon, pepper, and tomatoes.

In vitro and *in vivo* findings showed that compost tea enriched with potassium phosphate offered higher fungal inhibition and lower disease severity on *C. capsici*-infected chili plants than compost tea enriched with potassium bicarbonate. Al-Mughrabi (2007) similarly observed enhanced pathogen suppression in compost tea combined with potassium bicarbonate, although the effect was just 10%. Our findings suggest a synergistic effect between compost tea and potassium phosphate, potentially fortifying both biological and chemical defences in the plant. However, combination of compost tea and potassium bicarbonate resulted in unexpectedly high disease severity, making it less effective than the component alone. This combination may have produced antagonistic effects, potentially disrupting microbial interactions or pH balance essential for compost tea efficacy.

Finally, Kencozeb (80% w/w), a commonly used fungicide is effectively inhibited *C. capsici* growth and anthracnose symptoms on chili plants. These results were consistent with Patel *et al.* (2022) that reported high efficacy of Kencozeb against *C. capsici* with 91.28% inhibition. This fungicide is also the best used to control fruit rot and chili dieback (Bal *et al.* 2013). Its mode of action, which involves ethylene bisisothiocyanate sulphide (EBIS) and ethylene bisothiocyanate (EBI) release, underscores its role as a powerful tool against fungal pathogens (Gullino *et al*. 2010).

This study suggests that while fungicides like Kencozeb are effective, compost tea alone or compost tea enriched with potassium phosphate could serve as a sustainable alternative in managing *C. capsici* infection in chili plants.

Conclusion

Compost tea at various concentrations (1:5 to 1:20) demonstrated effective antifungal activity against *C. capsici*, the causative agent of anthracnose in chili plants. The microbial activity within compost tea remained potent across these dilutions and effectively reducing pathogen presence both *in vitro* and on chili leaves. Additionally, potassium phosphate and potassium bicarbonate (at 0.5% to 1.5%) also suppress *C. capsici* and reduce anthracnose symptoms. Enrichment of compost tea with inorganic salts (potassium phosphate or potassium bicarbonate) offers some reduction in disease severity; however, the results were inconsistent, possibly due to adverse interactions. Although fungicides also reduced disease incidence, their repeated use presents health risks and contributes to resistance development. Therefore, compost tea and inorganic salts emerge as cost-effective, sustainable alternatives to chemical fungicides for managing anthracnose disease.

Acknowledgements

The authors are grateful to the sponsor of this research, TAPERG/2023/UMT/2566 (Vot 55487) Universiti Malaysia Terengganu. Our gratitude also goes to all staff for their technical support.

Author Contributions

NFI conducted supervision, conceptualization, data validation, data analysis and editing the original draft. MAIMH wrote the original draft and data analysis. SL, NCS and IHMN revised the manuscript. All author agreed to the final version of manuscript.

Conflict of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

Funding Source

Universiti Malaysia Terengganu-TAPERG/2023/UMT/2566 (Vot 55487).

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