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Determining an Appropriate Fertilization Planning to Increase Qualitative and Quantitative Characteristics of Kiwifruit (*Actinidia deliciosa* L.) in Astaneh Ashrafieh, Gilan, Iran

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ABSTRACT: The lack of balanced use of fertilizers is one of the reasons for the low yield and the low quality of kiwifruits in Gilan Province, Iran. In order to determine a suitable fertilization planning for kiwi orchards (*Actinidia deliciosa* L. cv. Hayward) in Astaneh Ashrafieh, an experiment was performed in 10 treatments with 3 replications based on a randomized complete block design with different amounts of fertilizers in different fertilizing methods. Treatments include different amounts of macro- and micronutrient fertilizers with foliar spraying of calcium, zinc, and potassium in different stages. In this study, the yield of each tree, the fruit firmness, sugar, pH, wet weight, percentage of dry matter, and the content of macronutrients (nitrogen, phosphorus, and potassium) and micronutrients (iron, zinc, and manganese) in the fruit were measured. The results showed that the treatment of 350 g urea, 500 g potassium sulfate, 500 g superphosphate, 80 g iron sulfate sprayed foliarly with 5 parts per thousand of zinc chelate and iron chelate, and foliar spraying with 0.5% of calcium during several stages for each tree has the highest effect on the yield of each tree, the fruit firmness, the fruit pH, and the percentage of the fruit dry matter, so such a yield of this treatment showed a difference of 7.9 kg with control.

KEYWORDS: kiwifruit, macronutrients, micronutrients, yield, foliar spraying

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Introduction

Fertilizer is one of the most important factors affecting the quality and quantity of fruits.[1] The optimal use of fertilizers is the most effective and most economical way to increase the yield of agricultural products and the production sustainability.[2] Choosing the correct fertilizer source, adjustment of the fertilization dosage, and its optimal use can increase the yield.[3] Unfortunately, due to the imbalanced use of chemical fertilizers in Iran, most elements that are effective in plants' nutrition are not included in fertilizer recommendations. This, in turn, aggravates some shortcomings and soil fertility.[4] Generally, in plant nutrition, not only does the sufficient amount of each element have to be available to the plant, but it is also of much importance to create a balance and to observe the ratio of nutritional elements. In the case of lack of nutrition balance, the addition of nutrients not only does not increase the yield but also causes a disruption in the plant growth, and ultimately a reduction in the yield.[5]

Correct nutrition not only improves the quality of the fruits but also decreases the damages and increases the storage life of the products.[6] Nitrogen is one of the constituent elements of many important molecules such as proteins, nucleic acids, some hormones, and chlorophyll;[7] and phosphorus plays an important role in the cellular structure and is the general source of energy in all biochemical activities in live cells.[8] Gonzalez-Garcia et al[9] declared that potassium plays an important role in the enzyme activities and in the synthesis of amino acids and phenol-acids. Johnson et al[10] concluded that potassium may be relevant to the postharvest kiwifruit, but its role is less important than nitrogen. Potassium may cause antagonism in the uptake of calcium and its effects on plants that can be related to cationic competition.[11]

Although calcium is considered as an important nutrient that is effective in the inner quality of kiwifruit,[12] fertilization may have positive or negative effects on the capability of calcium use and its uptake from the soil.[13] Fertilization in Ca-deficient soils is a necessity, and this is very important in acidic soils.[12] There are several reports about the role of micronutrients in enzyme reactions, metabolism and assimilation of carbon, nitrogen, and various plant combinations, transfer of sugar material, cellular division, regulation and conduction of water and consequently, increasing the photosynthesis capability, and the production of various plants.[14,15]

Kiwifruit is of the Actinidiaceae family and the *Actinidia* genus. This genus has several species,[16] but only three species, namely, *Actinidia deliciosa*, *Actinidia chinensis*, and *Actinidia arguta*, have been used commercially.[17] In Iran, various cultivars of *A. deliciosa* are cultivated such as Hayward, Abbot, Bruno, and Monty.[16] Commercially, Hayward is the most important cultivar of kiwifruit. Hayward produces large fruits with good smell, taste, and longer potential storage life. Mineral combination of kiwifruit is one of the factors affecting the inner quality of the fruit.[18] Furthermore, it is related to the postharvest quality and postharvest life of the kiwifruit.[19] According to Feng et al,[20] the difference in the firmness of the kiwifruit, at the time of harvest or at the end of storage, is mainly affected by the concentration of mineral elements during harvest.

In this study, the effects of various amounts of nutrients on the yield and qualitative and quantitative attributes of the kiwifruit are analyzed in different periods.

Materials and Methods

Research location. The study was carried out in a garden in the vicinity of Astaneh Ashrafieh. Astaneh Ashrafieh (Lat. 37°16′ N, Long. 49°56′ E, Alt. −2 m.) is about 35 km from Rasht. The experimental area is located in Lat. 37°18′18″ N, Long. 49°58′36″ E. The selected trees of the same cultivar (*A. deliciosa* L.) were completely similar in terms of age, growing conditions, and shade, and in agricultural terms, they all had similar conditions, including the amount of water, the type of soil, and other farming conditions.

The kiwifruit vine grows naturally at altitudes between 600 and 2000 m, with a relative humidity of 76%–78%. Alternating warm and cold spells during the winter will reduce flowering. Acceptable climates for *Hayward* kiwifruit must have winter temperatures below 7°C for 600–700 hours. A frost-free season of 225–240 days is needed for kiwifruit since vines leaf out in March, bloom in May, and are harvested in October or early November. Temperatures below −12°C in mid-winter will kill all young vines and some old bearing vines. Frost below −1.0°C in spring will kill shoots and ruin the crop. Kiwifruit vines need frequent irrigation or rainfall to grow well so they can be grown in areas of heavy summer rainfall or hot dry summer areas when given irrigation. Kiwifruit grow well in hot summer areas with maximum temperatures up to 45°C if adequate water is provided daily for the plants. For good growth, the vine needs deep, fertile, moist but well-drained soil, preferably a friable, sandy loam. Heavy soils subject to water logging are completely unsuitable. Vines that are planted where water sits on the surface following rains are likely to develop crown rot. Soil pH should be between 5.0 and 6.5.

Table 1. Some soil characteristics before the experiment (depth of 0–30 cm).

PROPERTY	VALUE
Electrical conductivity (dS/m)	0.21
pH	7.77
Neutral material (%)	7.50
Organic material (%)	7.50
Nitrogen (%)	0.14
Phosphorus (mg/kg)	43.0
Potassium (mg/kg)	504
Texture	Loam
Soil classification (soil taxonomy)	Hapludalf

The abovementioned climate conditions are at the studied area. The soil was sampled, and some of its physical and chemical characteristics were measured (Table 1).

Experimental design and treatments. The study was conducted on the basis of a completely randomized block design with three replications in 30 experimental plots on 30 trees (14 years). Distance between trees was 4 m. Specifications of the treatments, carried out, are given in Table 2. The first stage was done in the first week of April, the second stage in the first week of June, the third stage in the first week of July, the fourth stage in the first week of August, the fifth stage in the first week of September, and the sixth stage toward the end of September. Specifications of the applied treatments are presented in Table 2. Stages 1 and 2 refer to soil application of fertilizers; urea as fertigation and other fertilizers were placed at a depth of 15 cm in the soil in one-third outer canopy of trees.

Evaluation of fruit properties. The yield of each tree was calculated after harvesting all the fruits of each treatment. Among the harvested fruits of each treatment, six fruits were randomly chosen from each tree, and their weight was measured using a digital scale and their average was recorded as the fresh weight. After measuring the fresh weight of the fruit, the samples were oven-dried at 75°C for 48 hours to estimate their dry weight and the percentage of dry matter.

From the harvested fruits of each treatment, six fruits were randomly selected from the trees, and after peeling, they were mixed in a mixer and their acidity was estimated by a pH meter, model EDT GP 353. To measure the dissolved solids, a manual refractometer (model RHB-32) was used. For this purpose, some of the fruit juice was poured in the glass plate of the refractometer, and its Brix degree was read. The firmness of the fruit was measured by a penetrometer device (model GY-1) with a power of 15 kg/cm^2.

Measurement of nutritional elements in each fruit. In this stage, first, 0.3 g of the dried sample of the fruit was transferred to a 50 mL volumetric flask, and 3 mL of a mixture of acids (sulfuric acid and salicylic acid) and hydrogen peroxide

Table 2. Treatments applied in the experiment.

TREATMENT	SPECIFICATIONS
T_1 (2 N_{350} P_{500} K_{500})	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate
"Control"	**Stage 2:** 350 g Urea
T_2 (2 N_{350} P_{500} K_{500} Mn_{40}) Fe_{80}	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate + 80 g Iron sulfate + 40 g Manganese sulfate
	Stage 2: 350 g Urea
T_3 (2 N_{350} Fe_{80} Mn_{40})	**Stage 1:** 350 g Urea + 80 g Iron sulfate + 40 g Manganese sulfate
	Stage 2: 350 g Urea
T_4 (2 N_{350} P_{500} Fe_{80} Mn_{40})	**Stage 1:** 350 g Urea + 500 g Triple super-phosphate + 80 g Iron sulfate + 40 g Manganese sulfate
	Stage 2: 350 g Urea
T_5 (2 N_{350} P_{500} K_{500} Fe_{80})	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate + 80 g Iron sulfate
	Stage 2: 350 g Urea
T_6 (2 N_{350} P_{500} K_{500} Fe_{80} 2 $S_{Zn,Fe}$)	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate + 80 g Iron sulfate
	Stage 2: 350 g Urea
	Stage 3: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 5 per thousand of iron chelate
	Stage 4: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 5 per thousand of Iron chelate
T_7 (2 N_{350} P_{500} K_{500} Fe_{80} 2 S_{Zn})	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate + 80 g Iron sulfate
	Stage 2: 350 g Urea
	Stage 3: Foliar spraying with 5 per thousand of Zinc chelate
	Stage 4: Foliar spraying with 5 per thousand of Zinc chelate
T_8 (2 N_{350} P_{500} K_{500} Fe_{80} 2 $S_{K,Ca,Zn}$)	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate + 80 g Iron sulfate
	Stage 2: 350 g Urea
	Stage 3: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 1 per percent of Potassium sulfate + foliar spraying with 0.5 per percent of Calcium chloride
	Stage 4: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 1 per percent of Potassium sulfate + foliar spraying with 0.5 per percent of Calcium chloride
T_9 (2 N_{350} P_{500} K_{500} Fe_{80} 4 S_{Ca} 2 $S_{K,Zn}$)	**Stage 1:** 350 g Urea + 500 g Potassium sulfate + 500 g Triple super-phosphate + 80 g Iron sulfate
	Stage 2: 350 g Urea
	Stage 3: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 1 per percent of Potassium sulfate + foliar spraying with 0.5 per percent of Calcium chloride
	Stage 4: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 1 per percent of Potassium sulfate + foliar spraying with 0.5 per percent of Calcium chloride
	Stage 5: Foliar spraying with 0.5 per percent of Calcium chloride
	Stage 6: Foliar spraying with 0.5 per percent of Calcium chloride
T_{10} (2 N_{350} Fe_{80} 4 S_{Ca} 2 $S_{K,Zn}$)	**Stage 1:** 350 g Urea + 80 g Iron sulfate
	Stage 2: 350 g Urea
	Stage 3: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 1 per percent of Potassium sulfate + foliar spraying with 0.5 per percent of Calcium chloride
	Stage 4: Foliar spraying with 5 per thousand of Zinc chelate + foliar spraying with 1 per percent of Potassium sulfate + foliar spraying with 0.5 per percent of Calcium chloride
	Stage 5: Foliar spraying with 0.5 per percent of Calcium chloride
	Stage 6: Foliar spraying with 0.5 per percent of Calcium chloride

was added to the volumetric flasks, and the fruit extract was prepared after a few stages.[21] In the extract, the total nitrogen was measured through titration method after distillation by Kjeldahl distillation apparatus (Model Hach-23130-20), potassium was measured using the flame photometer model Jenway, at a wavelength of 766.5 nm,[21] phosphorus was measured using the Murphy and Rilley method by a spectrophotometer model Apel-PD-303UV at a wavelength of 470 nm,[22] and iron, zinc, and manganese were measured using a flame atomic absorption spectroscopy instrument.

Data were analyzed by SPSS Software Package, and the means were compared by least significant difference (LSD) test.

Pearson correlation ratio was computed based on equation between fruit properties and nutrients concentration of the fruit.

$$R_{X,Y} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sigma_X \sigma_Y}$$

$R_{X,Y}$ is Pearson correlation ratio, X and Y are nutrients concentration and fruit qualitative properties, respectively, and σ is standard deviation.

Results and Discussion

Qualitative and quantitative indices of the kiwifruit. The data variance analysis (Table 3) shows that the effect of different concentrations of microelements on stiffness, sugar level, and pH of the fruit was significant at 1% level; and on the yield of each tree, fresh weight of the fruit and the percentage of dry matter of the fruit was significant at 5% level.

Yield of each tree. According to Table 4, treatment T_9 (the soil application of urea, potassium sulfate, superphosphate, and iron sulfate; and foliar spray of zinc chelate, potassium sulfate, and calcium) had the highest effect on the productivity of the tree, which showed a 7.9 kg difference with control. The next most effective treatment was T_7 (the soil application of urea, potassium sulfate, superphosphate, and iron sulfate, and foliar spray of zinc chelate), which also showed the best yield. The lowest yield was related to the treatment T_2 (the soil application of urea, potassium sulfate, superphosphate, iron sulfate, and manganese sulfate), which had no significant difference with control. Data indicated an increase in the yield of each tree with foliar spray of zinc along with nitrogen. Foliar spray of zinc chelate and potassium sulfate in two stages during the growth of the fruit is the cause of this increase in the yield. Zinc, nitrogen, and potassium have a significant effect on the formation of the fruit.[23] Zinc is a micronutrient that is necessary for plants, animals, and human beings,[24] which is required for the formation and production of suitable fruit with satisfactory size.

The results of a study by Tadayyon and Rastegar[25] on Jahrom local oranges showed that the treatments with 2 and 4 g/L of zinc sulfate increased the production of each tree by, on average, 14 kg (=5 tons/ha) as compared with control. Khayyat et al[26] mentioned in their studies that foliar spray of zinc sulfate, in date palms, significantly increased the fruit yield, the fruit length, and the weight of the flesh, without affecting the seed properties. Foliar spray of zinc chelate and urea is effective on the mean weight of Manzanilla cultivar of olive fruit.[27]

Fruit firmness. According to Table 4, treatment T_9 resulted in the highest fruit firmness, which had a difference of 0.46 with control. Kiwifruit is one of the garden products in Iran, and it is one of the research priorities to obtain its maximum quality. In this regard, fruit firmness is one of the important qualitative properties in determining the product ripeness and acceptability.[28] Nowadays, the fruit firmness indicator is used as a simple and quick method in determining some postharvest physiological properties of the product such as the ripeness of the product.[29] The increasing trend of the fruit firmness in treatments T_8, T_9, and T_{10} as compared with the control treatment can be a reason for foliar spraying with calcium in several stages during the growth of the fruit. Calcium is an important nutrient that is effective on the inner quality of the kiwifruit. Because of the key role of calcium in protecting the cell wall and the penetrability of the membrane, there is a direct relation between the amount of calcium and the fruit firmness, especially at the end of storage.[30,31] The kiwifruit firmness is used to determine the quality after harvesting the fruit, and the rate of decrease in the tissue firmness during storage has a significant effect on the shelf life and the marketability of the fruit.[32]

Dissolved solids. The highest degree of dissolved solids in the kiwifruit during harvest is related to treatment T_3 (soil application of urea, iron sulfate, and manganese sulfate; Table 4), which showed two Brix degrees as compared with treatment T_9 and showed a difference of 0.83 with control. Table 4 indicated that this treatment caused the fruit firmness. So, it can be said that there is a negative correlation between the fruit firmness and the amount of dissolved solids during harvest so that stiffer fruit have less sugar.

Determining the ripeness is the most important part of the inner evaluation of the fruits, which depends on a few factors such as the amount of sugar, tissue firmness, and pH.[33] The taste of the fruit depends on organic acids and the sugar

Table 3. Analysis of variance of qualitative and quantitative properties of kiwifruit.

SOURCE OF CHANGES	MEAN SQUARED						
	DEGREES OF FREEDOM	THE YIELD OF THE TREE	FRUIT FIRMNESS	FRUIT SUGAR	FRUIT pH	FRUIT WET WEIGHT	DRY MATTER (%) OF THE FRUIT
Replication	2	12.3^{ns}	1.02**	0.54^{ns}	0.03^{ns}	41.2^{ns}	2.42*
Treatment	9	38.7*	0.06**	1.83**	0.06*	106.8*	2.13*
Error	20	6.7	0.002	0.28	0.02	34.7	0.78
Total	29	491.5	0.95	22.20	0.85	2328.4	34.8
C.V	–	12.8	7.5	9.71	6.30	9.5	8.8

Notes: ** and * show significance at the 1% and 5% levels, respectively. ^{ns}Not significant at the 5% level.

Table 4. Effect of different levels of fertilizers on the quantitative and qualitative indices of kiwifruit.

TREATMENT	YIELD (kg)	FRUIT FIRMNESS (Kgf)	DISSOLVED SOLIDS (%)	FRUIT pH	FRESH WEIGHT (g)	DRY MATTER (%)
T_1 (2 N_{350} P_{500} K_{500}) "The control treatment"	39.2 ef	2.77 c	7.00 abc	3.53 ab	90.5 bc	17.5 c
T_2 (2 N_{350} P_{500} K_{500} Mn_{40} Fe_{80})	38.1 f	3.03 abc	7.50 a	3.15 c	91.7 abc	17.6 c
T_3 (2 N_{350} Fe_{80} Mn_{40})	42.5 bcde	3.00 abc	7.83 a	3.38 abc	88.6 c	18.1 bc
T_4 (2 N_{350} P_{500} Fe_{80} Mn_{40})	42.1 cdef	2.87 bc	7.67 a	3.38 abc	95.4 abc	18.4 abc
T_5 (2 N_{350} P_{500} K_{500} Fe_{80})	40.7 def	2.93 abc	7.17 ab	3.26 bc	102.8 ab	17.4 c
T_6 (2 N_{350} P_{500} K_{500} Fe_{80} 2 $S_{Zn,Fe}$)	43.8 abc	3.17 ab	6.17 bc	3.39 abc	93.7 abc	18.6 abc
T_7 (2 N_{350} P_{500} K_{500} Fe_{80} 2 S_{Zn})	46.8 ab	3.00 abc	7.67 a	3.23 bc	105.4 a	19.1 ab
T_8 (2 N_{350} P_{500} K_{500} Fe_{80} 2 $S_{K,Ca,Zn}$)	42.8 cde	3.10 abc	6.00 bc	3.45 ab	102.1 abc	19.3 ab
T_9 (2 N_{350} P_{500} K_{500} Fe_{80} 4 S_{Ca} 2 $S_{K,Zn}$)	47.1 a	3.23 a	5.83 c	3.64 a	102.5 abc	19.7 a
T_{10} (2 N_{350} Fe_{80} 4 S_{Ca} 2 $S_{K,Zn}$)	46 abc	3.10 abc	6.17 bc	3.52 ab	99.5 abc	19.3 ab

of the fruit. In citrus fruits, among the three main elements, potassium causes more increase in the percentage of organic acids such as citric acid and ascorbic acid. Also, potassium increases the amount of acids in apples. In treatments T_8, T_9, and T_{10}, foliar application of potassium is carried out in two stages during the growth period of the fruit, and these treatments had the lowest degree of dissolved solids. Recent researches show that if a fruit tree is in the range of potassium deficiency, the increase in potassium will increase its storage life. Nijar[34] reported that foliar application of manganese on deficient citrus trees caused a significant increase in the soluble solids in the fruit juice.

Fruit pH. The lowest amount of pH is associated with treatment T_2 with an amount of 3.15, which in contrast to treatment T_9 (the maximum amount of pH), shows a difference of 0.49, and in contrast to control, shows a difference of 0.38 (Table 4). These data indicate that soil application of urea, potassium sulfate, superphosphate, iron sulfate and manganese sulfate decreased fruit pH, and foliar application of zinc chelate, potassium sulfate, and calcium had a positive effect on the amount of pH. In apple trees, potassium causes an increase in the fruit acid and also in citrus fruits; potassium causes an increase in the percentage of organic acids such as citric acid and ascorbic acid. The amount of sugar in fruit and its pH are important indicators showing the physiological changes in a plant.[29] In a study on grapes, Taherkhani and Golchin[4] showed that the highest degree of pH and dissolved solids in the fruit were obtained by foliar spray of iron. The results of a study on lemons cv. Lisbon showed that the maximum amount of ascorbic acid in the fruit and also the large fruits were obtained by the application of 500 g iron sulfate per tree through fertilizer deep placement technique and foliar spray of 0.5% of iron sulfate.[35]

Fresh weight of the fruit. The maximum amount of fresh weight of the fruit was obtained in treatment T_7 (the soil application of urea, potassium sulfate, superphosphate, and iron sulfate along with foliar spray of zinc chelate), which was 105.4 g, showing a difference of 14.9 g with control (Table 4). In general, higher uptake of nitrogen in plants results in higher uptake of water and fruit fresh weight and lower dry matter.[36] Zinc and iron have the highest effect on increasing the fresh and dry weight and the amount of chlorophyll in the leaf.[37]

Percentage of dry matter. Table 4 shows that treatment T_9 (the soil consumption of urea, potassium sulfate, superphosphate, and iron sulfate and foliar spray of zinc chelate, potassium sulfate, and calcium) have the highest effect on the percentage of dry matter, which is 2.2% higher than that of the control treatment. A high amount of dry matter during harvest is one of the factors affecting fruit firmness positively. Also, a positive relationship has been reported between the fruit firmness and the amount of dry matter.[20]

Concentration of nutritional elements in the fruit. The results of analysis of variance (Table 5) shows that the effect of treatments was significant on the amount of nitrogen and potassium at the 5% level and on phosphorus, iron, and zinc at the 1% level.

In treatments T_9, T_8, and T_6, which showed the maximum fruit firmness, the concentration of nitrogen was lower than in the other treatments (Table 6). The general trend shows a negative correlation of dry matter with the concentration of nitrogen (Table 7). Also, Boyd and Barnett[38] reported that in kiwifruit, high amount of nitrogen is related to the softness of the fruit during harvest and at the end of storage. The increase in nitrogen in the plant reduces the quality of the kiwifruit. In general, higher uptake of nitrogen in the plants resulted in higher absorption of water and lower dry matter.[36] Due to creating a congested crown in fruit trees, nitrogen results in the production of fruit with lower dry matter.[39] High amounts of nitrogen increases the amount of nitrogen in the fruit and the internal ethylene and decreases the fruit firmness during harvest. Based on Table 7, a negative significant correlation is observed between nitrogen and fruit firmness (0.609). The absence of a significant response of potassium concentration in treatments with foliar spray can be associated with the high

Table 5. Variance analysis related to the effect of treatments on the nutrients in kiwifruit.

SOURCE OF CHANGES	MEANS OF SQUARES						
	DEGREES OF FREEDOM	NITROGEN	POTASSIUM	PHOSPHORUS	IRON	ZINC	MANGANESE
Replication	2	0.053^{ns}	4102.3**	2700.6*	1.74^{ns}	0.34**	0.12**
Treatment	9	0.67*	2029.06*	9135.91**	11.51**	0.21**	0.02**
Error	20	0.19	542.24	774.01	1.12	0.02	0.005
Total	29	9.98	29109.67	97703.43	125.99	2.22	0.26
C.V	–	14.16	11.80	10.22	30.70	23.83	12.70

Notes: ** and * show significance at the 1% and 5% levels, respectively. ^{ns}Not significant at the 5% level.

concentration of soil potassium and the supply of potassium to the plant through the soil.

Also, the maximum amount of manganese was for treatment T_3 (soil application of urea, iron sulfate, and manganese sulfate) with an amount of 0.85, which showed a difference of 0.2 mg/kg. Plaza et al[40] estimated the amount of manganese in the kiwifruit to be 0.07 mg per 100 g fresh matter. These data showed that the application of manganese sulfate resulted in higher amount of manganese in the fruit. Table 7 shows a significant and considerable correlation between Zn concentration of fruit and fruit firmness. According to Table 5, the maximum amount of zinc in the fruit was obtained from treatment T_{10} (soil application of urea and iron sulfate along with foliar spray of zinc chelate, potassium sulfate, and calcium) with an amount of 0.78 mg/kg, which exhibited a 0.63 difference with control. Its minimum amount occurred under treatment T_5 (soil application of urea, potassium sulfate, superphosphate, and iron sulfate) with an amount of 0.05. In 2006,[41] FAO reported that the amount of the element zinc in kiwifruit was 0.05 per 100 g fresh matter. Given this fact, the amount of zinc in the fruit was increased by foliar spray of zinc chelate during the fruit growth. With an increase in zinc, the production of tryptophan and auxin growth hormones increases. Auxin plays a role in photosynthesis and the growth and development of the leaf and the stem of the plant. Zinc plays a role in increasing the permeability of the cell wall and thus increases the plant's resistance to biotic stresses (pests and diseases) and abiotic stresses (drought and temperature).[42] The manifest point is the noticeable consideration of zinc in treatments with foliar spray of zinc as compared with treatments without zinc application. It seems that because of high concentration of phosphorus in the soil and the antagonistic competition of the two elements, namely, zinc and phosphorus, zinc inhibits the absorption of phosphorus, resulting in a significant and positive response of the plant to the absorption of zinc through foliar spraying.

Conclusion

Results showed that an appropriate planning in the consumption of different fertilizers for kiwi orchards can be causes to the higher yield and quality of fruit in Gilan Province, Iran, because there was a significant difference between yield and fruit properties of some treatment than in the control. Altogether, the results showed that the consumption of 350 g urea, 500 g potassium sulfate, 500 g superphosphate, and 80 g iron sulfate in conjunction with foliar spray of 5 per thousand of zinc chelate and iron chelate

Table 6. Effect of different rates of fertilizers on the nutrient concentration of kiwifruit.

TREATMENT	NITROGEN (%)	POTASSIUM (mg/kg)	PHOSPHORUS (mg/kg)	IRON (mg/kg)	ZINC (mg/kg)	MANGANESE (mg/kg)
T_1 (2 N_{350} P_{500} K_{500}) "The control treatment"	3.74 ab	376.6 a	266.5 cd	9.80 ab	0.15 de	0.65 bc
T_2 (2 N_{350} P_{500} K_{500} Mn_{40} Fe_{80})	3.16 bc	382.7 a	355.3 a	6.94 bc	0.12 de	0.80 ab
T_3 (2 N_{350} Fe_{80} Mn_{40})	3.95 a	317.4 bcd	213.9 ef	7.67 b	0.22 cde	0.85 a
T_4 (2 N_{350} P_{500} Fe_{80} Mn_{40})	3.37 bc	314.3 d	234.7 de	7.52 bc	0.20 de	0.78 ab
T_5 (2 N_{350} P_{500} K_{500} Fe_{80})	3.68 ab	315.3 cd	257.1 cde	11.45 a	0.05 e	0.62 c
T_6 (2 N_{350} P_{500} K_{500} Fe_{80} 2 $S_{Zn,Fe}$)	3.09 bcd	354.8 abc	298.1 bc	6.76 bc	0.48 bc	0.68 bc
T_7 (2 N_{350} P_{500} K_{500} Fe_{80} 2 S_{Zn})	3.19 bc	356.1 ab	341.3 ab	6.20 c	0.62 ab	0.67 bc
T_8 (2 N_{350} P_{500} K_{500} Fe_{80} 2 $S_{K,Ca,Zn}$)	2.89 cd	320.7 bcd	296.8 bc	7.32 bc	0.58 b	0.65 bc
T_9 (2 N_{350} P_{500} K_{500} Fe_{80} 4 S_{Ca} 2 $S_{K,Zn}$)	3.17 bc	329.7 bcd	282.8 c	6.03 c	0.55 b	0.62 c
T_{10} (2 N_{350} Fe_{80} 4 S_{Ca} 2 $S_{K,Zn}$)	2.56 cd	355.1 ab	176.1 f	7.40 bc	0.78 a	0.65 bc

Table 7. Pearson correlation ratio between nutrients concentration of fruit and fruit qualitative properties.

	YIELD	FRUIT FIRMNESS	DISSOLVED SOLIDS	FRUIT pH	FRESH WEIGHT	DRY MATTER
Nitrogen	−0.476	−0.609*	0.625	−0.171	−0.460	−0.689*
Potassium	−0.243	−0.086	0.004	−0.166	−0.295	0.209
Phosphorus	−0.166	0.137	0.085	0.500	0.168	0.062
Iron	−0.577	−0.649*	0.210	−0.110	−0.097	−0.719*
Zinc	0.848**	0.656	0.612	0.421	0.530	0.913**
Manganese	−0.308	−0.210	0.681*	−0.429	0.695	0.320

Notes: *Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level.

and foliar spray of 0.5% of calcium during several stages for each tree had the highest effect on the yield per tree, fruit firmness, fruit pH, and percentage of the fruit dry matter so that the yield of this treatment showed a difference of 7.9 kg per plot in relation to the control treatment. The positive and significant correlation between zinc concentration of the fruit and yield and firmness of the fruit shows a necessity in the use of zinc fertilizer by foliar spray of zinc chelate during the fruit growth. Foliar spray of calcium caused fruit firmness, which is effective in increasing the fruit quality after harvest.

Author Contributions

Conceived and designed the experiments: AMT, MER and DH. Analyzed the data: AMT and MER. Wrote the first draft of the manuscript: AMT and MER. Contributed to the writing of the manuscript: AMT. Agree with manuscript results and conclusions: AMT, DH and SAS. Jointly developed the structure and arguments for the paper: AMT and DH. Made critical revisions and approved final version: AMT, DH and SAS. All authors reviewed and approved of the final manuscript.

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