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Yield losses estimation in declined orchards and role of farmer's agronomic practices on citrus orchards health in Punjab, Pakistan

Zafar Iqbal[1], Salman Ahmad[1*], Muhammad Asim[1], Mohsin Raza[1], Malik Abdul Rehman[2], Waqas Raza[1], Muhammad Zohaib Anjum[1], Ghaffar Ahmad[1]

[1]*Department of Plant Pathology, College of Agriculture, University of Sargodha, Sargodha, Pakistan*

[2]*Citrus Research Institute Sargodha, Pakistan*

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Abstract

Citrus is most cultivated fruit crop in province Punjab of Pakistan. Since many years, the orchards of Punjab have been facing severe problem of citrus decline. The goals of present research was to estimate yield losses on three main declined cultivars of citrus and assessing role of farmer's agronomic practices on the disease incidence of citrus decline. For these two goals, a comprehensive survey was planned in citrus belt of Punjab. Yield losses were computed comparing yield of healthy and declined citrus trees. To study the role of farmer's agronomic practices, questionnaire was developed comprising different questions. The questions were related to orchard age, number of irrigations to be applied to orchards, cultivated citrus varieties, and effect of fertilizer applications, organic amendments and intercropping on the disease incidence of citrus decline. The yield losses results indicated that feutrells early, mausambiand Kinnow varieties were facing 79%, 77% and 76% reduction in yield, respectively. The survey results exhibited that disease incidence of citrus decline was observed low in orchards receiving 6-10 irrigations, with no intercropping, age under ten years, and in which farmers were applying phosphorous, nitrogen and potash fertilizers in adequate amount. Disease incidence was less in orchards receiving organic matter in addition to fertilizers applications. Survey results showed that yield of citrus orchards is significantly lowering due to citrus decline. This study further recommends young plantations, irrigations 6-10, no intercropping, and use of organic matter with optimal applications of phosphorous, nitrogen and potash fertilizers in citrus orchards.

* **Corresponding Author:** Salman Ahmad ✉ salman.ahmad@uos.edu.pk

Introduction

Citrus is one of the most important fruit crops of the world that belongs to family *Rutaceae,* comprising 130 genera and seven subfamilies (Khan, 2015). Pakistan is bestowed with fertile land and favorable climatic conditions for citrus cultivation. Mostly grown citrus varieties in Pakistan are Kinnow, Mausambi, Feutral's Early, Sweet lime, Grape fruit, Rough lemon and Lemon. Among them, Kinnow is at the top with 86% of the total citrus production of the country and is followed by Musambi (10%), Feutral's Early (4%) and Red blood (1%) (Memon, 2017). Kinnow of Pakistan is famous due to its unique and delicious taste. Pakistan is ranked 12th in citrus with more than 2.5 million tons production and is grown on an area of 206569 hectares. Citrus is cultivated in all provinces of Pakistan, but most of the citrus is cultivated in province Punjab due to copious amount of irrigation water and favourable climatic conditions. Province Punjab is producing 2,315,895 tons citrus annually, which is 98% of the total production of the country, out of which 70% is occupied by kinnow. Major citrus producing areas of Punjab are Sargodha, Multan, Lahore, Sahiwal, Sialkot, Faisalabad, Mianwali, Gujranwala, Jhang and Lyyah. Sindh is producing 31,259 tons citrus and is cultivated in districts viz. Nawabshah, Sukkuar and Khairpur. Production of KPK is 3,125 tons and major areas of cultivation are Mardan, Sawabi, Peshawar, Nowshera, Hazara and Sawat. Main areas for citrus production of Baluchistan are Kech, Makkran and Sibbi which are producing 7,350 tons (Memon 2017). Citrus fruit export is important source of foreign exchange for Pakistan and citrus export value of the country is 200 million USD per annum (Malik, 2014). Citrus yield per hectare in Pakistan is 10-12 tons while in the other citrus producing countries it is up to 26 tons per hectare (Iqbal, 2014). Citrus decline is the main reason for low yield.

Decline is a complex problem which gradually reduces the yield and finally orchard becomes unproductive. Both biotic and abiotic factors play their role in citrus decline. Fungi, bacteria, nematodes and virus are main biotic factors that are involved in citrus decline. Abiotic factors include nutrient imbalance, irrigation and cultural practices (Srivastava and Singh, 2009).

Abiotic factors also play significant role in citrus decline. Abiotic factors include nutrient imbalance, irrigation and cultural practices. Nutrient imbalance refers to excess or deficiency of nutrients. Excess and deficiency of nutrient are very harmful to citrus tree. Excess of Phosphorous is responsible for crinkle rind of citrus fruit. Deficiency of zinc produces rosette leaves while it's excess causes twig dieback, leaf burn and defoliation. Excessive amount of copper is reason for root damage and stunted growth of citrus plant (Srivastava and Singh, 2005).

Current research was planned with the objectives to study predisposing factors ultimately leading to decline manifestation, Study nutritional stress/influence on trees and Role of intercropping with decline manifestation.

Materials and methods

Surveys of different citrus growing areas of Punjab, Pakistan, were conducted to assess decline incidence. Collection of diseased specimens from citrus orchards was also done during assessment work. Areas visited during surveys included district Sargodha (Koatmomin, Bhalwal, Shahpur, Sargodha, Silanwali, Sahiwal), Faisalabad (Jaranwla), Toba Taik Singh (Gojjra, Toba Taik Singh), Multan (Shujjabad) and Khanewal.

Predisposing factors

A questionnaire was prepared for collection of background information and predisposing factors. Questionnaire included questions related to orchard age, variety name, agronomic practices, and number of irrigations, fertilizer applications, intercropping and organic amendments.

Disease incidence

In each citrus growing areas mentioned above, fifteen orchards were visited. In each orchard, 20 plants were selected at five sites; four plants on each corner

of the cubic orchard and four at right middle of the orchard. Then disease incidence was measured by using following formula (Safdar *et al.* 2010):

$$DI(\%)=\frac{\text{Number of infected plants}}{\text{Total number of inspected plants}}\times 100$$

Yield losses due to decline

Three plants (declined, partially declined and healthy) were assessed in each orchard using 0-5 rating scale described by Kazmi *et al.* (2005). According to this scale:

Yield losses were calculated on the basis of three parameters which included number of fruits, fruit size and fruit drop from four sides of each plant (healthy, partially declined, and declined). Then the average of these parameters (number of fruits, fruit size, fruit drop) was taken and yield losses were quantified using following formula (Cooke, 2006):

$$\text{Yield losses}=(X-Y)/\times 100$$

X=Number of fruit on healthy plant

Y=Number of fruit on diseased plant

Statistical analyses

Analysis of the data was performed using statistical software package Statistix (version 10; Statistix Analytical Software, USA). ANOVA was used in all analyses while means were compared using LSD values (at $P<0.05$) (Steel *et al.* 1997).

Results

A survey of different citrus growing areas of Punjab was conducted for collection of samples and estimation of yield losses. One hundred and twenty orchards were visited for this purpose.

Citrus decline incidence in different districts of Punjab

Citrus decline incidence varied significantly ($P \leq 0.05$) in different districts of Punjab. Highest disease incidence (DI) was observed in tehsil Kotmomin (48.33%) followed by tehsil Sargodha (47.5%), Silanwali (44.44%) and Shahpur (36.11%).

In district Sargodha, Tehsil Sahiwal and Bhalwal were least affected with DI 35.55% and 30%, respectively. DI in Toba Taik Singh, Faisalabad and Multan was 31.11%, 26.11% and 22.22%, respectively (Fig. 1A).

Table 1. Disease Rating Scale.

Scale	Rating
0	Healthy Plants
1	1-10% decline
2	11-20%Partially declined
3	21-30%
4	31-50
5	More than 50% Declined

Role of predisposing factors in citrus decline

Effect of irrigations on citrus decline

Number of irrigations significantly ($P \leq 0.05$) affected citrus decline. There was different trend of farmer's irrigations. On the basis of survey results, number of irrigations was placed in to four combinations 1-5, 6-10, 11-15, 16-20, respectively. The results showed that number of irrigations plays significant ($P \leq 0.05$) role in citrus decline. DI was less at 6-10 irrigations while it was high at ≥15 irrigations. Results showed that DI of citrus decline significantly increased as number of irrigations increased (Fig. 1B).

Effect of fertilizer applications on citrus decline

Effect of fertilizer applications was significant ($P \leq 0.05$) on citrus decline. Highest DI (48.33%) was recorded in orchards where no fertilizer was applied while lowest DI (17.5%) was recorded where nitrogen, potash, phosphorous and zinc fertilizers were applied (Figure 3). Second lowest DI (25%) was recorded where nitrogen, potash and phosphorous fertilizers were applied.

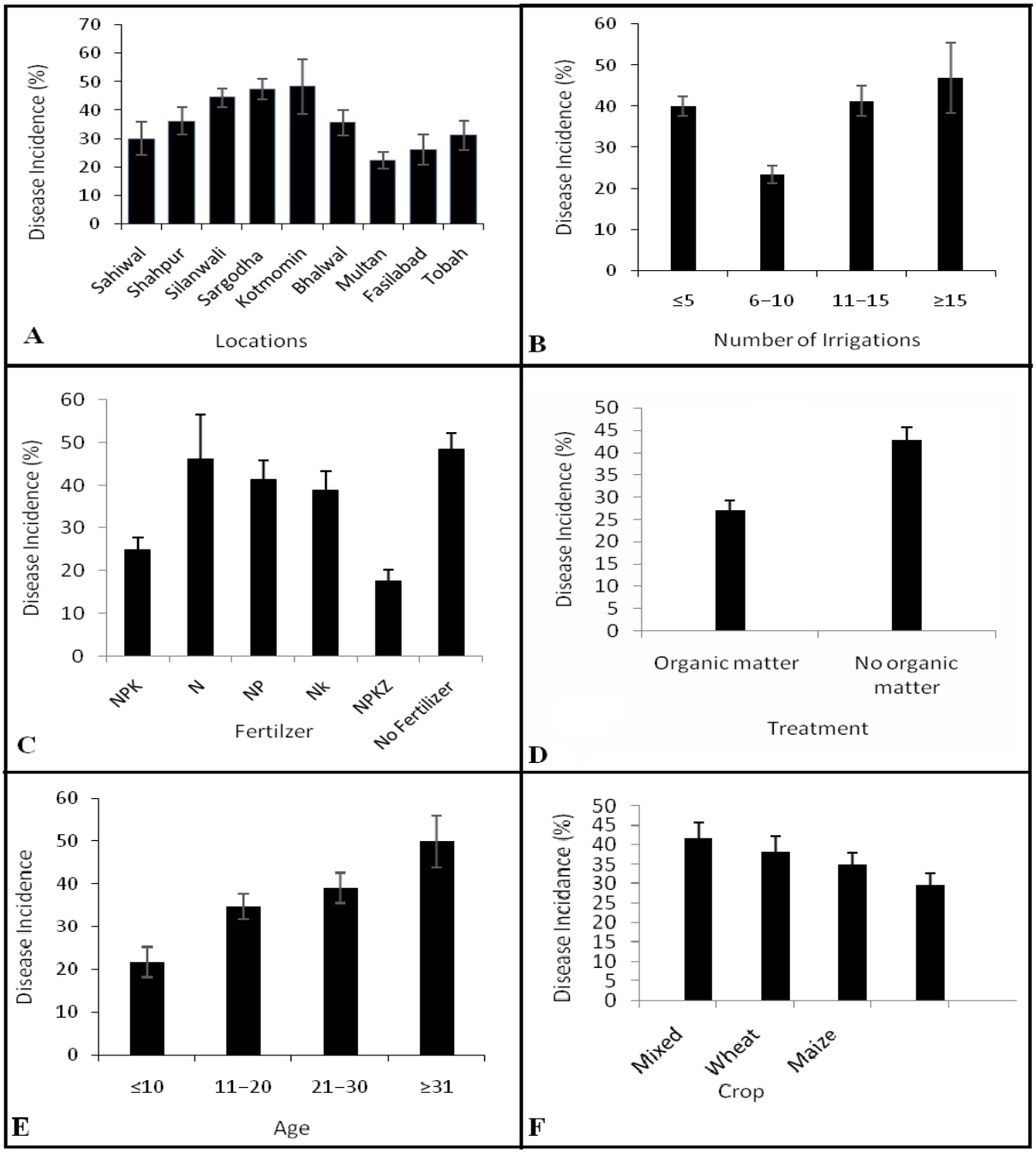

Fig. 1. A. Incidence of citrus decline in different districts of Punjab B. Effect of irrigation on citrus decline incidence C. Effect of fertilizer application on citrus decline D. Effect of organic matter application on citrus decline E. Effect of age of orchard on citrus decline F. Effect of Intercropping on citrus decline.

The effect of single fertilizer and combination of two fertilizers did not significantly affect DI of citrus decline (Fig. 1C).

Effect of organic amendment on citrus decline

Organic matter effect was significant ($P \leq 0.05$) on citrus decline (Fig. 1D). Orchards having applications of organic matter showed less DI (27.16%) compared to orchards receiving no organic matter (42.79%).

Effect of orchard age on citrus decline

For the evaluation of citrus decline DI in relation to age, orchards were divided into four categories, ≤10, 11-20, 21-30 and ≥30 (Fig.1E).

It was found that DI significantly ($P \leq 0.05$) increased with the increase of orchard age. Lowest DI (21.66%) was observed at ≤10 years orchard age while highest DI (50%) was noted in orchards aged ≥30.

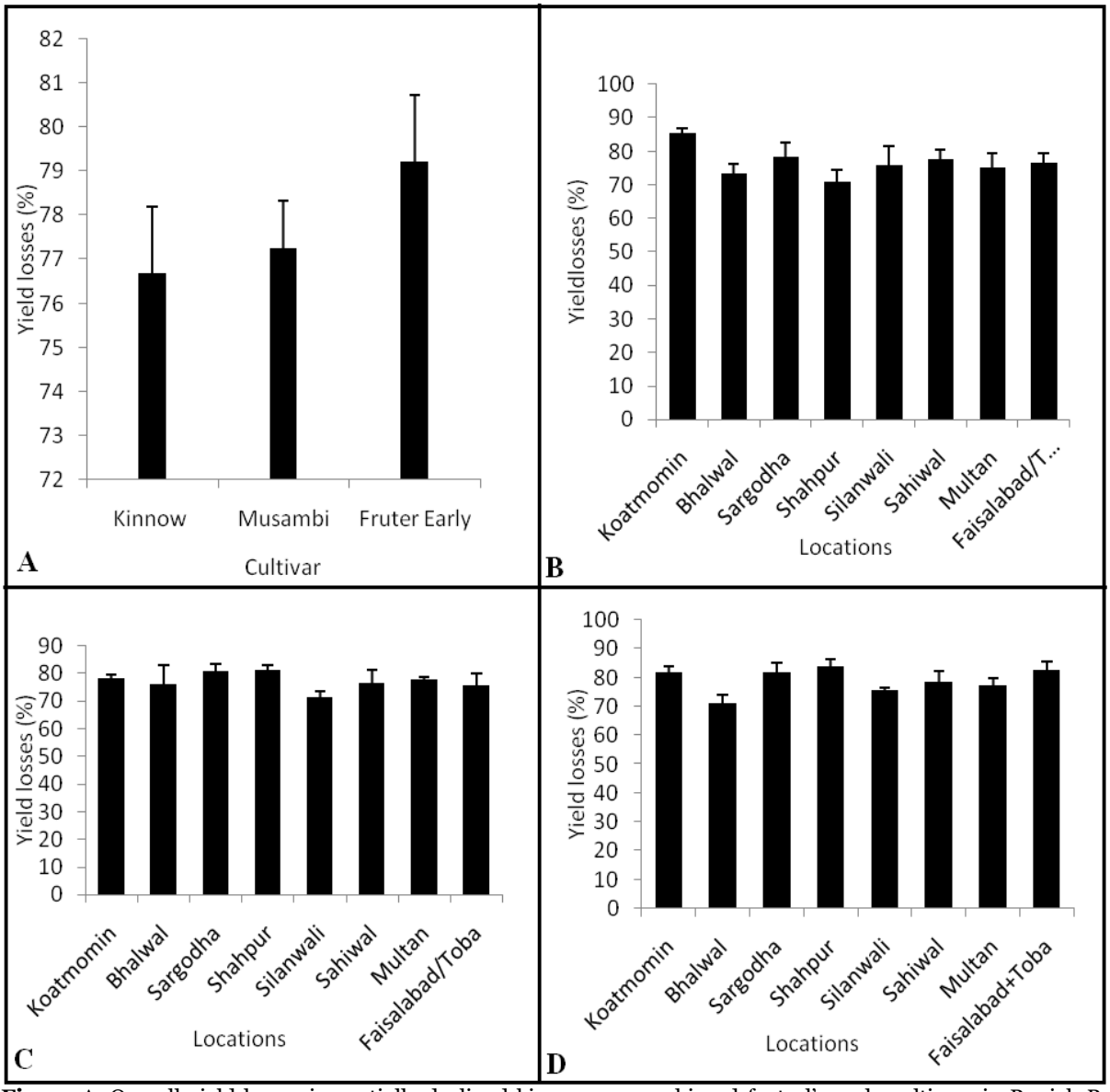

Fig. 2. A. Overall yield losses in partially declined kinnow, musambi and feutral's early cultivars in Punjab B. Yield losses in partially declined kinnow orchards C. Yield losses in partially declined mausami orchards D. Yield losses in partially decline feutrals early orchards.

Effect of intercropping on citrus decline

Wheat, maize and berseem intercropping or mixed cropping was observed in citrus orchards. DI (41.72%) was significantly ($P \leq 0.05$) highest in orchards where mixed cropping was done (Fig. 1F). Lowest DI (29.84%) was observed in orchards where no intercropping was practiced. Orchards having wheat and berseem intercropping showed 38.12% DI, while with maize intercropping DI was 35%.

Yield losses in partially declined citrus orchards of Punjab

Yield losses were also determined in partially declined citrus orchards of kinnow, mausambi and feutral's early. Highest yield losses were observed in feutrals early 54.32% followed by mausambi 50.84% and kinnow 46.14% (Fig. 2 A). There was significant ($P \leq 0.05$) difference in yield losses of these partially declined cultivars in different citrus growing areas. In case of kinnow, maximum yield losses were observed in Kotmomin (58.11%) followed Multan (55.96%), Faisalabad/Toba (51.96%), Sahiwal (47.22%), Silanwali (41.62%), Bhalwal (40.66%), Shahpur (37.27%) and Sargodha (36.44%) (Fig. 2B). In mausambi, highest yield losses were found in Sargodha (62%) followed by Shahpur (58.65%),

Silanwali (54.44%), Kotmomin (53.86%), Faisalabad/Toba (51.43%), Sahiwal (45.48%), Multan (40.93%) and Bhalwal (40.14%) (Fig. 2C). In partially declined feutral's early orchards, maximum yield losses were estimated in Shahpur (61.31%) followed by Kotmomin (59.91%), Silanwali (57.07%), Sargodha (55.26%), Sahiwal (54.41%), Faisalabad/Toba (53.57%), Multan (51.67%) and Bhalwal (41.32%) (Fig. 2D).

Yield losses in declined orchards of Punjab

Citrus decline is significantly ($P \leq 0.05$) affecting yield of citrus in all citrus growing areas of Punjab. Yield losses were measured for three major cultivars viz., kinnow, mausambi and feutral's early. Maximum yield losses of 79.22% were found in feutral's early followed by mausambi (77.26%) and kinnow (76.68%) (Fig. 3A). When yield losses were estimated in kinnow in different citrus growing areas of Punjab, maximum yield losses were observed at Kotmomin (85.35%) followed by Sargodha (78.33%), Sahiwal (77.58%), Silanwali (75.97%), Faisalabad (76.69%), Multan (75.31%), Bhalwal (73.38%) and Shahpur (70.84) (Fig. 3B). In mausambi orchards, maximum yield losses were estimated in Shahpur (81.19%) followed by Sargodha (80.75%), Kotmomin (78.16%), Multan (77.86%), Sahiwal (76.67%), Bhalwal (76.07%), Faisalabad (75.71%) and Silanwali (71.67%) (Fig. 3C). In case of feutral's early orchard, higher yield losses were observed in Shahpur (83.81%) followed by Faisalabad (82.86%), Sargodha (81.97%), Kotmomin (80.90%), Sahiwal (78.68%), Multan (77.5%), Silanwali (75.72%) and Bhalwal (71.33%) (Fig. 3D).

Discussion

Pakistan citrus industry is in continuous yield loss in recent years and the major reason behind this loss is citrus decline. In present study, disease incidence of citrus decline was estimated throughout the Punjab, Pakistan. DI varied in different localities and it was found highest in Kotmomin (48.33%) and lowest in Multan (22.22%). The lowest incidence of citrus decline in Multan may be due to new plantations of citrus orchards with low microflora densities. Fateh *et al.* (2017) carried out the survey of DI of citrus decline in Sargodha region, and found lowest DI in citrus groves having young plantations.

Nutrients are absolutely essential for the defence of plant against different diseases. Deficiency of even a single nutrient may result in weakening of plant defence against diseases. In current study, it was observed that lowest decline (17.5%) was in the fields where a balanced dose of nutrients was being applied, while highest susceptibility of citrus trees to decline was observed in fields where no nutrient/s were being applied (48.33%). Masood *et al.* (2012) studied the effect of nutrients on the health of mango in relation to resistance against different diseases. They found that if nitrogenous and phosphorus-based nutrients are applied then there was significant reduction in disease severity from 30.69% to 8.39%. If zinc or copper compounds are mixed with these nutrients, further decrease in disease severity is possible (Masood *et al.*, 2012). On the basis of their studies, they recommended balanced amount of nutrients to mango orchards for their better growth and protection against diseases.

The survey revealed that applications of organic matter in the orchards have very positive effect on their health. In fact, soil fertility and porosity increase with the presence of beneficial micro-organisms in the soil (Adekiya and Agbede, 2017). In present survey, it was found that where FYM was being applied by the farmers, in those orchards DI was less. (Adekiya and Agbede, 2017) studied the effect of organic amendment (chicken manure) on tomatoes and found increase in yield by 7.6-45.2%, while quality was also improved such as amount of vitamin-C increased by 3.0-33.5%.

Irrigation has a significant role on plant health and increases ability of the plant against different stresses. Right amount of water at right time is much essential for the growth and protection of any crop against diseases. Citrus is much sensitive crop to irrigations. The quality of ground water is getting deteriorated and number of irrigations is either high or low.

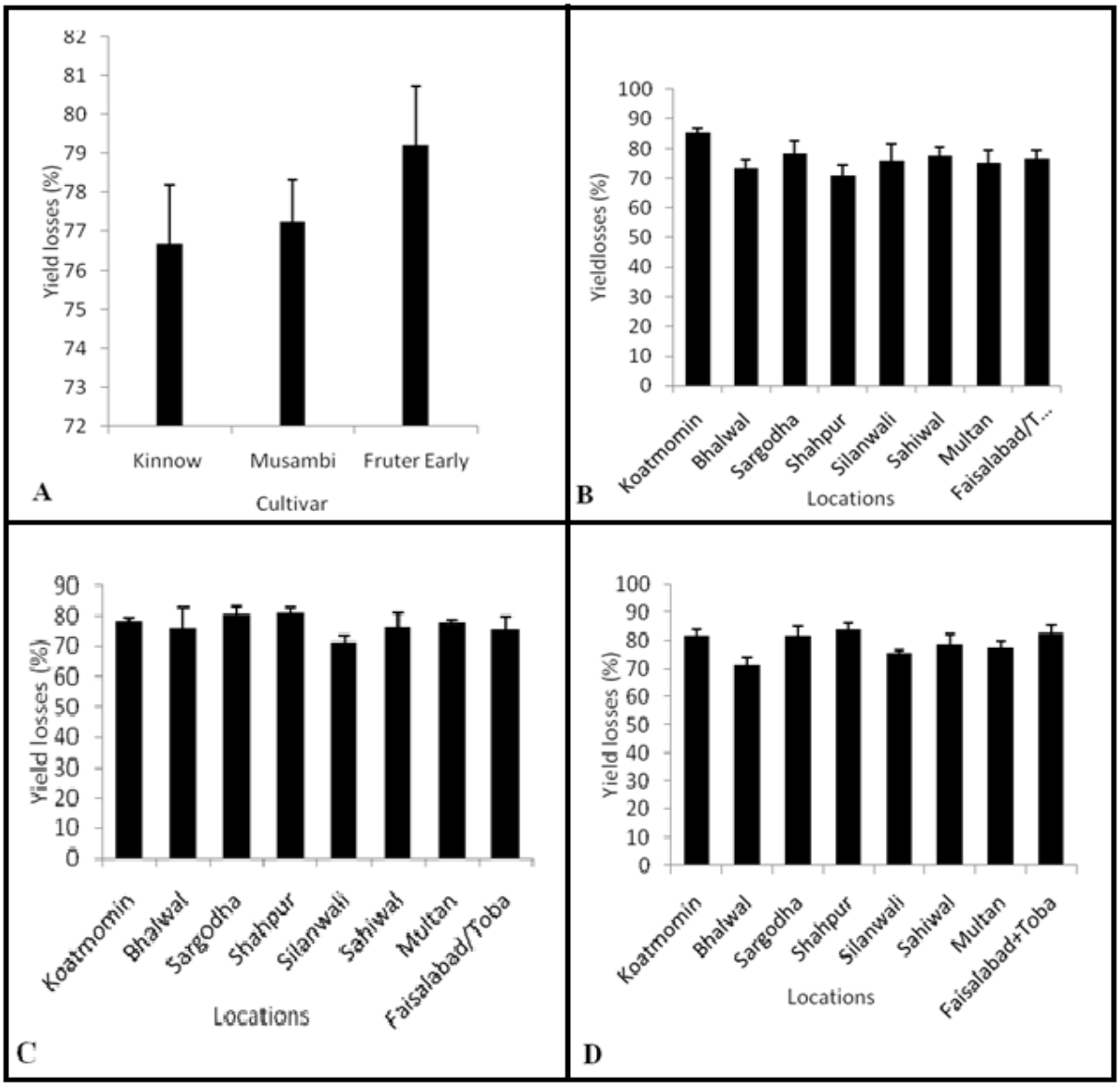

Fig. 3. A. Overall yield losses in declined kinnow, musambi and feutral's early cultivars in Punjab B. Yield losses in declined kinnow orchards C. Yield losses in declined musambi orchards D. Yield losses in decline Feutrals Early orchards.

In current survey, effect of number of irrigations was studied and it was found that high and low number of irrigations significantly increased DI. Panigrahi *et al.* (2016) found that water usage by citrus plants was much lower during February to March and highest during October to November. While in Pakistan no pattern is being followed for citrus irrigations; water is applied whenever available. Karaşahin *et al.* (2014) used different devices to check the water requirement and found that if right amount of water was applied in accordance with device measurements then an increase in green matter and crop yield was possible. Bajwa and Javaid (2007) carried out survey on shisham decline and found that decline was high (75–80%) around canal. They attributed this higher incidence of shisham decline due to undesired water availability to the plants on canal bank. Irrigation with proper planning, or by using different techniques to check water requirement of orchard, could boost up the yield of the orchard.

Orchard health can be maintained for longer periods, if balanced amount of nutrients is applied with preventive measures. However, old age orchards are more prone to diseases because of their weak defence against the pathogens (Savita and Nagpal, 2012).

In present research, it was found that DI was high in old age orchards compared to young. This in line with the findings of Maseko and Coutinho (2001) who carried out trials on the density of different pathogens on citrus and found that density and variety of pathogens increased as orchard age increased. Savita and Nagpal (2012) found high population of *Colletotrichum, Pythium* and *Phytophthora* species on aged citrus plants as compared to young plants.

In current survey, it was found that orchards having mixed cropping of exhaustive crops exhibited high DI, while orchards with no intercropping had less DI. The survey also revealed that intercropping was common practice in the citrus orchards of the Punjab. During survey, it was noticed that farmers having small holding were practicing more intercropping compared to those farmers holding large acreage. It was further observed that exhaustive crops such as wheat, maize and berseem were commonly cultivated in citrus groves. These crops in fact consume most of the nutrients resulting in nutrient deficiency of orchards which ultimately weakened the plants and enhanced decline syndrome (Hartemink, 2006). Cultivation of vegetables in citrus groves increases density of nematodes which also enhances decline (Irshad *et al.*, 2012). Dominguez *et al.* (2000) found that there was high density of the nematodes in the orchards where vegetables were grown. Intercropped crops require water when water is not suitable for citrus, for example, wheat requires more water in the month of November and from mid-February-March, while water requirement of citrus is more in the month of mid-September to mid-October. Panigrahi *et al.* (2016) conducted research on irrigation management of citrus orchards and reported that orchard health can effectively be managed by right time application of irrigation.

Conclusion

The current study revealed that citrus decline is prevalent in all citrus growing areas of Punjab, Pakistan. Koatmomin has been identified as the hotspot area of this syndrome. Intercropping, no use of organic amendment, inappropriate use of fertilizer and irrigation are the main reason of citrus decline.

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