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Original Research

Evaluating the Response of Insecticides and Fungicides for Rind Blemishes Management in Kinnow Mandarin (*Citrus nobilis* Lour × *Citrus deliciosa* Tenora) Fruits Caused by Biotic Factors

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ABSTRACT

Kinnow mandarin being produced in Pakistan faces different quality issues ending up in poor rind quality bearing blemishes on the peel. The main reason behind quality issues is inadequate production management including unoptimized production technology with an inappropriate spray schedule of insecticides and fungicides. Major blemishes found on the surface of fruit are biotic in nature (diseases and insects) and generally appear during the early 8-12 weeks of fruit setting. The objective of this study was to optimize insecticides and fungicides to manage rind blemishes in 'Kinnow' mandarin fruits caused by biotic factors. The present study was conducted during 2017-2018; there were four kinds of pesticides such as Actara (Thiamethoxam) or Confidor (Imidacloprid) and Nativo (Tebuconazole and Trifloxystrobin) or Topsin M (Thiophanate-methyl) sprayed to the trees at onset of fruit setting. The extent and nature of blemishes related to diseases and insects were significantly reduced after the spray of 0.3 g L^{-1} Nativo, 1.5 ml L^{-1} Confidor as compared to the application of Actara (0.24 g L^{-1} water) and Topsin M (2 g L^{-1} water), while the higher extent of blemishes was recorded in control block. Surface smoothness and peel colour of fruits showed significant improvement in sprayed trees compared to control. Likewise, preharvest sprays reduced the post-bloom and commercial fruit drop, resulting in a high yield per tree. However, the preharvest sprays showed a non-significant effect on organoleptic quality and biochemical attributes of 'Kinnow' fruit. Conclusively, the combination of Confidor (1.5 ml L^{-1} water) and Nativo (0.3 g L^{-1} water) sprays at fruit setting stage could be helpful in managing biotic blemishes in 'Kinnow' mandarin fruits resulted in an increased proportion of A-grade quality fruits in final pack out.

Keywords: *Fruit drop, pesticides, preharvest sprays, rind quality, organoleptic evaluation.*

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INTRODUCTION

Citrus belongs to family Rutaceae, a mainly cultivated crop of subtropical and tropical regions in the world (Shireen et al., 2018). Citrus is a highly nutritious fruit and considered a rich source of vitamin C (Malik et al., 2021), dietary components and antioxidant activity (Xu et al., 2008; Goulas and Manganaris, 2012). In Pakistan, citrus ranks top of the list in area (0.18 million ha) and production (2.47 million tons) among fruits (MNFSR, 2020). 'Kinnow' mandarin is considered as the prime cultivar of Pakistan, retain highest position in production (>2.1 million tons) and export (300,000 metric tons, worth > USD 180 million) (Anonymous, 2014).

'Kinnow' mandarin is prime cultivar which has dominated Pakistan's citrus industry (Khan et al., 2020). Nevertheless, 'Kinnow' mandarin fruit is fetching low prices in the international market; thus, the national economy faces a loss of millions of dollars annually (Anonymous, 2010). The reason behind lower price is low fruit quality production, mostly B grade. The basic reason for its downgrade quality is the higher extent of blemishes on the skin of fruit. Blemished fruit production has not only affected our export to international markets but also caused huge losses to 'Kinnow' growers. A comprehensive report in 2014 has been released on 'Kinnow' quality issues with their causes and provides a way out for

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possible management strategies. Poor rind quality has been reported as the major cause for farmgate rejection of fruits by the processors and traders. However, the rejection rate varies between 20 to 50%, sometimes rejecting the complete orchard due to poor management and quality (Malik and Khan, 2014). Such a high farm gate rejection and low price make our 'Kinnow' production and export unsustainable.

Rind blemishes developed on the fruit surface are mostly caused by insects visible on the cuticle, epidermal, and sub epidermal cells. The potential insects include peel miner, thrips, mites, red scale, and fruit fly, considered the main causal agent for fruit blemishes; however, some other insects like citrus psylla and mealybug also cause impact damage (Malik et al., 2021). Globally, the most recognized and suitable control of insects in the orchards can only be possible through the judicious application of pesticides (Khalid et al., 2012a). Lu et al. (2012) stated that growers have recently used different groups, including pyrethroids, neoncotinoids and organophosphate regarded as broad-spectrum insecticides. However, these pesticides are inexpensive in the market, and their uneven use markedly reduces the population of beneficial insects (Desneux et al., 2007). Neoncotinoid is known as novel, and the emerging class consists of different insecticides including Imidacloprid, Thiamethoxam, Nitenpyram, Acetamaprid, Thiacloprid and Chlothianidin generally employed by the growers due to their prime mode of action and shown impact on nicotinic receptors which ultimately affect transmission way of nervous system of insects (Zhang et al., 2007).

Earlier studies revealed that citrus groves had been found susceptible to different diseases markedly damaging the plant health and downgrade the external and internal fruit quality. Nevertheless, fungal infections, including citrus scab and melanose known as 'Virus' among the local community, have been reported as the most devastating issue in citrus quality, ends up in high rejection at farmgate (Malik and Khan, 2014; Malik et al., 2021). In addition, bacterial diseases such as citrus canker and greening are also reported in citrus groves, badly affecting the cosmetic quality of fruits (Ahmed, 2005). Currently, crop losses have been reported prevented from regular use of fungicides employed worldwide. However, the application of fungicides is extremely needed to be optimized to reduce the pesticide residues, environmental pollution, fungicide efficacy, risk of resistance development and negative impact of beneficial organisms (Rebollar-Alviter and Nita, 2011). Multiple chemicals have been formulated according to a specific disease or pathogen as earlier reported that Azoxystrobin, thiophanate-methyl found available in Topsin M fungicide and Trifloxystrobin is the active part of Nativo fungicide, and different copper-based fungicides extensively tested against different fungal infection in citrus by foliar sprays at different stages of fruit development (Chung, 2011; Gopal et al., 2014). Nevertheless, among different non-chemical approaches, fruits covered with brown paper bags and butter paper bags did not show any blemishes and were also free from citrus canker (Khan et al., 2021).

Nevertheless, the complete technology package for reducing rind blemishes and improving the quality of 'Kinnow' fruit on a commercial scale was tested and demonstrated. Considering the research gap and stakeholder needs, specifically citrus growers, it has been hypothesized that rind blemishes in 'Kinnow mandarin' can be reduced by using a combination of fungicides and insecticides. Hence, the present study evaluated the best combination of insecticides and fungicides application in reducing insect and disease-based (melanose, scab, canker etc.) skin blemishes in 'Kinnow' mandarin.

MATERIALS AND METHODS

Experiment design

The experiment was carried out on six-year-old 'Kinnow mandarin' plants having rough lemon (*Citrus jambhiri* Lush.) rootstock growing under uniform conditions from 2017-2018. This experiment was laid out according to Randomized Complete Block Design (RCBD), which comprises five treatments replicated six times in the whole orchard with an area of eight acres. The single tree was considered as an experimental unit. Pesticides with different combinations were sprayed to the experimental trees according to the following plan of treatments just after fruit setting. The treatments included: T_1 = Control, T_2 = Confidor (1.5 ml/L) + Nativo (0.3 g L^{-1} water), T_3 = Actara (0.24 g L^{-1} water) + Topsin M (2 g L^{-1} water), T_4 = Actara (0.24 g L^{-1} water) + Nativo (0.3 g L^{-1} water) and T_5 = Confidor (1.5 ml L^{-1} water) + Topsin M (2 g L^{-1} water). These pesticides contain specific active ingredients inside, such as Actara (Thiamethoxam), Confidor (Imidacloprid), Nativo (Tebuconazole and Trifloxystrobin) and Topsin M (Thiophanate-methyl), respectively. Evaluation of blemishes extent and pest monitoring was done in the field at monthly interval after treatment application. At commercial harvest stage, fruits were harvested treatment wise and shifted to the Postharvest Research and Training Centre, Institute of Horticultural Sciences, University of Agriculture, Faisalabad. The fruit was subjected to qualitative and quantitative analysis under lab conditions.

Extent and nature of blemishes

Data regarding the extent of blemishes were recorded during the whole growing season along the different stages of fruit development. 10 fruits per tree were selected at random and observed for extent of skin blemishes at monthly interval by visual observation. The procedure for evaluating skin blemish intensity was adopted with some modifications as reported by Ahmed (2005), Khalid et al. (2012b) and Malik et al. (2021), categorized on the basis of scale such as 1= < 1 cm^2, 2= 1-5%, 3= 6-10%, 4= 11-25%, 5= 26=50% and 6= >50%. Nature and type of blemishes were assessed at commercial harvest; about 10 fruits per replication were selected randomly from all treatments, including control. Data was recorded in terms of biotic (insects, diseases), abiotic (physical) and some physiological disorders. Biotic skin blemishes were in two categories: insects (feeding of red mite, fruit fly and thrips ring etc.) and diseases (melanose, citrus scab and citrus greening etc.).

Surface smoothness and peel colour

For estimation of surface smoothness, rating scale by Khalid et al. (2012a) was adopted; very rough = 1, rough = 2, slightly smooth =3, smooth = 4, and very smooth = 5. Fruit after harvest, subjected to visual observation of peel colour following rating scale; 100 % green = 1, 75 % green; 25 % orange = 2, 50 % green; 50 % orange = 3, 25 %green; 75 % orange = 4 and 100 % orange = 5 as earlier described by Khalid et al. (2012a).

Physical parameters of fruit

'Kinnow' fruit after harvesting was subjected to physical evaluation such as fruit yield per tree in terms of fruit number and weight (kg), average fruit weight (g), average peel weight (%), average weight of rag (%), juice (%) and organoleptic evaluation as earlier outlined by Nasir et al. (2016).

Organoleptic evaluation

Organoleptic evaluation of sensory characteristics was done according to described method by Hasan et al. (2020) for 'Kinnow' fruit. Treatments were coded and arranged according to replications in front judge's panel. Judges panel rewarded score according to given criteria such as 1: Dislike extremely, 2: Dislike very much, 3: Dislike moderately, 4: Dislike slightly, 5: Neither like nor dislike, 6: Like slightly 7: Like moderately, 8: Like very much and 8: Like extremely.

Biochemical parameters of fruit

After the evaluation of physical parameters, fruit juice was subjected to biochemical attributes such as SSC (soluble solid contents) with the help of handheld refractometer (ATAGO Japan), titratable acidity (TA %), SSC: TA ratio and ascorbic acid contents of 'Kinnow' fruit by using standard procedures (Khalid et al., 2017).

Statistical analysis

Collected data were statistically analysed using Software 8.1, and ANOVA techniques were applied to check the overall data significance and mean comparisons were done by least significant difference (LSD) (Steel et al., 1997).

RESULTS

Extent and nature of fruit blemishes

During May and June, minimum fruit blemishes intensity was observed (2.9) in T_2 (Confidor + Nativo) followed by T_3 (Actara + Topsin M), while maximum blemish extent was (5.56) in control and June month showed a similar trend (Fig. 1). From the month July 2017 up till harvest in January 2018, data was recorded for five treatments; July month had statistically significant results of blemishes extent; trees sprayed with Confidor and Nativo showed lower score (3.56) while higher was recorded for control plants (6). At final harvest in January, extent of blemishes was found lower (3.96) in T_2, where trees were sprayed with Confidor + Nativo followed T_4, T_5 and T_3 while a higher score (6) was recorded in control which accounts for >50% blemished fruits.

Disease factor was found more influential for causing blemishes in which melanose, scab and citrus greening recorded abundantly followed by insects and abiotic (physical) type. Results regarding nature (Fig. 2); representative fruits harvested from control (T_1) trees showed maximum disease incidence (6.6 fruits per plant) followed by fruits (2) affected by insect feeding moving towards physical type (branch rub or wind scratches) of blemishes. However, trees sprayed with package of Confidor and Nativo package effectively reduce disease incidence (2 fruits per plant) and insect feeding (0.4 fruits per plant) as compared to control (Fig. 3).

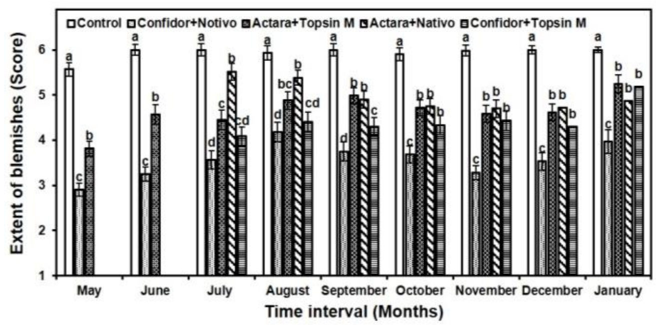

Figure 1: Effect of different insecticides and fungicides on extent of rind blemishes in 'Kinnow' mandarin fruits.

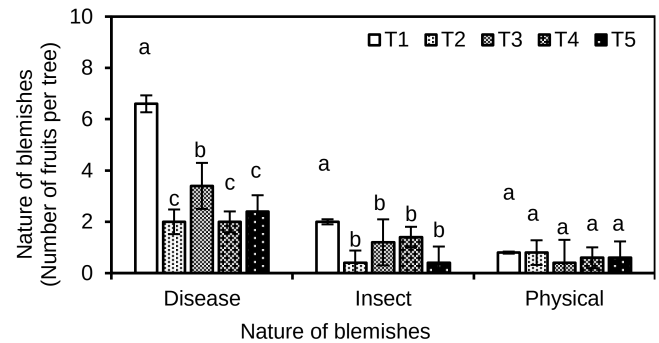

Figure 2: Effect of different insecticides and fungicides on nature of rind blemishes in 'Kinnow' mandarin fruit. T_1 = Control, T_2 = Confidor (1.5 ml/L) + Nativo (0.3 g L^{-1} water), T_3 = Actara (0.24 g L^{-1} water) + Topsin M (2 g L^{-1} water), T_4 = Actara (0.24 g L^{-1} water) + Nativo (0.3 g L^{-1} water) and T_5 = Confidor (1.5 ml L^{-1} water) + Topsin M (2 g L^{-1} water).

Fruit surface smoothness and peel colour

The data regarding surface smoothness revealed significant interaction of fungicide and pesticide spray on peel quality, especially surface smoothness of fruit. The highest surface smoothness score (4.65) was recorded in T_2 (trees subjected with Confidor + Nativo), having surface smooth to very smooth. In contrast, a lower score was measured in fruits harvested from control trees having rough to a slightly smooth surface (Fig. 3A). Likewise, significant results were observed in treated plant's fruit; scores were awarded according to the described procedure by Khalid et al. (2012a) for 'Kinnow' fruit. Fruit from conventional block having control plants showed an uneven distribution of colour with minimum score (2.15) depicted fruit with the proportion of 50% green and 50% orange, while maximum peel colour score (4.36) was recorded in T_2 (Confidor

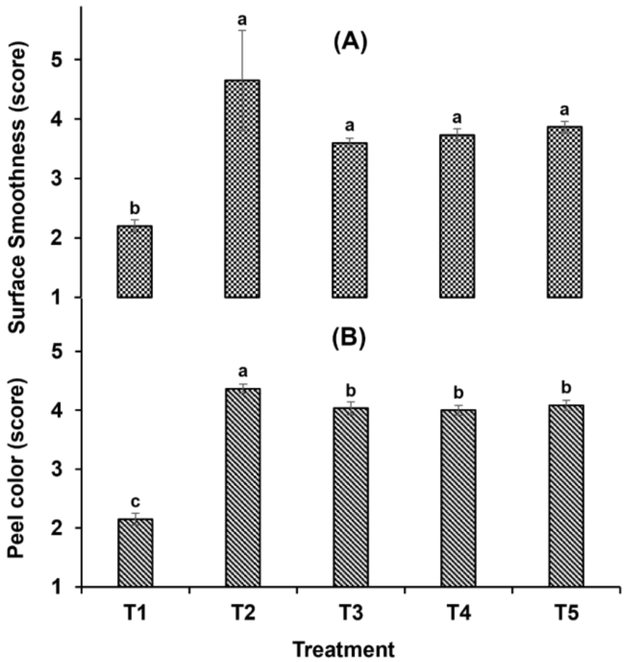

Figure 3: Effect of different insecticides and fungicides on surface smoothness (A) and peel color (B) of 'Kinnow' mandarin. T_1 = Control, T_2 = Confidor (1.5 ml/L) + Nativo (0.3 g L^{-1} water), T_3 = Actara (0.24 g L^{-1} water) + Topsin M (2 g L^{-1} water), T_4 = Actara (0.24 g L^{-1} water) + Nativo (0.3 g L^{-1} water) and T_5 = Confidor (1.5 ml L^{-1} water) + Topsin M (2 g L^{-1} water).

+ native), showing 75 to 100 percent orange colour followed by T_5, T_3 and T_4 respectively (Fig. 3B).

Physical parameters of fruit

Fruit yield per tree

As far as fruit yield is concerned, all treated plants had a significant impact on yield regarding the number of fruit and weight of fruit per tree. Higher yield (157.4 fruits/tree, 23.9 kg/tree) was recorded in T_3 in which plants were sprayed with Actara and Topsin M followed by T_5 (Confidor and Topsin M), T_2 (Confidor and Nativo) and T_4 (Actara and Nativo); while minimum yield (50 fruits/tree, 7 kg/tree) was recorded in T_1 control plants (Fig. 4A-B).

Average fruit, peel, rag, and juice weight

Regarding average fruit weight, significant differences were observed among treated and non-treated (control) 'Kinnow' mandarin plants. The maximum mean fruit weight (202.59 g) was measured in T_4 (Actara and Nativo), whereas minimum weight of fruit (113.77 g) was recorded in T_1 (control) (Fig. 4C). Plants treated with other fungicides and insecticidal sprays also gave good protection against diseases and insects involved in the deteriorating quality of fruit. The average weight of peel (%) of 'Kinnow' fruit was found significant among different treatments. However, highest weight of peel (31.96 %) was recorded in control plants (T_1) which were considered more than normal, followed by T_5 (27.69 %), T_4 (24.68 %) and T_3 (24.21 %), while

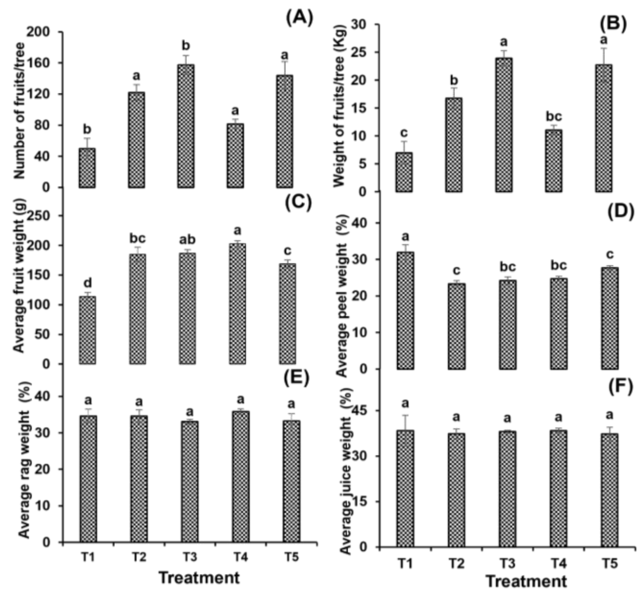

Figure 4: Effect of different insecticides and fungicides on physical quality attributes of Kinnow fruit. Vertical bars show ± SE of means. T_1 = Control, T_2 = Confidor (1.5 ml/L) + Nativo (0.3 g L^{-1} water), T_3 = Actara (0.24 g L^{-1} water) + Topsin M (2 g L^{-1} water), T_4 = Actara (0.24 g L^{-1} water) + Nativo (0.3 g L^{-1} water) and T_5 = Confidor (1.5 ml L^{-1} water) + Topsin M (2 g L^{-1} water).

minimum was recorded in T_2 (23.27 %) (Fig. 4D). The treatment of Confidor and Nativo (sprays) was found better than other treatments.

Results of rag weight (%) showed non-significant differences regarding different packages of fungicides/insecticides. The highest percentage of rag (34.61 %) was recorded in T_1 (control), and the lowest was observed in T_3 (33.04 %); plants subjected to Actara and Topsin-M spray (Fig. 4E). Non-significant results were obtained for an average weight of juice (%) in sprayed and non-sprayed plants. Maximum juice percentage was recorded in T_4 (38.38 %) followed by T_1 (38.37 %), T_3 (38.05 %), T_2 (37.35 %), while minimum was observed in T_4 (37.24 %) (Fig. 4F).

Organoleptic evaluation

Treatment application represents non-significant results regarding the sensory evaluation in 'Kinnow' mandarin fruit harvested from sprayed and non-sprayed plants. However, highest taste score (6.8) was observed in T_2 (Confidor + Nativo), and lower one was observed in T_1 (6.06) in which plants were subjected to farmer practice (Fig. 5). The fruit taste is the appealing attribute at both ends (consumers and processing stakeholders). Our results regarding taste proved that fungicides and insecticides spray does not affect the internal attributes of 'Kinnow' fruit. Non-significant results were recorded for a flavour of 'Kinnow mandarin' fruits harvested from sprayed and non-sprayed trees. However, maximum mean score (6.78) was recorded in T_3 (Actara + Topsin M) while minimum sore (5.92) was observed in T_4 (Actara + Nativo) shown in Fig. 5. Likewise, a statistically non-significant difference was noted for aroma in all treatments. However, highest score (7.1) for aroma was observed in T_3 (trees sprayed with Actara and Topsin-M, while the lower one was recorded in T_1 (control or farmer practice). A non-significant difference was obtained among various treatments regarding texture of 'Kinnow' mandarin fruit. The maximum score value was measured in T_3 (Actara + Topsin M) fruits regarding character 'texture' of 'Kinnow' mandarin while minimum (6.04) score was recorded in T_4 (Actara + Nativo) (Fig. 5).

Biochemical parameters

Soluble solid contents, titratable acidity, and sugar-acid ratio

SSC of 'Kinnow' mandarin juice was found statistically non-significant in the results of all treatments and replications. Maximum SSC (11.34 °Brix) was observed in T_5 (trees subjected to the sprays of Confidor and Actara) followed by T_2 (11.3 °Brix), T_3 (11.2 °Brix), T_4 (10.78 °Brix) while minimum (10.4 °Brix) was recorded in control trees. Titratable acidity results were statistically non-significant in 'Kinnow' mandarin fruit juice for both treated and non-treated trees (Fig. 6A). However, maximum TA (1.11 %) was calculated in control plants, while minimum (0.92 %) acidity was observed in fruit juice of plants treated with Confidor and Nativo sprays at preharvest level (Fig. 6B). Data regarding SSC: TA ratio was found non-significant among all treatments treated with chemical application or non-treated. However, trees sprayed with Confidor (insecticide) and Nativo (fungicide) showed highest SSC:TA ratio (12.34) followed by various interactions such as T5 (11.97), T4 (11.61), but minimum was observed in control treatment of plants (Fig. 6C).

Ascorbic acid content

Statistical data regarding ascorbic acid (mg 100 g^{-1}) revealed non-significant for whole experimental units in 'Kinnow' mandarin. Concerning the treatment effect, non-significant trend was observed; however, highest amount of ascorbic acid (58.51 mg/100 g) was measured in plants subjected to Actara and Nativo sprays (Fig. 6D).

DISCUSSION

In this study, rind quality (rind blemishes) was studied whole year to optimize package of fungicides and insecticides by its application to the young trees of 'Kinnow' mandarin at fruit setting stage while all parameters were analysed at harvest except the extent of a blemish in which fruits were under assessment during the whole year at monthly interval. The extent and nature of blemishes were significantly affected by combined application compared to control; Confidor @ 1.5ml L^{-1} and Nativo @ 0.3 g L^{-1} effectively reduce disease and pest inoculum on fruit surface. These results are similar to findings of Nativo fungicide (active part: Trifloxystrobin) having a positive impact on fruit quality of citrus, especially to inhibit fungal attack in the form of surface netting (citrus scab and melanose) as earlier reported by Malik and Khan (2014). Similarly, insecticides and fungicides also inhibit the population of thrips causing external damage in the form of a ring on the surface of fruit. Our results are supported by Grout et al. (2013), who reported that Confidor (Imidacloprid) showed the best results against citrus thrips by its soil application. Nativo is a protective and broad-spectrum fungicide that can reduce disease inoculum on peel surface and improve the quality and smoothness of 'Kinnow' mandarin. In our case, surface smoothness of fruit was improved in which plants sprayed with fungicides; Nativo followed by Topsin M. Fruit skin colour was also affected by the

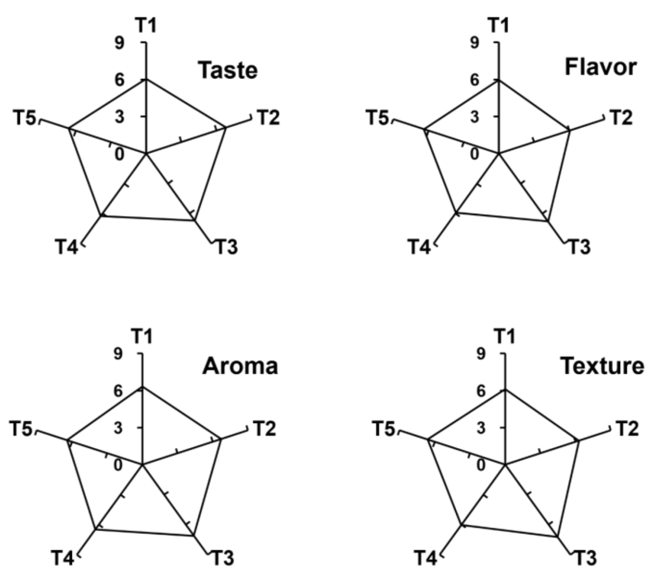

Figure 5: Effect of different insecticides and fungicides on organoleptic quality (taste, flavour, aroma, and texture) of Kinnow fruit. T_1 = Control, T_2 = Confidor (1.5 ml/L) + Nativo (0.3 g L^{-1} water), T_3 = Actara (0.24 g L^{-1} water) + Topsin M (2 g L^{-1} water), T_4 = Actara (0.24 g L^{-1} water) + Nativo (0.3 g L^{-1} water) and T_5 = Confidor (1.5 ml L^{-1} water) + Topsin M (2 g L^{-1} water).

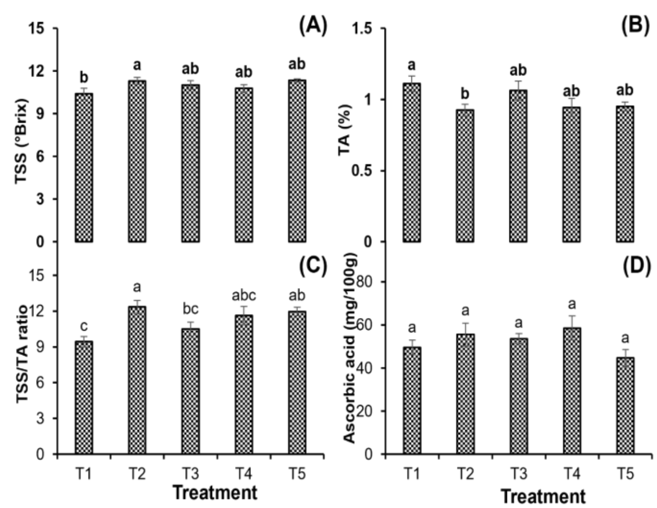

Figure 6: Effect of different insecticides and fungicides on biochemical attributes including TSS (A), TA (B) TSS/TA ratio (C) and ascorbic acid content (D) of Kinnow fruit. Vertical bars show ± SE of means. T_1 = Control, T_2 = Confidor (1.5 ml/L) + Nativo (0.3 g L^{-1} water), T_3 = Actara (0.24 g L^{-1} water) + Topsin M (2 g L^{-1} water), T_4 = Actara (0.24 g L^{-1} water) + Nativo (0.3 g L^{-1} water) and T_5 = Confidor (1.5 ml L^{-1} water) + Topsin M (2 g L^{-1} water).

use of pesticides and fungicides, which prevented from insect and disease damage and helped in the proper development of peel colour of 'Kinnow' fruit while our results are supported by the earlier findings of Amin et al. (2011) who revealed that development of peel colour in mango significantly affected by the pre and postharvest application of fungicides.

Preharvest or post-bloom fruit drop in citrus orchards has become a severe threat since the last few years. Many factors such as diseases (anthracnose, citrus greening) and environmental conditions are involved in fruit drop. The preharvest fruit drop is majorly caused by the fungus '*Colletotrichum acutatum*' spread in the whole orchard by windblown rain. In our concerned study on 'Kinnow' mandarin, higher production (in terms of fruit number and weight) and improved average fruit weight, peel weight and its diameter were recorded in trees subjected to fungicide sprays. Our study findings were strongly supported by Nasir et al. (2017), who reported that preharvest sprays of Nativo (Trifloxystrobin) at the flowering stage in mango greatly reduced disease percentage (92.03 %) of anthracnose and powdery mildew (90.19 %), followed by Topsin M (Thiophanate methyl) reduced disease inoculum less than 80%. Preharvest fungicide sprays significantly reduce disease incidence and give a higher yield per tree with improved quality in mango.

In the current study, trees sprayed with various combinations of fungicides and pesticides does not affect organoleptic characters (taste, flavour, aroma, and texture) and biochemical attributes (SSC, TA, SSC: TA ratio and ascorbic acid content) of 'Kinnow' mandarin fruit (Fig. 5 and 6). Fungicide application on mango with different combinations showed non-significant results on fruit for organoleptic characters (Jabbar et al., 2012), while pre- and post-harvest fungicidal application does not change biochemical attributes of fruit (Amin et al., 2011).

CONCLUSION

To sum up, the preharvest application of sprays in optimized concentration can significantly reduce the disease incidence and pest pressure in a citrus orchard. Findings of the present study led to the conclusion that 'Kinnow' mandarin trees sprayed with a combination of Confidor (1.5 ml L^{-1} water) and Nativo (0.3 g L^{-1} water) effectively reduced the extent and nature of fruit skin blemishes as compared to the trees sprayed with Actara (0.24 g L^{-1} water) and Topsin M (2 g L^{-1} water) and non-sprayed control trees. Rind quality parameters (peel colour, surface smoothness) were found to be improved through their application. Fungicide application markedly reduced the post-bloom drop of fruit and increased its productivity in terms of number and weight of fruit per tree. Hence, the adaptation of year-round production technology having an optimized schedule of preharvest sprays of fungicides and insecticides would reduce blemishes in 'Kinnow' mandarin and enhance A-grade quality fruits.

Author contribution statement

Mahmood Ul Hasan: Conceptualization, methodology, software, data curation, investigation, writing- original draft; **Basharat Ali Saleem:** Conceptualization, supervision, methodology, visualization; **Sajid Aleem Khan & Muhammad Shafique Khalid**: Planning, methodology; **Faisal Hayat & Raza Salik:** Writing- reviewing and editing.

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