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Evaluation of nitrate levels in tomatos collected from leading production regions of Khorasan Razavi province, Iran

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Abstract

Nitrate accumulation is a common problem in agriculture. To determine the factors contributing to nitrate accumulation in tomato fruits, the present study investigated the accumulated nitrogen content in tomatoes harvested in Iran's Khorasan Razavi province (Mashhad, Neyshabur, Torbat-Jam, Fariman, and Chenaran regions) in four consecutive years. At least 30 samples were collected from each growing area and analyzed. Our findings showed that nitrate accumulation was absent in areas where fertilizer application met crop and soil needs. The highest nitrate accumulation in fresh fruits was 487 mg/kg in fields where the plants received 207 kg/ha of nitrogen fertilizer; the nitrate content of the samples was above the standard critical concentration in 71.67% of the regions studied. Nitrate accumulation in tomatoes from Khorasan Razavi province was high, which can adversely impact the quality of this crop in this region.

Key words: Fertilizers, pollution, nitrogen, vegetables

Introduction

Since nitrate is detected in most vegetables and can adversely affect human health, its levels in plant tissues should always be evaluated (Jun *et al.,* 2013). Many factors affect nitrate accumulation in plant tissues, including plant type, environmental parameters, fertilizer type, or irrigation water quality. Low light, high temperatures and water stress usually decrease the activity of the nitrate-reducing enzyme and result in its accumulation. Application of chemical fertilizers without considering soil analysis and plant needs can lead to water contamination and accumulation of chemicals in plant tissues at toxic levels (Malakouti, 2016).

Human activities and industrial agriculture have led to a disruption of the natural nitrogen cycle and a gradual increase in the amount of nitrate accumulated in the environment (Chan, 2011). Nitrate is present in most vegetables, especially those eaten fresh or raw. Its endogenous concentration in plant tissues varies from region to region. Previous studies have shown that fresh vegetables, especially summer crops, are the primary source of nitrate in the diet of humans and animals, as nitrate accumulates in these products (Chou *et al.,* 2003).

Prolonged application of nitrogen fertilizers has been shown to increase nitrate levels in vegetables. Management of fertilizer application can reduce nitrate levels in various vegetables. Slow-release nitrogen fertilizers such as sulfur-coated urea can minimize nitrate accumulation in plants (Zareabyaneh and Bayatvarkeshi, 2014). Jolleini and Doosti (2011) reported a positive correlation between nitrate accumulation and application of nitrogen fertilizers in potato and tomato crops. Similar results have been reported by Malakouti and Tabatabai (1998).

Rezaeian-Bajgiran (2006) found that nitrate concentrations in vegetables (*e.g.*, tomatoes, cucumbers, eggplants, watermelons, green peppers, and red peppers) grown in Mashhad, Neishabour, and Sabzevar ranged from 2 to 46 mg/kg dry weight, with most samples below standard critical levels. Shahbazzadegan *et al.* (2010) reported that nitrate levels in vegetables in Ardabil were below standard limits. In a study by Tabande and Safarzadeh Shiraze (2018) on Zanjan's leafy vegetables, leek and parsley met permissible standards, while some dill and coriander crops exceeded critical limits (6.28%). Esfandiaribiat *et al.* (2014) observed significant changes in nitrate metabolism in roots and shoots of Iranian spinach ecotypes with increased nitrogen concentrations.

Since the consumption of tomatoes, fresh or processed (tomato paste), is high in Iran, a quality assessment of this vegetable seems necessary in terms of nitrate content and other compounds that can accumulate in toxic amounts in the fruits. Khorasan Razavi province is a center of tomato cultivation in Iran, with 15,000 hectares of tomato fields and a production of 750,000 tons. The present study aimed to evaluate nitrate accumulation in tomatoes produced in this area (Khorasan Razavi province). Since nitrate accumulation in tomatoes depends on a number of factors, including nitrate concentration of irrigation water, amount of nitrogen fertilization, and environmental factors, the effects of these factors on nitrate accumulation in tomatoes were also studied.

Materials and methods

The study spanned five cities in Khorasan-Razavi province—Mashhad, Neishabour, Torbat-e-Jam, Fariman, and Chenaran—

encompassing 20,000 hectares of tomato fields. These fields, vital for meeting regional demand, were randomly chosen, yielding 161 tomato samples collected during commercial harvests. The data, analyzed through correlation studies, pertained to furrow irrigation from deep wells across all fields. Detailed information, such as farmers' names, sampling timing, cropping practices, irrigation cycles, and fertilizer use (especially nitrogen), was meticulously recorded.

The samples were washed with tap water and then with distilled water. Tomatoes were dried at ambient temperature, 25° C for twelve hours, the fruits were then weighed with a digital scale and their fresh weight was recorded. The samples were oven-dried at 70 °C and weighed to determine their dry weight.

Portions (0.1 g) of sample tissues were suspended in 10 mL distilled water, kept at 45 °C for 1 hour and then filtered through Whatman filter paper. Samples were extracted and analyzed within 24 hours after extraction when stored at 4 °C. The derivative spectrophotometric determination of nitrate was done according to Lastra (2003).

To study the factors affecting nitrate accumulation in fresh fruit, environmental factors such as nitrate content of irrigation water, fertilizer consumption, and climatic parameters of the sampling region were recorded.

Data were analyzed with SPSS, Excell was used for chart design.

Results and discussion

The average nitrate concentration (mg/kg fresh weight) in the studied samples is presented in Table 1. Statistical analysis showed that this parameter's standard deviation and mean value did not differ in most samples, so the distribution of residual nitrate was normal. The lowest nitrate accumulation (409.2 mg/kg fresh weight) was found in samples from Torbat-e-Jam, and the highest nitrate accumulation was found in samples from Mashhad (440.4 mg/kg fresh weight). The coefficient of variation of nitrate accumulation in different regions was high, which means that the variability in the studied area varied between low to medium. According to the classification of Wilding *et al.* (1983), edaphic and water-related factors (in an area affecting the concentration of elements in plant tissues) with a coefficient of variation higher than 50% are classified as highly variable.

Table 1. Average tissue nitrate concentration and statistical characteristics of tomato fruit samples in different regions of Khorasan Razavi during experimental period (3 years)

Sampling location	Mashhad	Fariman	Torbat Jam	Neyshabour	Chenaran
Number of Samples	38	30	31	31	32
Nitrate concentration (mg/kg fresh weight)	219.3	225.1	198.5	204.9	208.7
Variation domain	440-55.9	425.3-59.1	409.2-49.9	411.2-59.4	329.7-56.9
Standard deviation	113.55	124.15	125.21	122.14	104.03
Variation coefficient	0.518	0.552	0.631	0.596	0.498

According to the Iranian national standard no. 16596, the maximum nitrate concentration in fresh tissue of tomato fruits should be limited to 120 mg/kg. The European Commission set this parameter at 50 mg/kg (The Commission of the European Communities, 1999). The limit for the average daily intake of nitrate (ADI) set by the National Standards Institute of Iran is 3.7 mg/kg body weight, considering dietary habits, per capita consumption, and variety of foods.

In general, nitrate accumulation was above the permissible limit in 62.5% (Chenaran) to 71.6% (Mashhad) of the tomato fields, and the range of variation was also relatively high (Table 2).

Table 2. Frequency (%) of maximum nitrate content residue in tomato samples

Sampling location	Frequency of samples with lower than 120 mg/kg fresh weight accumulated nitrate (%)	Frequency of samples with higher than 120 mg/kg fresh weight accumulated nitrate (%)
Mashhad	28.94	71.06
Fariman	30.00	70.00
Torbat Jam	29.03	70.97
Neyshabour	32.25	67.75
Chenaran	37.50	62.50

Our results show that nitrate accumulation in tomato fields of Khorasan-e-Razavi province is high and poses a serious threat to the quality of this crop. In areas where fertilization was according to the soil test and the actual needs of the crop, nitrate accumulation was low (less than 120 mg/kg fresh weight), while in several farms with high nitrogen fertilization (more than 350 kg/ha), increased nitrate accumulation (up to 440 mg/kg fresh weight) was observed. Although, as mentioned above, nitrate accumulation depends on a number of factors, nitrogen fertilization was considered the most critical factor.

The amount of nitrogen fertilizer applied (independent parameter) and nitrate accumulation in tomato fruit (dependent parameter) were strongly correlated ($R^2 = 0.713$), and the positive slope of the curve (equation 1) shows that as nitrogen fertilizer application increases, nitrate concentration in tomato fruit also increases (Fig. 1).

$$Y = 0.3647X + 202.8 \qquad \text{Eq. 1}$$

Our results showed that in regions where nitrogen fertilizers were applied at rates higher than 250 kg/ha, the average accumulated nitrate increased by 27 mg/kg fresh weight with each 10 kg increase in fertilizer application. The lowest accumulated nitrate concentration (49.2 mg/kg fresh weight) was observed in regions where 200 kg urea per hectare had been applied, and the highest accumulated nitrate concentration (440.4 mg/kg fresh weight) was found at sites where 375 kg urea per hectare had been used.

The variation in nitrate accumulation in different regions suggests that, in addition to the amount of nitrogen fertilizer applied, soil- and water-related factors, climate, cultivar, and crop maturity are responsible for these differences. Kafeshani *et al.* (2013) found similar results. Optimally applied nitrogen fertilizers lead to lower nitrate accumulation in plant tissue (Malakouti *et al.,* 2005).

The correlation between climatic factors, nitrate concentration in irrigation water, fertilizer application rate and nitrate accumulation in tomato fruits showed that nitrate accumulation in tomato was

Table 3. Correlation between the nitrate content of irrigation water and applied nitrate and nitrate concentration in tomato fruit

Factor	Nitrate concentration of the fruit	Applied nitrate	Irrigation water nitrate content
Irrigation water nitrate content	0.92***	0.77 ***	1
Applied nitrate	0.83 ***	1	0.77 ***

Significant at $P \leq 0.01$ **

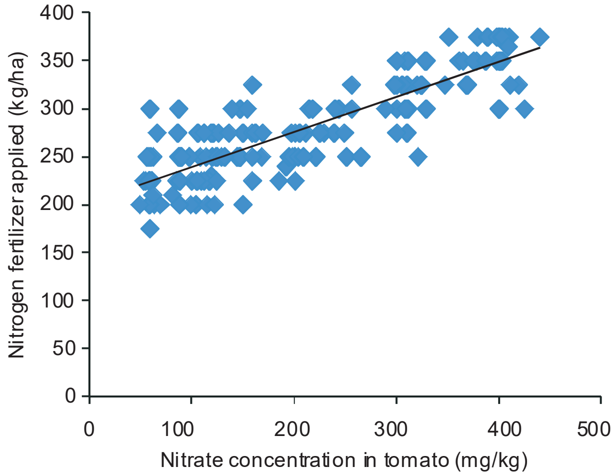

Fig.1. Correlation between nitrogen fertilizer application and nitrate accumulation in tomato

positively and significantly correlated with the nitrate content in irrigation water and the amount of nitrogen fertilizer applied (Table 3). Therefore, table 3 presents only those factors that were significantly correlated with nitrogen accumulation in tomatoes.

The nitrate concentration of the irrigation water had the most significant influence (correlation coefficient=0.92) on nitrate accumulation in the fruits. The amount of nitrate fertilizer applied was the second important factor affecting nitrate accumulation in tomato fruits (correlation coefficient=0.83). Since nitrate concentration in irrigation water was positively and significantly correlated with nitrate accumulation in tomatoes, the correlation between nitrate content in water and climatic parameters was determined (Table 4).

In summary, nitrate accumulation in tomato samples from key production centers in Khorasan Razavi province exceeded critical standard limits. Fields with nitrogen fertilizer tailored to crop needs and soil analysis had nitrate accumulation below permissible limits. A positive correlation existed between irrigation water nitrate content, fertilizer application, and tomato fruit nitrate levels. With nearly 70% of studied tomato samples showing high nitrate levels and Iran's substantial per capita tomato consumption, it is crucial to educate farmers and the public for societal health.

Table 4. Correlation between climatic factors and nitrate content of irrigation water

Climatic factors	Correlation
Relative humidity of April	-0.18**
Relative humidity of May	-0.17*
Relative humidity of June	-0.19**
Relative humidity of July	-0.19**
Relative humidity of August	-0.18**
Relative humidity of September	-0.17*
Sunny hours of September	-0.16*
Precipitation of October	0.15*
Precipitation January	-0.16*
Relative humidity of January	-0.18*
Frosty days of February	-0.17*
Sunny hours of October	-0.19*
Relative humidity of October	-0.18*
Sunny hours of November	-0.17*
Relative humidity of November	-0.18*
precipitation of December	-0.17*
Average temperature of December	-0.16*
Sunny hours of December	-0.16*
Relative humidity of December	-0.17*
Relative humidity of February	-0.17*
Relative humidity of March	-0.19*

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