Int. J. Phytopathol. 11 (01) 2022. 01-08 DOI: 10.33687/phytopath.011.01.3555

Available Online at EScience Press
International Journal of Phytopathology
ISSN: 2312-9344 (Online), 2313-1241 (Print)
https://esciencepress.net/journals/phytopath

FLOWER INDUCTION AND CONTROL OF INFLORESCENCE DISEASES IN MANGOES USING SELECTED FUNGICIDES AND CHEMICAL FERTILIZERS

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ARTICLE INFO

Article History
Received: December 03, 2021
Revised: March 21, 2022
Accepted: April 30, 2022

Keywords
Ceratocystis fimbriata
Fungicides
Mangifera indica
Sudden death disease
Flower induction
Inflorescence diseases

ABSTRACT

Mango (*Mangifera indica* L.) is widely considered an important fruit and a major crop in tropical and subtropical regions around the world. Mango is susceptible to a variety of diseases throughout its life cycle, but diseases that strike during the flowering stage cause significant losses and have a direct impact on productivity. Flowering in mango is unreliable from season to season because environmental signals for flower initiation are frequently inconsistent. During the current research, we identify the most promising laboratory-grade synthetic chemical, chemical fungicide, or their feasible combination that promotes floral development, induces flowering, and combats inflorescence diseases, which reduce production. For this investigation, a field trial was conducted with multiple treatments. Compared to the control, the potassium nitrate treatment resulted in the highest flowering/flower emergence (8.67%), followed by calcium carbonate (7.33%) and potassium nitrate with the combination of Champion (6.66%) and Cabrio Top (5.32). Minimum flowering occurred on plants treated with fungicides alone, i.e., Contaf Plus (3.33%), compared to the control (1.33%). Contaf Plus was the most effective chemical against all inflorescence diseases in the field. The disease with the highest incidence was blossom blight at 42.90%, followed by apical necrosis at 39%, mango deformity at 17.70%, and powdery mildew at a low of 0.40%. The combined application of potassium nitrate and Copper hydroxide exhibited the best response in the field for inducing flowering and flower set on mango inflorescences, while potassium nitrate and calcium nitrate were the most effective for inducing flowers on mango trees when treated independently. Current research is extensive on the inducement of flowering and inhibition of flower disease through the application of chemicals alone or in combination.

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INTRODUCTION

Mango (*Mangifera indica* L.) is a unique species with respect to growth, nature, and peculiar characteristics. The climatic conditions of Punjab and Sindh provinces favor mango cultivation, but sometimes changes in the environment and the manifestation of diseases become the significant causes of low productivity in Pakistan. No doubt, mango is prone to various diseases throughout its development stages, but diseases at the flowering stages of mango cause more losses and directly affect productivity (Jose *et al.*, 2000). Apical necrosis, blossom blight, and powdery mildew are primarily diseases of mango flowers and can be easily managed with an integrated disease management approach including

sprays of fungicides during the flowering season (Misra *et al.*, 2012).

Mango from one season to the next is unreliable because the environmental signals for flower initiation are often inconsistent, subtle, or poorly defined in most cultivations like Chaunsa (S.B). Some chemicals like Potassium Nitrate (KNO_3) and Calcium Nitrate ($CaNO_3$) are used not only to break the dormancy but also to enhance the flowering, especially in the conditions when winter prolongs or cold temperature for flower induction may not be sufficient sometimes due to environmental changes (Batista *et al.*, 2016). The occurrence of rainfalls during the flowering season is another environmental predisposing factor that may help in the proliferation of apical necrosis, blossom blight, powdery mildew, etc. Gill and Jawandha (2012) observed that the vegetative development of trees is delayed as the frequency of disease increases. Then, trees become alternate bearers annually. Although its pathogenicity test is still to be conducted but keeping in view it's high incidence it was imperative to explore this hazard in detail. It was reported that apical necrosis of mango prevails during the period of dormancy in winter and is categorized on the basis of quick development of necrotic scratches on sprouts and leaves Gill and Jawandha (2012).

The symptoms caused by the disease involve necrosis of vegetative and flower buds and bud failure. *Colletotrichum gloeosporioides* and *Alternaria alternata* is the cause of blossom blight of mango. This is the severely destructive disease of mangoes in the New South Wales of Australia, shattering early leaves and habitually producing defoliation of flush growth. If wet weather arises during flowering, anthracnose causes extreme blossom blight which causes inflorescences (flower panicles) destruction and prevents fruit set. Wetting of surfaces and the conditions of temperature hinge on the infection of inflorescences. The lower temperatures (10-13 ℃) require a much longer duration of time for wetness than higher temperatures (22–25 ℃).

This critical situation demands the study to simultaneously overcome the abiotic and biotic stresses during the flowering stages of mango. The loss of inflorescence panicles occurs when inflorescence turns black and unequal spots appear and coalesce. Flower panicle death occurs when the flowers turn black and uneven spots grow and merge. Mohamed Nor *et al.* (2013) reported that mango malformation disease is the reason for severe yield loss of up to 80%. Severe fatalities of this old problematic disease were reported every year. It was reported that the plants between the ages of 4-8 years undergo severe loss (90.9%) from vegetative malformation Singh and Jawanda (1961). As twisted inflorescence neglects to deliver fruiting bodies, the harm to every single tree may differ from 50-80%, and in serious cases, the misfortune might be practically complete (Rymbai and Rajesh, 2011). Hence, considering the field-oriented issue raised by the mango growers, it is imperious to conduct a comprehensive experiment to observe the effect of different chemicals to induce the flowering and control of flower diseases in mango after testing their compatibility in the laboratory.

MATERIALS AND METHODS

Fungicides and chemicals

Three commercially used fungicides viz., Champion, Cabrio Top and Contaf Plus were purchased from Syngenta and Bayer Crop Sciences, Pakistan while the chemical products viz, potassium nitrate (KNO_3) and calcium nitrate ($CaNO_3$) used were brands of Sigma Aldrich, USA. The compatibility tests of KNO_3 and $CaNO_3$ and with the following fungicides were done in laboratory conditions. The dose of KNO_3 was kept constant with the concentration of 1% in each test, while the fungicides were used according to their recommended doses for mango as mentioned against each fungicide (Table 1 and 2).

Preparation of various concentrations of fungicides and chemicals for field application

A total of 11 concentrations of these three fungicides and two chemicals were prepared while control was kept untreated. For the field application fungicides and chemicals were prepared with the following scheme:

T_1 = KNO_3,
T_2 = $CaNO_3$,
T_3 = Champian,
T_4 = Cabrio Top,
T_5 = Contaf Plus,
T_6 = KNO_3+ Champion,
T_7 = $CaNO_3$+ Champion,
T_8 = KNO_3 + Cabrio Top,
T_9 = $CaNO_3$ + Cabrio Top,
T_{10} = KNO_3 + Contaf Plus,
T_{11} = $CaNO_3$+ Contaf Plus,
T_{12} = Control (unsprayed plants).

Selection of mango trees

A total of 36 mango trees of the variety Chaunsa (S.B) located at the Mango Research Institute (MRI), Multan was selected and tagged for further research objectives. The selected plants were sprayed three times during the dormant period in January, and later two consecutive sprays after one-week intervals were performed in all selected trees. In each selected plant, 20 different inflorescence branches were randomly selected and tagged for treatment spraying and observing the influence of diseases. The experiment was conducted in a randomized complete block design (RCBD) with three replications.

Table 1. List of fungicides with their active ingredient and recommended doses.

Sr. No.	Fungicides	Active Ingredient	Dose	Company
1.	Champion 77% (w/w)	Copper hydroxide- $Cu(OH)_2$ 770g/kg(77% w/w)	38g/15liter	(Jaffer Brothers)
2.	Cabrio Top 60% (WDG)	Pyraclostrobin 50g/kg (Metiram 550g/kg)	23g/15liter	(FMC United (Pvt.) Ltd.)
3.	Contaf Plus 5.1% (w/v) SC	Hexaconazole 51g/l 5%(w/w)	23ml/15liter	(Jaffer Brothers)

Table 2. List of chemicals with their recommended dose.

Sr. No.	Chemicals	Dose	Company
1	Potassium Nitrate (KNO_3)	150g/15liter	Sigma Aldrich, USA
2	Calcium Nitrate ($CaNO_3$)	150g/15liter	Sigma Aldrich, USA

Data collection

Data regarding the observations made in the sprayed plants were collected according to the following scale:

0 = No infection,
1 = 1 to 10 % of area infected,
2 = 11 to 25 % of area infected,
3 = 26 to 50 % of area infected,
4 = > 50 % of area infected for further analysis.

Disease influence from apical necrosis, powdery mildew, mango malformation, and blossom blight was determined using the formula:

$$\text{Disease incidence \%} = \frac{\text{No. of infected inflorescence}}{\text{Total No. of inflorescence}} \times 100$$

$$\text{Disease severity index} = \frac{\text{Sum of all the score of individual inflorescece}}{\text{Total No. of inflorescence observed}} \times \frac{100}{\text{Maximum scale}}$$

Statistical analysis

The collected data sets of the effect of various treatments on the induction of flowering and control of flower diseases in mango were subjected to analysis of variance (ANOVA) using (SAS® 2002). Treatment means were compared using Fisher's least significant differences (LSD) at (P = 0.05). Disease incidence and the disease severity of the various flower diseases were also analyzed by the said test.

RESULTS

The research in question was aimed to find out the most promising synthetic chemical of laboratory grade, chemical fungicide or their possible combination which not only promotes the flower development but also induce flowering and combat inflorescence diseases which are the main reason to lessen the yield.

The results showed that maximum flowering/ flower emergence was observed with the treatment KNO_3 (8.67%) followed by $CaNO_3$ (7.33%), KNO_3 with the combination of Champion (6.66%), and KNO_3 with the combination of Cabrio Top (5.33%) compared to control. Minimum flowering occurred on the plants treated with the fungicides alone i.e., Contaf Plus

(3.33%) compared to control (1.33%). In the case of Apical necrosis, Contaf Plus gave maximum control on apical necrosis of mango with 1.33% followed by Cabrio Top with 2.67% compared to the control (11.33%).

Similarly, Contaf Plus also gave the best control for blossom blight with 0.00 mean followed by the Cabrio Top with a 1.67 mean compared to the control (10.33). KNO_3 with the combination of Champion and $CaNO_3$ with the combination of Cabrio Top gave 100% control of the mango malformation disease which is said to be a century-old disease of the mango compared to the control (9.66%). While KNO_3 and $CaNO_3$ also performed best, with 1.33 and 2.33% respectively, to control mango malformation compared to the other diseases.

Powdery mildew was noticed minimum on the inflorescence as it was observed that all the treatments gave good response for the control of the powdery mildew of mango especially the KNO_3 and $CaNO_3$ gave the best response against the disease. Phytotoxicity was noted on all the plants when chemicals or any other treatment individually or in combination were applied. Maximum toxicity was noted on inflorescence when only fungicides were applied followed by the combination of the fungicides with synthetic chemicals. Maximum fruit setting was noted on treatment KNO_3 and $CaNO_3$ followed by the combination of chemicals with the fungicides while fungicides only did not appear to set maximum flowering on any plant (Table 1).

Incidence percentage of different diseases appeared on mango inflorescence on Chaunsa cultivar

The incidence of each of the inflorescence diseases assessed indicates that the blossom blight disease was maximum on the inflorescence (n=309) followed by apical necrosis with n=281 infected mango inflorescence, mango malformation with 127 infected inflorescence, and minimum infected inflorescence was observed with the powdery mildew of mango (Figure 1). Maximum disease incidence was 42.90% for blossom blight followed by 39.00% with apical necrosis, 17.70% with mango malformation, and a minimum 0.40% was recorded with powdery mildew (Figure 2).

To induce flowering and flower setting T6 (KNO_3+ Champion) treatment showed the best response in the field on mango inflorescence when used in combination while KNO_3 and $CaNO_3$ also proved to be best for the induction of flowers when applied separately on the mango trees (Table 2). All the treatments gave good response for controlling flower diseases, i.e., mango malformation, blossom blight, apical necrosis, and powdery mildew. We observed a unique response of these treatment applications on the mango flowers during the flowering season to induce the flower buds and suppress the flower infection either by the bacteria or fungi (Table 3).

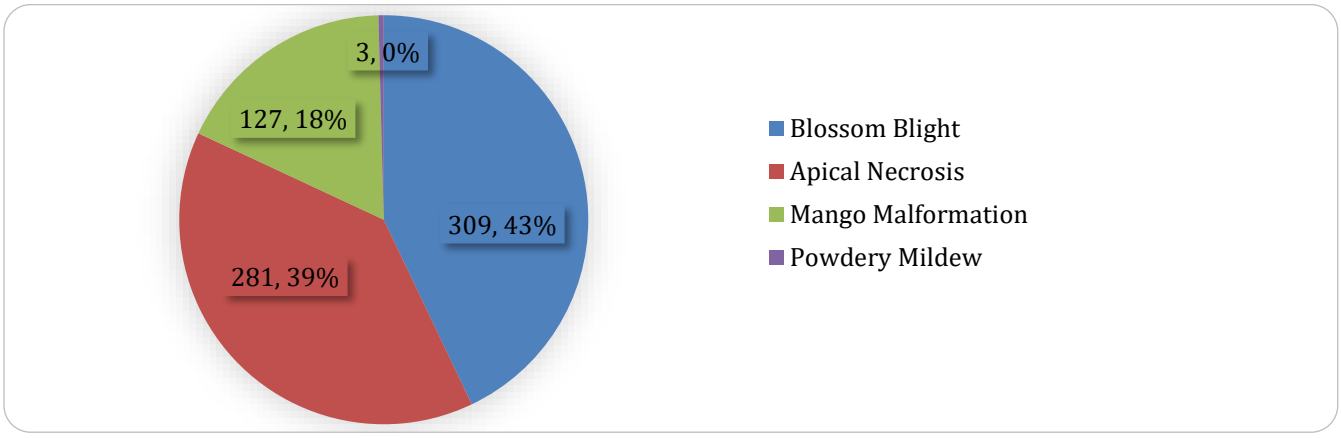

Figure 1. Summary of inflorescence infected by various pathosystems on Chaunsa as indicated in number against the total inflorescence observed with percent disease incidence.

Table 1. Dynamics of mango inflorescence attributes and inflorescence diseases (%) in exposure to different treatments alone and in combinations in the field on mango trees (Chaunsa Summer Bahisht).

Treatments	F.E	A.N	B.B	M.M	P.M	P.T	F.S/ No of fruits
KNO_3 (8.34)*	8.67±0.33 a	4.67 ± 0.33	5.67 ± 0.33	1.33 ± 0.33	0.00 ± 0.00	1.00 ± 0.00	119.33 ± 0.88
$CaNO_3$(7.69)	7.33±1.09 b	5.33 ± 1.09	6.66 ± 0.82	2.33 ± 0.27	0.00 ± 0.00	1.00 ± 0.00	11.67 ± 0.72
Cu $(OH)_2$(8.01)	5.33±0.67	4.33 ± 0.67	3.33. ± 0.33	1.33 ± 0.23	0.00 ± 0.00	1.00 ± 0.00	111.33 ± 0.58
Cabrio Top (7.68)	4.00±2.31	2.67 ± 0.33	1.67 ± 1.33	1.33 ± 0.33	0.00 ± 0.00	1.00 ± 0.00	109.33 ± 0.88
Contaf Plus (8.13)	3.33±0.67	1.33 ± 0.13	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.00 ± 0.00	103.00 ± 1.53
KNO_3+ Cu $(OH)_2$(8.24)	6.66±0.58 c	4.66 ± 0.14	4.67 ± 0.58	0.00 ± 0.00	0.00 ± 0.00	1.00 ± 0.00	111.33 ± 0.88
$CaNO_3$+ Cu $(OH)_2$(8.11)	5.33±0.33 d	2.67 ± 0.13	2.99 ± 0.00	0.33 ± 0.13	1.00 ± 0.33	1.00 ± 0.00	114.33 ± 0.31
KNO_3 + Cabrio Top (8.10)	5.33±0.33 d	4.67 ± 0.33	3.00 ± 0.38	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	107.33 ± 1.15
$CaNO_3$ + Cabrio Top (7.90)	5.99±0.33 d	3.67 ± 0.33	2.00 ± 0.00	1.00 ± 0.0	0.00 ± 0.00	1.00 ± 0.00	112.33 ± 0.31
KNO_3 + Contaf Plus (8.30)	4.00±1.33	4.67 ± 0.33	4.66 ± 0.00	0.33 ± 0.11	1.66 ± 0.00	1.01 ± 0.00	101.33 ± 0.88
$CaNO_3$+ Contaf Plus (8.12)	5.00±1.15	4.67 ± 1.03	6.66 ± 0.00	0.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	110.33 ± 1.76
Control (unsprayed plants)	1.33±0.33	11.33 ± 0.88	10.33 ± 1.86	9.66 ± 1.11	3.36 ± 0.13	3.00 ± 1.13	77.09 ± 1.76

* Values in the parenthesis in treatment column are the negative log of hydrogen ion concentration (pH) of the solutions prepared in the laboratory and sprayed in the field.
F.E= Fruit emergence, A.N= Apical necrosis, B.B= blossom blight, M.M= Mango malformation, P.M= Powdery mildew, P.T= Pyhtotoxicity, F.S= Fruit setting on trees.

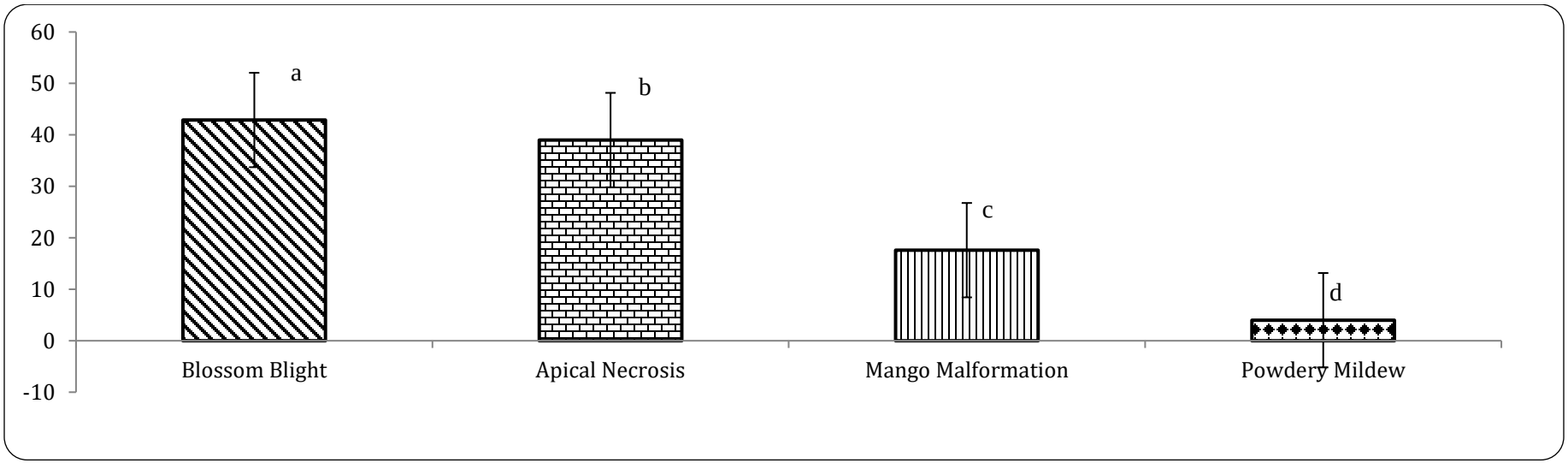

Figure 2. Disease incidence percentage of various pathosystems recorded on mango inflorescence.

Table 2. Effect of different chemicals and fungicides treatments to induce inflorescence/flower setting in mango trees (Chaunsa Summer Bahisht).

Treatments	Flower emergence/ Fruit setting (%)	Increase in flower emergence (%)	Increase in flower emergence (times)
KNO3	8.67	551.88	5.51
$CaNO_3$	7.33	451.14	4.51
Cu $(OH)_2$	5.33	300.76	3.00
Cabrio Top	4.00	200.75	2.00
Contaf Plus	3.67	175.94	1.75
KNO_3+ Cu $(OH)_2$	6.66	400.76	4.00
$CaNO_3$+ Cu $(OH)_2$	4.00	200.75	2.00
KNO_3 + Cabrio Top	5.99	350.38	3.50
$CaNO_3$ + Cabrio Top	5.33	300.76	3.00
KNO_3 + Contaf Plus	5.33	300.76	3.00
$CaNO_3$+ Contaf Plus	5.00	275.94	2.75
Control	1.33	----	----

Table 3. Decreases in the percentage of mango inflorescence diseases after exposure to different treatments alone and in combinations in the field on mango trees (Chaunsa Summer Bahisht).

Treatments	Apical necrosis (%)	Blossom blight (%)	Mango malformation (%)	Powdery mildew (%)
KNO3	35.00	82.86	91.99	96.33
$CaNO_3$	56.25	71.43	87.32	93.11
Cu $(OH)_2$	87.50	88.57	98.34	94.33
Cabrio Top	75.00	85.70	97.34	99.66
Contaf Plus	62.50	97.10	88.23	99.99
KNO_3+ Cu $(OH)_2$	37.50	57.10	81.12	99.99
$CaNO_3$+ Cu $(OH)_2$	92.50	71.40	96.66	98.99
KNO_3 + Cabrio Top	75.00	57.11	92.34	89.11
$CaNO_3$ + Cabrio Top	87.50	94.28	99.11	98.37
KNO_3 + Contaf Plus	87.50	88.57	93.45	96.78
$CaNO_3$+ Contaf Plus	25.00	73.42	81.11	79.32
Control	-	-	-	-

DISCUSSION

Mangoes (*Mangifera indica* L.) is universally regarded as superb fruit and one of the significant fruit crop in tropical and subtropical areas of the world. India, Pakistan, Brazil, Australia, South Africa, Egypt, and the USA are the major producers of mango (FAO, 2016). Mango production is vulnerable to many biotic and abiotic problems, yet the most important problems are inflorescence i.e., bud dormancy, bud swelling, bud braking, flower emergence, and fruit set. In our research field trial was performed to check the efficacy of various treatments. The treatments were, the spray of KNO_3, $CaNO_3$, Champion, Cabrio-Top, Cantof Plus, combination of KNO_3 and Champion, $KNO_3$and Cabrio-top, $KNO_3$and Cantof plus, $CaNO_3$and Champion, $CaNO_3$Cabrio-top, $CaNO_3$andcontaf-plus. We observed that maximum flowering/ flower emergence was observed with the treatment KNO_3 (8.67%) followed by $CaNO_3$ (7.33%) and $KNO_3$with the combination of Champion (6.66%) and $KNO_3$with the combination of Cabrio Top (5.33%) was calculated compared to control. Minimum flowering occurred on the plants treated with the fungicides alone i.e., Contaf Plus with 3.33% compared to control which was recorded at only 1.33%. Andrés *et al.* (2008) noted that PBZ and KNO_3 application induced a larger number of advanced panicles in relation to the control, with higher values observed as the PBZ dose increased. However, in total flowering, there was no significant difference between treatments ($p<0.05$). PBZ did not have negative effects in the quality of fruit of neither

cultivar. The treatments with higher PBZ doses had higher TSS content, less TA, less firmness, and greater weight loss. Both cultivars were different in TA of the ripe fruits. Our results are in line with (Bhuiyan *et al.*, 2007), who reported foliar KNO_3 application at 13 kg/ha, significantly (P<0.05) reduced the mean disease incidence, severity, and leaf shedding assessed during the trial period. He also demonstrated that foliar application of KNO3 may be effective in reducing the effect of Alternaria leaf blight of cotton. Bellgard (2002) observed phenomena of Alternaria leaf blight expression on cotton plants in northern Australia. Considerable variation of disease incidence and severity, and leaf shedding at various heights of cotton plants have been reported. Unfortunately, leaf potassium levels were not determined.

Our results are also parallel with Maloba *et al.* (2017) who observed (KNO_3) spray produced inflorescences compared to controls. We observed maximum fruit setting was noted on treatment KNO_3 and $CaNO_3$ followed by the combination of chemicals with the fungicides while fungicides only did not appear to set maximum flowering on any plant. Similarly, Luo *et al.* (2017) reported that although ethephon and KNO_3 reportedly stimulate mango flowering in the tropics, were ineffective during the floral promoted and non-promoted periods.

We also observed the inflorescence disease in response to these applications and our results depict that in the case of apical necrosis, Contaf Plus gave maximum control on apical necrosis of mango with 1.33% followed by Cabrio Top with 2.67% compared to the control which was recorded 11.33%. Similarly, Contaf Plus also gave the best control for blossom blight with a 0.00 mean followed by the Cabrio Top with a 1.67 mean compared to the control (10.33). $KNO_3$with the combination of Champion and $CaNO_3$with the combination of Cabrio Top gave 100% control of the mango malformation disease, which is said to be a century-old disease of the mango compared to the control (9.66%). While KNO_3 and $CaNO_3$ also performed best, with 1.33 and 2.33 respectively, to control mango malformation compared to the other diseases. Powdery mildew was noticed minimum on the inflorescence as it was observed that all the treatments gave good response for the control of the powdery mildew of mango especially the $KNO_3$and$CaNO_3$ gave the best response against the disease. Phytotoxicity was noted on all the plants when chemicals or any other treatment individually or in combination with others was applied. Maximum toxicity was noted on inflorescence when only fungicides were applied followed by the combination of the fungicides with synthetic chemicals. Tongumpai *et al.* (1989) obtained similar findings, who observed that soil application of $Cu(OH)_2$ resulted in a significant increase in flowering and slightly earlier flowering and literally reduced the inflorescence disease by its foliar spray of with potassium nitrate 8 weeks after the treatment. Our results are in accordance with (Ramírez and Davenport, 2010) reported that KNO_3 sprayed plants produced the greatest number of inflorescences per plant. The variation in the number of inflorescences per plant treated with different chemicals among the varieties may be due to the genetic potential of the varieties.

Similarly, Bibi *et al.* (2019) found that after spraying with calcium nitrate tip burn injuries and cause phytotoxicity are smaller, and the calcium content in leaves increases because calcium makes more stiff cell membranes. While Cengiz and David (2002) stated that supplementary calcium nitrate could overcome the effects of high salinity on fruit yield and whole plant biomass in cucumber plants. Yildirim *et al.* (2007) observed that calcium nitrate slowly would be solved in soil solution, so it can't act fast. In contrast, it is one of the major sources of nitrogen in combination with other fertilizers to develop tree growth. Calcium is considered one of the most important minerals determining fruit quality since it is required for cell elongation and cell division (Hocking *et al.*, 2016). Abd El-Megeed *et al.* (2007) found that fruit retention of many other fruit trees had been improved under similar applications with calcium.

ACKNOWLEDGEMENTS

The authors are highly thankful to the staff of Mango Research Institute, Multan for their cooperation and help during the research.

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CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

AUTHORS CONTRIBUTIONS

All the authors have contributed equally to the research and compiling the data as well as editing the manuscript.