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Improving Yield and Fruit Quality of 'Siyahoo' Mandarin (*Citrus reticulata*) by Foliar Application of Nitrogen and Harvest Time

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ABSTRACT

'Siyahoo' mandarin (*Citrus reticulata*) is one of the most important high-quality cultivars of citrus. The alternate bearing, especially in old trees, is one of the most important economic problems faced by this cultivar, which adversely affects the fruit quality. This study was carried out to examine the effects of the timing of nitrogen foliar application (mid-November, mid-December, and mid-January) as urea 0.5% and harvest time (the first time: concordant with the minimum commercial ratio of TSS/TA and the second time: 45 days after the first time) on improving the fruit yield and quality of 'Siyahoo' mandarin during five successive years from 2012 to 2017 using 36 trees. The results showed that the second harvest time (conventionally practiced) produced the highest yield compared to the first harvest time (for the lowest TSS/TA ratio). The highest yield was obtained in the second harvest time when nitrogen was sprayed in November. The significant interaction of harvest time and spray timing revealed the lower pH (~3) in the first harvest compared to the second one (~4). Nitrogen spraying in November and January yielded the highest (8-10) and lowest (<8) TSS/TA ratio, respectively. Although, the effect of the timing of nitrogen spraying on the fruit weight was not significant, spraying in January increased the fruit weight by 10% compared to the November spraying. Variations in the fruit diameter followed a similar pattern to variation in the fruit weight, which was due to their correlations. In conclusion, it is recommended to harvest the fruits after second nitrogen application, because the higher fruit yield and quality in terms of sweetness and flavor (TSS/TA ratio) are more acceptable.

Introduction

The alternate bearing is a common economic problem among some fruit trees such as citrus, mango, pistachio, apple, and olive. In the alternate bearing after one high-yielding year (On-year), fruit production will be reduced for one or several years (Off-year). This phenomenon in citrus is influenced by a

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variety of factors including cultivar and rootstock, tree age, flowering habit, holding fruit on the tree for a long time, pollination, number of seeds in the fruit, amount of leaf photosynthesis, vegetative and generative growth equilibrium, environmental factors such as temperature and moisture stresses, pests and diseases, nutrition and irrigation (Verreynne and Lovatt, 2009).

The alternate bearing significantly affects the fruit yield, size, ripening time and quality. The fruit size and damage to the tree in the On-years are among cases that increase the importance of alternate bearing; in this regards mandarins are the special citrus species. For this reason, the major part of researches into the alternate bearing has been focused on the mandarin cultivars. Usually, in mandarins in the On-years, the fruit size is small, the fruit quality is low and the fruit ripening is delaying. For instance, in Pixie mandarin in the On-year about 50% of the fruits are out of market standard (Verreynne and Lovatt, 2009). In the Off-years, although the fruit quality is better than the On-year, the grower lose benefit due to the low yield and the decrease in the external fruit quality such as rough surface (Moghbeli-Hanzaei and Tafazolli, 2002). Therefore, it is expected that the controlling alternate bearing could improve fruit quality.

'Siyahoo' mandarin (*Citrus reticulata*) is one of the most important high-quality cultivars of citrus with about 5000 hectares of land under cultivation. This citrus species has been known in Iran and some other countries (Ahmadi et al., 2019). The alternate bearing, especially in old trees, is one of the most important economic problems faced by this cultivar, which adversely affects the fruit quality. The existence of large numbers of fruits on trees and their competition as the carbohydrate sinks, consequently reducing tree vigor, will affect flowering in the next year (Verreynne and Lovatt, 2009). Early fruit harvest in the On-year decreases the intensity of alternation bearing. This operation also helps increase the crop yield in the next year (Fotouhi-Ghazvini, 2011). It is believed that the harvest time or duration of remaining fruit on trees affects the intensity of flowering via accumulation of the stored carbohydrate or other controlling factors such as hormones (Van der Merwe, 2012). Also in other fruit trees, it has been shown that the produced hormones in apple seeds prevent induction of flowers for the next year (Jackson, 2003).

Ahmad et al. (1995) found that the foliar application of urea is more effective than the soil application of nitrogen and it increases the fruit set and yield as well as the fruit size. Marschner (1995) showed that the root activity such as absorption decreases at the beginning of the reproduction stage because of competition for carbohydrate uptake. In this case, the foliar application of nutrients can be compensated for nutrient deficiencies. Stander et al. (2018) found that leaf macronutrients in the alternate bearing of 'Nadorcott' mandarin trees are not related to differences in flowering and vegetative shoot development, and appear to be a consequence of fruit load and not a determinant thereof. El-Otmani et al. (2002) reported that foliar-applied urea is an efficient, cost-effective way to supply nitrogen to Clementine trees and reducing alternate bearing. In a study, it was observed that the foliar application of 0.5-3% urea before and after the fruit harvest affected tree growth, flowering and fruit set of Mihowase Satsuma mandarin (Mudau et al., 2004). The foliar application of urea on high-yield trees enhanced the flower number and on low-yield trees decreased the flower number. The foliar application of urea at a 1% concentration one week before and after harvesting improved the nutrition status of trees and increased the fruit set (Yamanishi, 1995). Supplying nitrogen, zinc, and boron at the critical time has special importance. Bud swelling time is one of the critical stages. The increasing value of the above elements in leaves and flower buds even if there is no shortage, lead to increase in yield and improve the fruit qualitative properties because of the metabolic and physiological roles of these elements (Asadi-Kangar Shahi and Akhlaghi-Amiri, 2005).

The results of a study about the application time of low-biuret urea for increasing and improving the yield and marketing index and fruit quality of pigmented sweet orange indicated that the foliar application of low-biuret urea in mid-November significantly increased the yield and first-class fruits compared with the control treatment (Saleem et al., 2008). They also observed that the November application improved the qualitative fruit parameters in comparison with the control treatment. The significant reduction in the fruit weight and diameter, as well as the aborted seeds of the fruit, was recorded in all treatments. The highest amount of these parameters was observed for the control treatment and the foliar application of low-biuret urea on December 15th, October 15th, and November 15th were in the next classes. The highest fruit weight and diameter (108.3 g and 56.9 mm, respectively) were detected by the foliar application on November 15th. The low-biuret urea had no effect on the fruit juice, peel weight and acidity (Saleem et al., 2008). The severity of the alternate bearing appears to be related to extremes in crop load and to late harvest in the on-crop year. In some cases, heavy crops are still on the tree during floral induction and sometimes during full bloom and initial fruit set and in these cases; earlier harvest is not an option (Verreynne, 2009). They concluded that the reason for this observation was the absence of carbohydrate stock due to the ripened fruit competition on the tree.

Dennis (2003) believed that nutrient deficiency can decrease flowering and bearing of fruit. The findings of Moradi (2007) demonstrated that the foliar application of urea increased the leaf nitrogen concentration, TSS, fruit peel thickness, percentage of fruit set and yield of Thomson navel sweet orange. The highest fruit yield in each tree was observed for the foliar application of 0.5% urea in July and 1.0% urea in March (94.83 and 93.40 kg tree^{-1}). About Unshu mandarin, the highest fruit yield in each tree (201 kg tree^{-1}) was observed for the foliar application of 0.5% urea in September (Moradi, 2007). In the present study, to reduce alternate bearing of 'Siyahoo' mandarin, the effect of application time of nitrogen as urea via the foliar application as well as the time of fruit harvesting were evaluated during five successive years.

Materials and Methods

At first, ten-years-old trees on sour orange rootstock were selected and their On- and Off-year were distinguished. The present study was conducted during five successive years on 36 mature trees 'Siyahoo' mandarin in the Farghan region, Hajiabad, Hormozgan (56° 19´ 59´´ E and 28° 08´ 36´´ N). A full-factorial experiment in randomized complete block design with three different occasions of urea (0.5% N) foliar application in the autumn and two different harvest occasions, resulting in six treatments, was done during five successive years. The trees were in three blocks with two replicating trees per treatment and block. All autumn applications of urea were followed by two spring foliar applications of urea (0.5% N): at full bloom and about two weeks after petal abscission. The autumn application occasions of urea were mid-November, mid-December and mid-January, and two harvest occasions were early (at the minimum commercial TSS/TA ratio) and late (45 days after early harvest). The six treatments included:

1) mid-November application of urea + early harvest, 2) mid-November application of urea + late harvest, 3) mid-December application of urea + early harvest, 4) mid-December application of urea + late harvest, 5) mid-January application of urea + early harvest and 6) mid-January application of urea + late harvest.

At the onset of the study, all individual trees were randomly allocated to treatment and then the urea application was utilized every On-year for each tree. The treatments included three autumn foliar applications of urea at 0.5% nitrogen (mid-November, mid-December, and mid-January) and two fruit harvest times [the first time: concordant with the minimum commercial ratio of TSS/TA about early January (40 weeks after full bloom) and the second time: 45 days after the first time]. The total soluble solid (TSS) is usually measured by a manual refractometer and its amount increase at the beginning of the ripening stage. The total acid (TA) was also assessed by titration with a 0.1 N NaOH solution and its amount decreases at the beginning of the ripening stage in the mandarin cultivars (Van der Merwe, 2012). The following foliar application in the three mentioned times, two spring foliar applications of urea were uniformly performed at the same previous concentration (at full bloom and one to three weeks after petal abscission) for all experimental units. The urea treatments were only sprayed in the On-year.

During the experiment, the operation of protection, including irrigation, fertilization, and weed control were uniformly carried out for all trees. The assessed parameters consisted of fruit yield, fruit weight, fruit length and diameter, pH, TSS, TA, and TSS/TA ratio. The data was analyzed using the MSTAT-C software and the means were compared by Duncan's multiple range test (DMRT) and the charts were drawn using the Excel software.

Results

The results of the analysis of variance demonstrated that there was a significant difference among years for the fruit yield, average fruit weight and fruit diameter ($p < 0.05$). Spraying time of urea had a significant influence on average fruit weight ($p < 0.01$) (Table 1).

Table 1. Analysis of variance concerning the effect of foliar application time of urea and harvest time on the studied attributes of 'Siyahoo' mandarin during five years

S.V	D.F	Mean square (M.S)					
		Fruit yield	pH	TSS/TA	Fruit weight	Fruit length	Fruit diameter
Replication (R)	2	22.4^{ns}	0.089^{ns}	0.235^{ns}	109.2^{ns}	21.6^{ns}	23.6^{ns}
Year (Y)	4	214.6^{*}	0.035^{ns}	0.365^{ns}	592.0^{*}	29.0^{ns}	157.4^{*}
Error	8	41.3	0.101	0.451	114.3	32.0	38.0
Spraying time (A)	2	39.7^{ns}	0.056^{ns}	0.521^{ns}	962.6^{**}	33.3^{ns}	32.6^{ns}
Harvest time (B)	1	254.6^{*}	0.022^{ns}	3.691^{*}	56.7^{ns}	28.4^{ns}	15.2^{ns}
AB	2	365.1^{**}	1.621^{**}	4.521^{**}	745.1^{**}	30.2^{ns}	11.8^{ns}
YA	8	452.1^{**}	0.099^{ns}	5.632^{**}	698.6^{**}	19.2^{ns}	325.4^{**}
YB	4	359.2^{**}	2.321^{**}	5.892^{**}	45.5^{ns}	159.6^{*}	41.6^{ns}
YAB	8	32.2^{ns}	0.078^{ns}	0.652^{ns}	98.3^{ns}	38.6^{ns}	31.9^{ns}
Error	50	53.9	0.109	0.717	112.3	39.4	42.5
C.V%		18.6	4.8	8.7	15.6	11.2	13.0

^{ns}Not significant, *Significant at $p < 0.05$, **Significant at $p < 0.01$.

The harvest time was effective on fruit yield and TSS/TA ratio ($p < 0.05$). There was a significant interaction between the foliar application time and the harvest time about the fruit yield, pH, TSS/TA ratio and average fruit weight ($p < 0.01$). The interaction between years with each factor was significant in some parameters. It was no observed significant interaction among year, foliar application time and the harvest time (Table 1).

Yield

A comparison of the mean data showed that the fruit yield in the second harvest time (45 days after the first time that was concurrent with gardener harvest time) was significantly higher than the first harvest time (concordant with the minimum commercial ratio of TSS/TA) (Fig. 1A). The fruit yield was different in various years (Fig. 1B). A Comparison of different years showed fluctuation in the crop yield. However, in the final years of the experiment, a range of fluctuation was lower than in the early years. The yield of 'Siyahoo' mandarin according to the time of foliar application during five years demonstrated that the fruit yield in the final years decreased compared to the early years in all time treatments of foliar application. Figure 1C shows the interaction between years and the harvest time. Yield fluctuations decreased in both harvest times in the final years of the experiment that the total yield in the final years decreased in comparison with the early year of the experiment. Furthermore, the amount of the yield reached the final years, however, the yield of the second harvest time was slightly higher than that of the first harvest time.

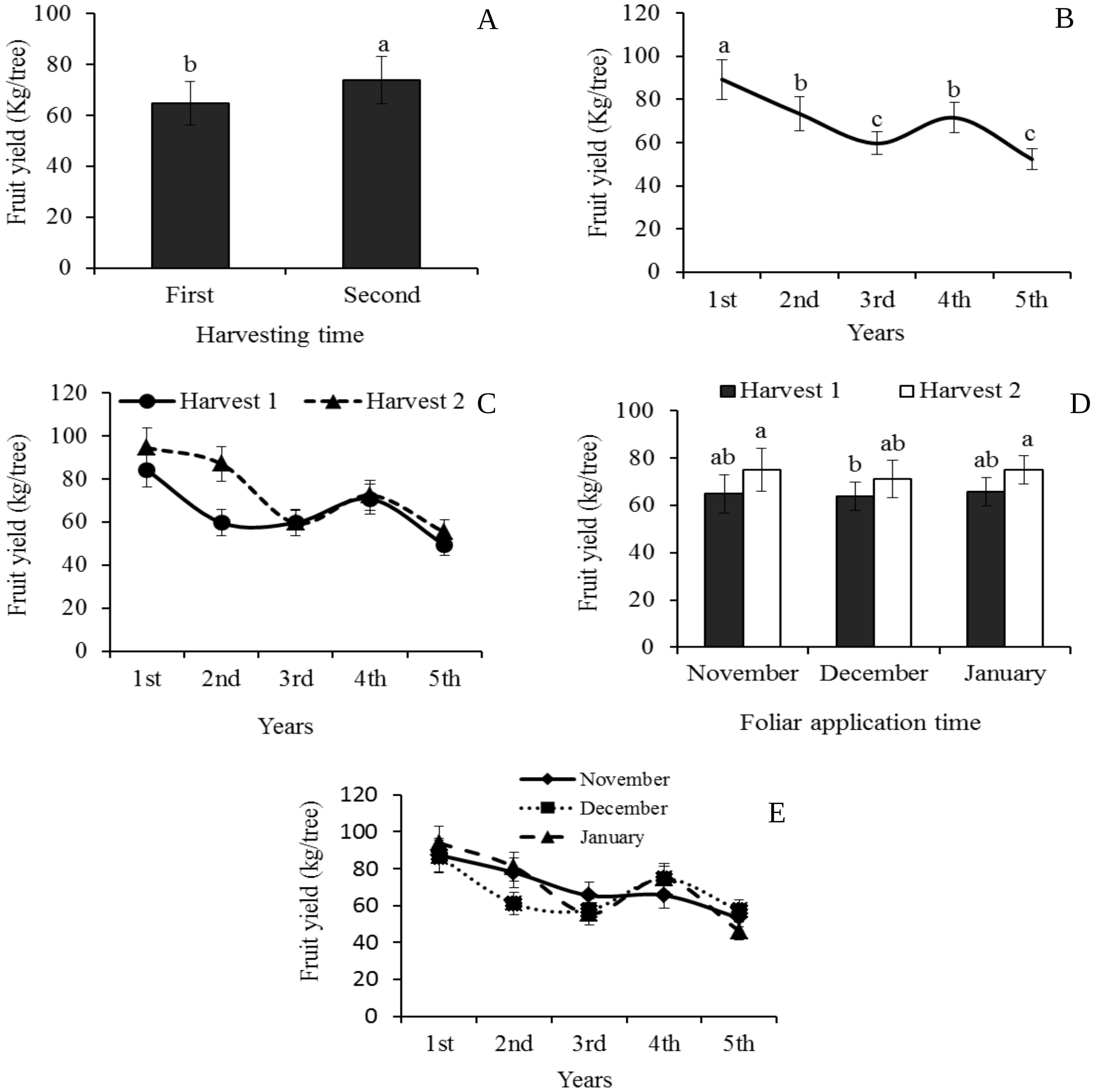

Fig. 1. Effect of harvest time (A), year (B), interaction between year and harvest time (C), interaction between the time of 0.5% urea foliar application and harvest time (D) and interaction between year and foliar application time (E) on fruit yield of 'Siyahoo' mandarin.

The time of foliar application of urea had no significant effect on the fruit yield. However, the foliar application of urea in mid-November increased the fruit yield compared to the mid-December and mid-January foliar application with 11 and 16%, respectively. The interaction of the foliar application of urea and the harvest time on the fruit yield of 'Siyahoo' mandarin was significant (Fig. 1D). Generally, the fruit yield in the second harvest time was more than the first harvest time in all foliar application times. The highest fruit yield was observed for the foliar application of urea in mid-November and the second harvest time; however, it had no significant difference with two other foliar applications in the second harvest time. The lowest fruit yield was observed in the foliar application of urea in mid-December and the first harvest time, although it had no significant difference with two other foliar applications at the first harvest time. Fig. 1E shows changes in the procedure for the fruit yield in different foliar application times for five years. Totally, in the final years compared to the early years, the reduction in the fruit yield was observed for all foliar application times. Yield fluctuations in the foliar application in mid-November were lower.

Fruit juice pH

The interaction of the harvest time and years significantly led to a change in the fruit juice pH (Fig. 2A).

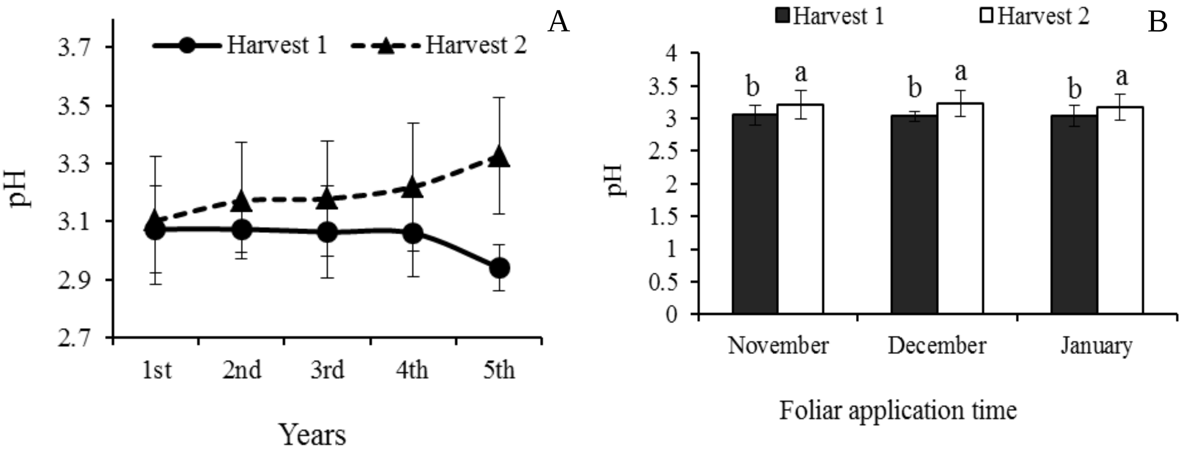

Fig. 2. Interaction between harvest time with years (A) and harvest time with nitrogen foliar application time (B) on fruit juice pH of 'Siyahoo' mandarin.

The individual effect of the time of foliar application and years had no significant effect on the pH of fruit juice. In all years, the fruit juice pH in the second harvest time was higher than the first harvest time. The interaction of foliar application time and harvest time (Fig. 2B) indicated that in all foliar application times, the fruit juice pH in the first harvest time was significantly lower than the second harvest time.

TSS/TA ratio

The harvest time had a significant effect on the TSS/TA ratio. This ratio in the second harvest time was significantly more than the first harvest time (Fig. 3A). The total titrable acid (TA) in the first harvest time was significantly more than the second harvest time (their difference was about 11%). This difference was predictable because the first harvest time had been adjusted based on the lowest ratio of TSS/TA. The foliar application time had no significant effect on the TSS/TA ratio, but the interaction of foliar application time and harvest time made significant changes in this qualitative parameter (Fig. 3B) so that the lowest TSS/TA ratio was observed for all foliar application times and the first harvest time.

The lowest TSS/TA ratio in the second harvest time was related to the foliar application of urea in mid-January, which was due to a higher concentration of TA in this foliar application time. During five years of the experiment, the ratio of TSS/TA had the ascending procedure in both harvest times, but the amount of this parameter in the second harvest time was constantly more from the second year onwards and in the final years of the experiment their differences were also increased (Fig. 3C). Figure 3D shows the effect of nitrogen foliar application times on the ratio of TSS/TA during the years of the experiment. The highest ratio of TSS/TA was observed for the foliar application in mid-December (8.06) and the lowest was related to mid-January (7.80).

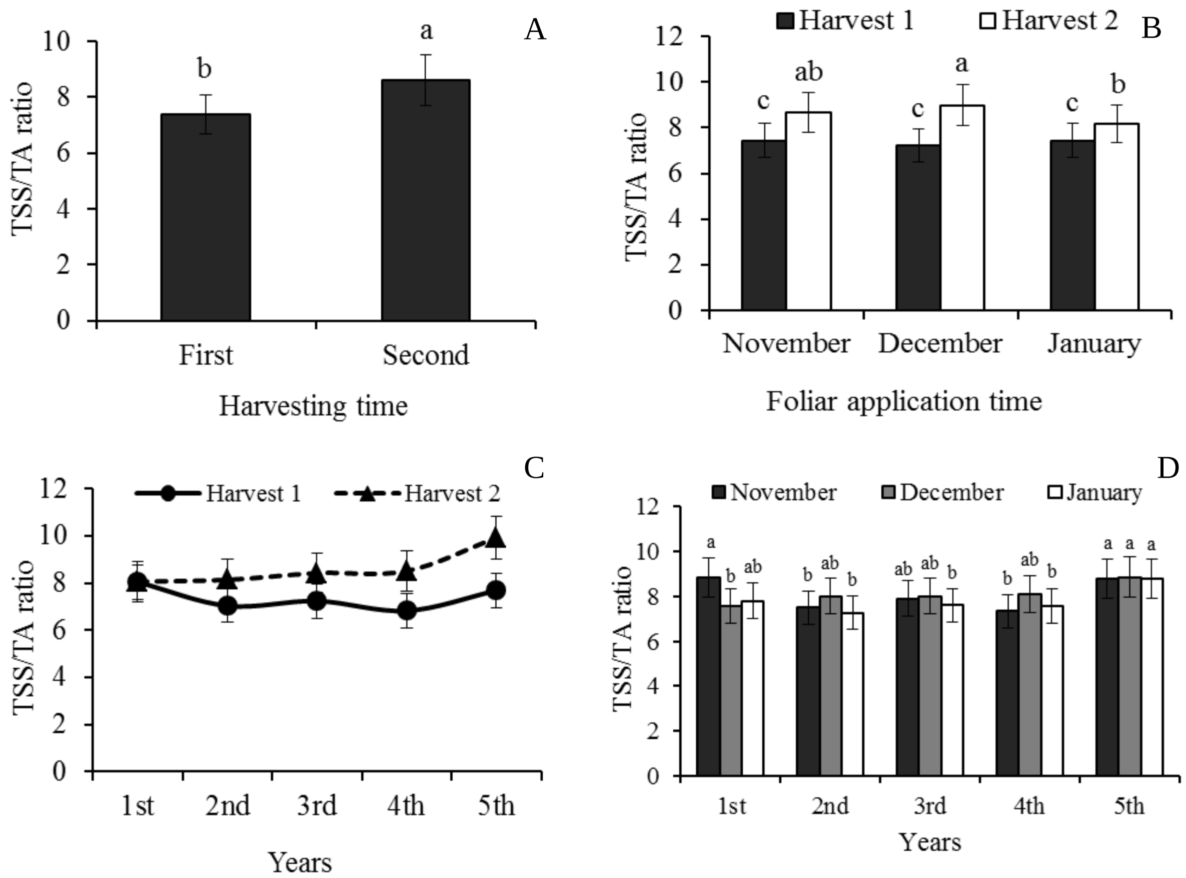

Fig. 3. Effect of harvest time (A), interaction between nitrogen foliar application with harvest times (B), years with harvest time (C) and nitrogen foliar application time with years (D) on TSS/TA ratio of 'Siyahoo' mandarin.

Fruit weight

The harvest time had no significant effect on fruit weight. The effect of foliar application times was significant on the fruit weight so that the foliar application in mid-December and mid-January compared to mid-November could be increased by about 10% fruit weight (Fig. 4A). Generally, the fruit weight had a significant change in the successive years, but in two final years, it was not observed any significant change (Fig. 4B). An evaluation of the effect of the foliar application time on the fruit weight for five years indicated that the lowest fruit weight was observed for the foliar application in mid-November (Fig. 4C).

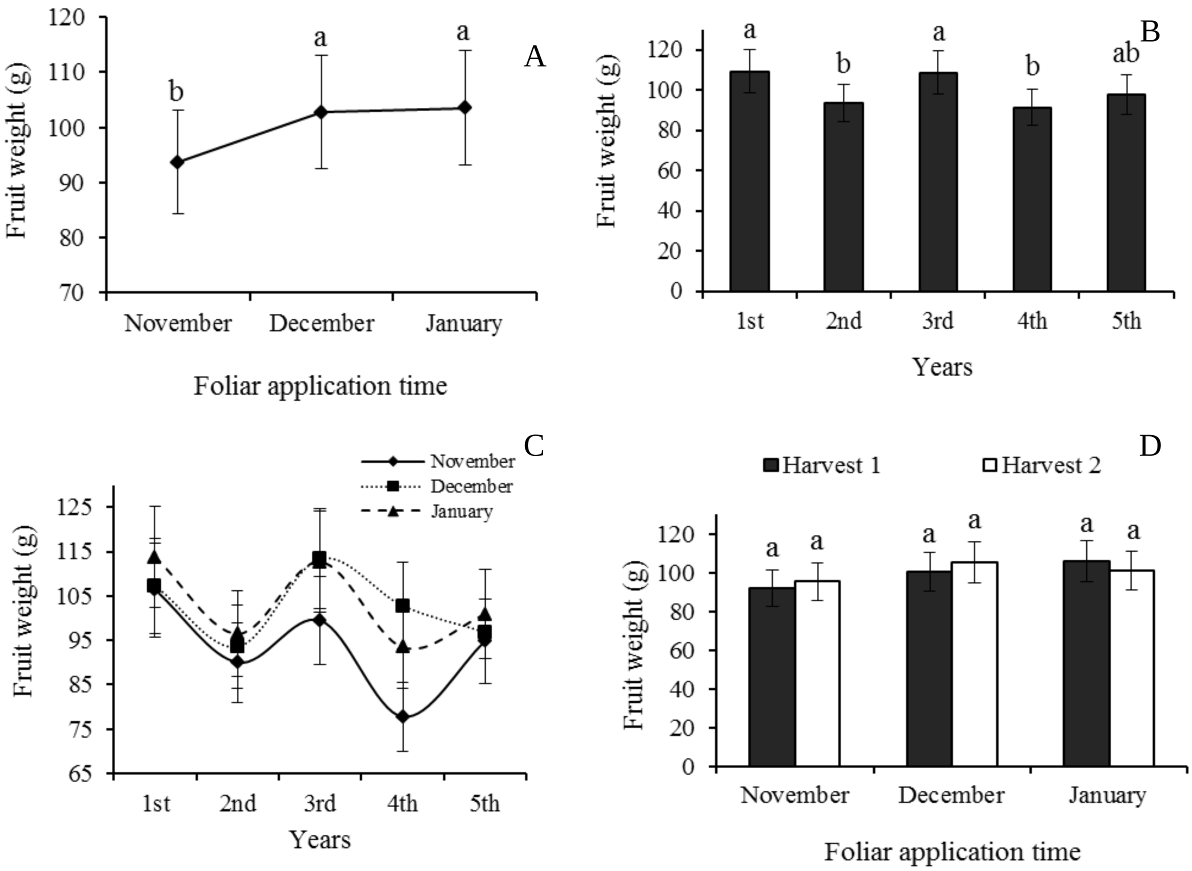

Fig. 4. Effect of nitrogen foliar application time (A), year (B), the interaction between year and nitrogen foliar application time (C) and interaction between harvest time and nitrogen foliar application (D) on fruit weight of 'Siyahoo' mandarin.

Evaluation of fruit weight in two harvest times during five years demonstrated that in two final years (77.98 and 83.93 g), the lowest fruit weight was related to the first harvest time. There was no significant change in the fruit weight influenced by the interaction of the foliar application time and harvest time (Fig. 4D).

Fruit length

The harvest time and foliar application time of urea, as well as their interaction, did not affect the fruit length; however, the foliar application of urea in mid-January led to increase in the fruit length by 5% more than in mid-November. An assessment of urea foliar application times in different years indicated that in all years, the foliar application of urea in mid-January led to increasing the fruit length in comparison with other foliar application times. Evaluation of the effect of harvest times on the fruit length in different years showed that the second harvest time had an increasing effect on the fruit length in all years except the second year (Fig. 5).

Fruit diameter

The harvest time and foliar application time of urea, as well as their interaction, did not affect the fruit diameter, but the fruit diameter significantly changed during different years (Fig. 6A). Figure 6B shows the effect of foliar application time in the different years of the experiment on the fruit diameter. The smallest fruit diameter was observed for the foliar application of urea in mid-November during different years. The harvest time led to changes in the fruit diameter during five years of the experiment.

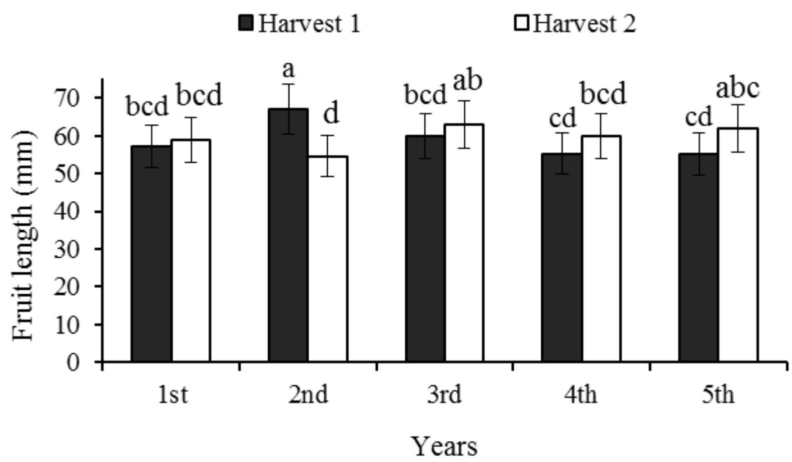

Fig. 5. Effect of harvest time on fruit length of 'Siyahoo' mandarin for five years.

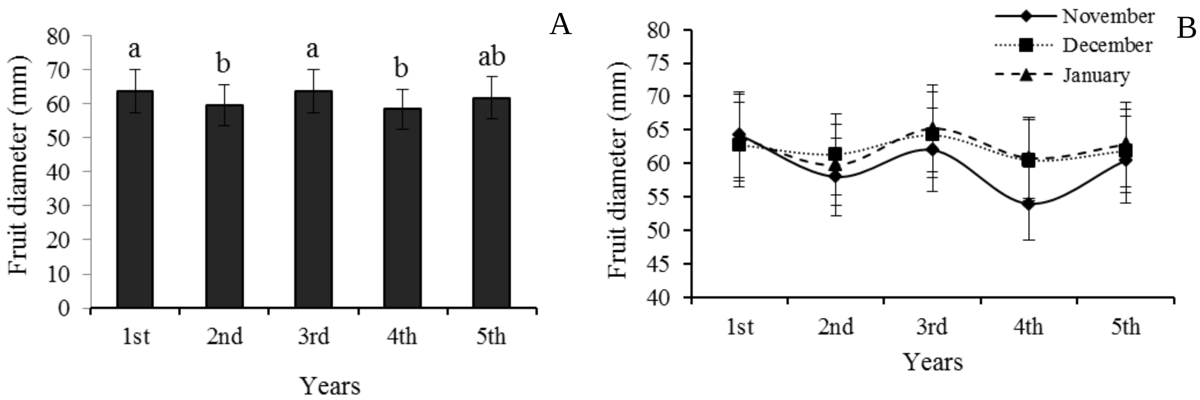

Fig. 6. Effect of the year (A) and interaction between nitrogen foliar application time and year (B) on fruit diameter of 'Siyahoo' mandarin.

Discussion

According to the obtained results of the present study, the fruit yield in the second harvest time was significantly higher than the first harvest time. The reason for an increase in the yield in the second harvest time might be due to the juiciness and enlargement of fruit. Therefore, the second harvest time is better from an economic viewpoint. In addition to the high fruit yield in the second harvest time, the harvested fruits in this stage were sweeter and marketable. In addition, the fruit yield was different in various years. This indicates that the treatments can be partially effective in reducing the yield fluctuation or adjusting the alternate bearing. Hayatbakhsh and Eshkavari (1998) reported that the effect of year was significant on the yield of sweet orange.

Based on the findings of present study, 'Siyahoo' mandarin according to the time of foliar application during five years demonstrated that the fruit yield in the final years decreased compared to the early years in all time treatments of foliar application. Possible reasons for the reduction of yield especially that of 'Siyahoo' mandarin in the final years compared to the early years can be due to an incidence of drought and resonance of citrus decline in Hormozgan province. In a study, it was reported that the fruit set in the trees sprayed with urea at January and February was significantly more than the control treatment, but it was not any significant change in the concentration of nitrogen of the leaves (Ali and Lovatt, 1994). In another study, it has been shown that the application of urea during two On- and Off-years had no significant effect on the yield of Kinnow mandarin trees (Moghbeli-Hanzaei and Tafazzoli, 2002). The results of our study are not in line with the findings of Kumar and Ranvira (1988) and Kolier et al. (1988) concerning the positive effect of the application of urea on lemon and mandarin cv. 'Montenegrina'. A difference in the method of treating (foliar application or dipping shoots in solution), the age of leaves and shoots age and concentration of nitrogen in leaves may be possible reasons for difference in the findings of the application of urea in citrus (Lea-Cox and Syvertsen, 1995).

Our study indicated that the fruit yield in the second harvest time was more than the first harvest time in all foliar application times. Generally, to avoid of lowest fruit yield, gardeners should have refrained from early harvest as well as the foliar application of urea in mid-December. In terms of the fruit yield, the best time of foliar application of urea is mid-November and the best harvest time is 45 days after when TSS/TA ratio is in the lowest amount.

Regarding to the pH of fruit juice, since the fruits were kept longer on the tree in the second harvest time and their ripening was increased (more sweet fruits), an increase in the pH of fruit juice in this harvest time was not strange.

The results of the present study demonstrated that the foliar application time had no significant effect on the TSS/TA ratio. Inefficacy of foliar application time of nitrogen on the fruit TA has also been reported by other studies (see Moghbeli-Hanzaei and Tafazzoli, 2002), which can be due to sufficiency of nitrogen in the plant (Mudau et al., 2004).

Our results indicated that the effect of foliar application times was significant on the fruit weight. Moghbeli-Hanzaei and Tafazzoli (2002) demonstrated that the application of urea in the On- and Off-years had no significant effect on the thinning of the fruit and the average fruit weight. There was no significant change in the fruit weight influenced by the interaction of the foliar application time and harvest time. Mudau et al. (2004) did not detect any difference in the fruit size using the foliar and soil applications of different concentrations of urea in Satsuma mandarin. Rabe (1994) observed a significant effect of the application of urea before blooming on Shamouti sweet orange, Ellendale tangor, and Minneola tangelo. Our results were not in line with the findings of the study done by Albigo (2007), so that the foliar application of urea and NPK in winter increased the fruit productivity.

The foliar application of urea in mid-January led to an increase in the fruit length by 5% more than that in mid-November. Sufficiency of nitrogen in the plant has been referred as a reason for the ineffectiveness of foliar application of nitrogen on the fruit length (Mudau et al., 2004). The second harvest time had an inductive effect on the fruit length in all years except the second year. It is reported that sucrose foliar application has an adjusted alternate bearing cycle in Satsuma mandarin trees, also that this treatment increased the average diameter and weight of fruits (Akhlaghi amiri et al., 2016).

The fruit diameter significantly changed during different years. These changes were similar to changes in the fruit weight during the experiment. The foliar application time in the different years of the experiment affects the fruit diameter. These changes were similar to the changes in fruit weight. The reason for this similarity was the high correlation between fruit diameter and fruit weight (fruit largeness). The harvest time led to changes in the fruit diameter during five years of the experiment. Similar to the previous studies, changes in the harvest time on the fruit diameter during the experiment were similar to the changes in the fruit weight. There are some evidences indicating that nitrogen is required for auxin synthesis. Urea foliar application eliminated the need for some growth factors like polyamines in nitrogen metabolism. Application of urea at full bloom and summer physiological drop improved the yield due to an increase in flower number and fruit size (Akhlaghi- Amiri et al., 2016).

Conclusion

Based on the findings of present study, it is recommended that the harvest of 'Siyahoo' mandarin fruit should be postponed to the second harvest time because, in addition to higher yield, the qualitative parameters of the fruit (sweetness, better flavor and high ratio of TSS/TA) would be improved. Moreover, the foliar application of urea in mid-November could be used to prevent yield fluctuation during various years. The utilization of different concentrations of nitrogen and other nutrient elements, especially micro-nutrients can be also suggested for future studies.

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Conflict of interest

The authors indicate no conflict of interest for this work.

References

1. Ahmad M.A, Abdelfattah M.E, Mohamed Y.H. 1995. Effect of urea, some macronutrients, and growth regulator foliar sprays on the yield, fruit quality, and some vegetative characters of Washington navel orange tree. HortScience 30(4), 880.

2. Ahmadi K, Ebadzadeh H.R, Hatami F, Hosseinpour R, Abdshah H. 2019. Agricultural statistics, Vol. III: Horticultural crops. Jahad-Keshavarzi Ministry, 166 p. (In Persian)

3. Akhlaghi-Amiri N, Asadi Kangarshahi A, Arzani K, Barzegar M. 2016. Calyx biochemical changes and possibility of reducing Thomson orange June drop by nutrition elements and growth regulators. International Journal of Horticultural Science and Technology 3(2), 179-186.

4. Albigo L.G. 2007. Effect of winter- and spring time applications of foliar urea, NPK, or K-phosphate sprays on the productivity of citrus in central Florida. Proceeding of the Florida State Horticultural Society 120, 64-66.

5. Ali A.G, Lovatt J.J. 1994. Winter application of low biuret urea to the foliage of Washington navel orange increased yield. Journal of American Society of Horticultural Science 119, 1144-1150.

6. Asadi-Kangar Shahi A, Akhlaghi-Amiri N. 2005. Evaluation of the possibility of reduction of the alternate bearing of Unshu mandarin using balanced nutrition and foliar application of urea, carbohydrates and thinning materials. Final Report, Agricultural and Natural Resource Research Center of Mazandaran. Registration No. 85/1273, 36 pp. (In Persian)

7. Dennis F.J. 2003. Flowering, pollination and fruit set and development. In: D.C. Ferree and I.J. Warrington, eds. Apples: Botany, Production and Uses. CABI Publishing, Cambridge, MA. pp. 153-166.

8. El-Otmani M, Ait-Oubahou A, Zahra F, Lovatt C.J. 2002. Efficacy of foliar urea as an n source in sub-stainable citrus production systems. Acta Horticulture 594, 611-617.

9. Fotouhi-Ghazvini R, Fattahi-Moghaddam J. 2011. Citrus growing in Iran. 3rd Publication. Guilan University Press. 368 pp. (In Persian)

10. Hayatbakhsh A, Eshkavari A.R. 1998. Assessment and determine the best consuming time of complex micro-element fertilizer and its effect on balancing alternate bearing and abscission of Thompson navel sweet orange. Final Report, Iranian Citrus Research Institute. Registration No. 78/66, 17 pp. (In Persian)

11. Jackson J.E. 2003. Flowers and fruits. Chapter 9: In: Biology of Apples and Pears. Cambridge University Press, New York, N.Y., pp. 268-308.

12. Kolier O.C, Marodin G.A, Manica I, Shwarz S.F, Barradas C.I.N. 1988. Response of mandarin (*C. deliciosa* L. cv. Montenegrina) to chemical manual fruit thinning. Proceeding of American Society of Tropical Horticulture 30, 45-47.

13. Kumar R, Ranvira KK. 1988. Effect of growth regulators and urea sprays on the regulation of

crop in lemon (*C. Limon* L.). Indian Journal of Horticulture 45, 224-228.

14. Lea-Cox J.D, Syvertsen J.P. 1995. Nitrogen uptake by citrus leaves. Journal of American Society of Horticultural Science 120, 505-509.
15. Marschner H. 2012. Mineral Nutrition of Higher Plants. 3rd Edition. Academic Press, Elsevier, 649 pp.
16. Moghbeli-Hanzaei M.J, Tafazzoli E. 2002. Effect of GA, NAA, Ethephone and urea on controlling alternate bearing of Kinnow mandarin (*Citrus reticulata* Blanco c.v Kinnow). Science and Techniques of Agriculture and Natural Resources 6(3), 91-102. (In Persian)
17. Moradi B. 2007. Effect of foliar application of urea on fruit set and quality of two citrus cultivars of northern Iran. 10th Iranian Soil Science Congress, p. 198. (In Persian)
18. Mudau F.N, Tuwana S, Theron K.I, Rabe E. 2004. Effect of timing and method of nitrogen application on rind color, fruit size, internal fruit quality and yield of Mihowase Satsuma' mandarin (*Citrus unshiu* Marc.). South African Journal of Plant and Soil 21 (2), 90-93.
19. Rabe E. 1994. Yield benefits associated with pre-blossom low biuret urea sprays on *Citrus* spp. Journal of Horticultural Science 69, 495-500.
20. Saleem B.A.T, Malik A.U, Maqbool M, Islam-Ud-Din M, Farooq M, Rajwana A. 2008. Early winter spray of low biuret urea improves marketable yield and fruit quality of sweet oranges. Pakistan Journal of Botany 40(4), 1455-1465.
21. Stander O.P.J, Barry G.H, Cronj P.J.R. 2018. The significance of macronutrients in alternate bearing 'Nadorcott' mandarin trees. HortScience 53(11),1600-1609.
22. Van der Merwe I.S. 2012. Studies on the phenology and carbohydrate status of alternate bearing ‘Nadorcott’ mandarin trees. M.Sc. Thesis, Dept. of Horticultural Science, Stellenbosch University, South Africa, 72 pp.
23. Verreynne J.S, Lovatt C.J. 2009. The effect of crop load on budbreak influences return bloom in alternate bearing Pixie mandarin. Journal of American Society of Horticultural Science 134, 299-307.
24. Verreynne J.S. 2009. Alternate bearing in citrus. Citrus research International (PTY) Ltd. 2(5-6): 1-5.
25. Yamanishi O. 1995. Trunk strangulation and winter beating effect on carbohydrate level and its relation with flowering, fruiting and yield of Tosa Buntan Pummelo grown in plastic house. Journal of Horticultural Science 70, 85-95.