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Variable-Rate Fertilization for Citrus Orchard Management †

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Abstract: All tropical and subtropical areas of the world are suitable for citrus cultivation. In managing fertilizer application efficiency in orchards, variable-rate technology (VRT) has been demonstrated to be an important element. This article aims to study the significance of variable-rate fertilization for citrus in the arid region of Pakistan. The NPK was calculated before the application of the variable-rate fertilizer. The plant height and stem girth were determined before and after fertilizer application. The preliminary results revealed that the stem girth performed significantly better than the plant height after applying fertilizer by VRT. The preliminary results showed a significant difference in the fruit yield between the VRT and uniform-rate fertilizer application.

Keywords: variable-rate technology; citrus; stem girth; plant height; fertilizers

1. Introduction

Pakistan is a producer and exporter of citrus, ranked sixth overall globally, with an average production of 2,468,671 tons in an area of 181,650 hectares [1]. Citrus fruit occupies a dominant economic position in the world's fruit sector and is commercially grown in over 130 countries. However, Pakistan only contributes 2.9% of the world's production of citrus fruit, such as mandarin and oranges, due to its low average yield compared to worldwide trends [2]. The cost of production has increased due to rising inflation, while the yield has stagnated. Although citrus has the potential to be a significant crop, proper research has not been undertaken to boost its productivity. Despite the introduction of modern technologies, such as precision agriculture, VRF, etc., and their impressive outcomes, farmers have not yet adopted them to improve the yield of their orchards [3]. VRF application has the potential to improve fertilizer use efficiency, reduce the cost of production, and reduce the environmental impacts [4,5]. Variable-rate technology (VRT) is a key site-specific precision agriculture technique that empowers variable dose input control in the field dependent on the crop and soil spatial variability [6,7]. Although this technology is well known and efficient, growers have not yet implemented it as their major method of fertilization [8]. The objective of this study was to reduce the loss of fertilizers via the traditional method of fertilization and to reduce the toxicity caused by the excessive use of fertilizers.

2. Materials and Methods

2.1. Experimental Site

Citrus groves located at the University Research Farm Koont of PMAS-AAUR, Rawalpindi, were selected for this research to evaluate the impact of the VRT on citrus growth and yield; the map of the area is shown in Figure 1.

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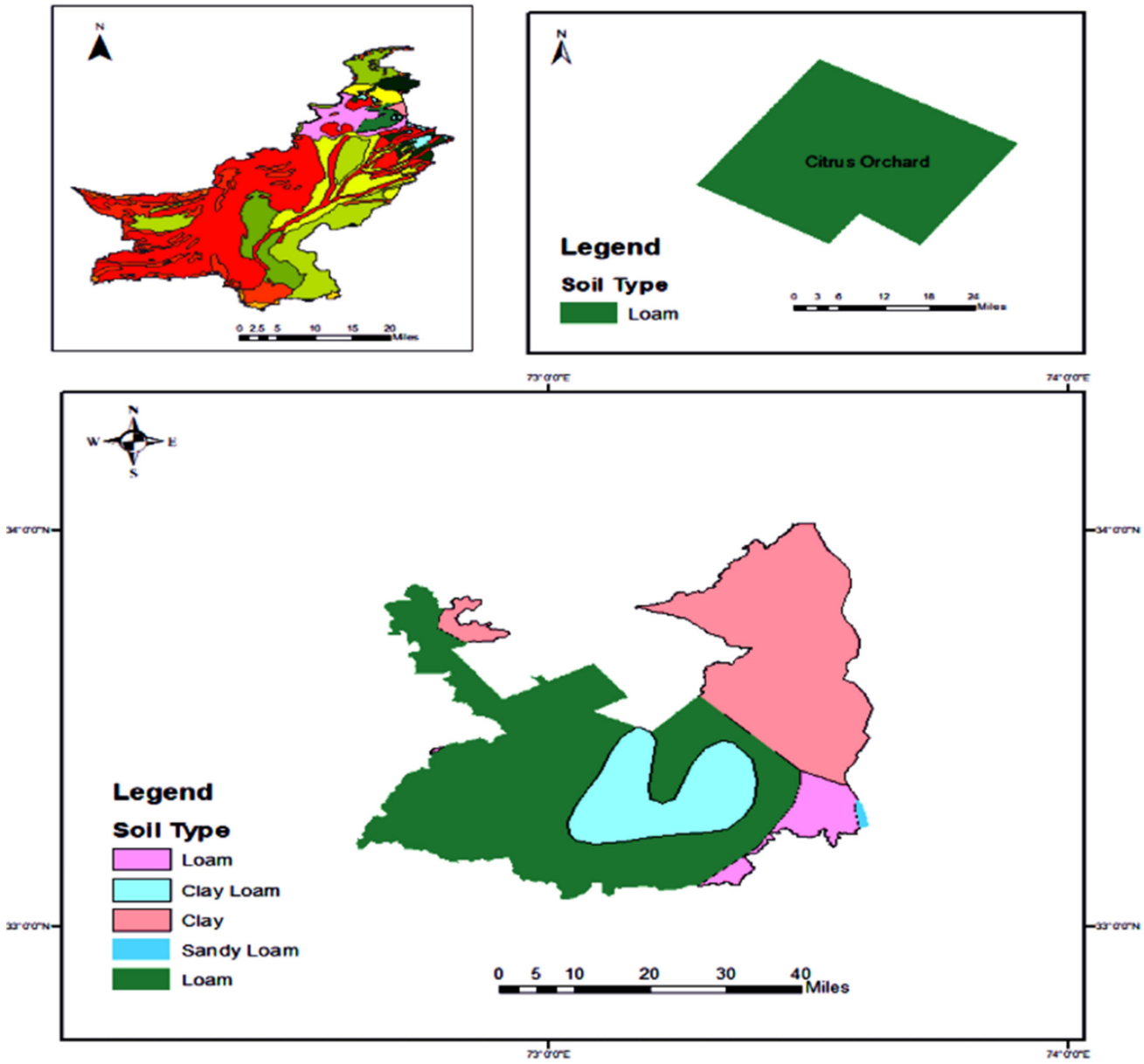


Figure 1. Map of the study area, the citrus orchard, and Rawalpindi.

2.2. Experiment Framework

The selected field for the experiment had been under URF for the past few years. Plants with an age of more than five years were selected for this research. The VRF was applied based on the canopy volume. The plants were divided into three groups having different canopy volumes, as shown in Table 1. The plant canopy was measured with the formula $1/2\pi r^2 \times h$.

Table 1. Plant groups based on canopy volume.

Groups ID	Canopy Volume (ft^3)	Nitrogen (g)	Phosphorous (g)	Potassium (g)
A1	300–450	875	1390	500
A2	450–600	1050	1675	600
A3	600–750	1250	1940	700

Soil sampling was performed to verify the accuracy of the recommended doses, carried out by soil proximal sensors. The plant height, stem girth, and fruit yield were measured to evaluate the effect of the VRF. A statistical comparison was performed to evaluate the impacts of the variable-rate fertilization on the plant height and stem girth.

3. Results

3.1. Plant Height

The plant height plays a significant role in the development of plant physiology [4]. Plant height readings were taken at regular intervals over time. The results indicated that the heights of the plants under the variable-rate fertilization (VRF) and uniform-rate fertilization showed only a small difference; the results are shown in Table 2. On the other hand, the plants under VRF performed well with less input as compared to the plants under uniform-rate fertilization.

Table 2. Comparison of the plant height under the URF and VRF (2021).

Canopy Volume (ft^3)	Sample	N	Mean	*p*-Value	Mean	**p*-Value
			July 2021			**July 2022**
300–450	VRF	3	8.20	0.0503	8.63	0.018087
	URF	3	8.03		8.60	
450–600	VRF	3	10.33	0.0236	10.83	0.008688
	URF	3	9.83		10.43	
600–750	VRF	3	9.90	0.0230	10.50	0.158950
	URF	3	10.73		11.43	

***p*-value** less than 0.05 shows significant results.

3.2. Stem Girth

A significant influence was observed in the stem girth in the plants receiving VRF as compared to the plants under URF, especially in the second interval of the reading; the results are shown in Table 3.

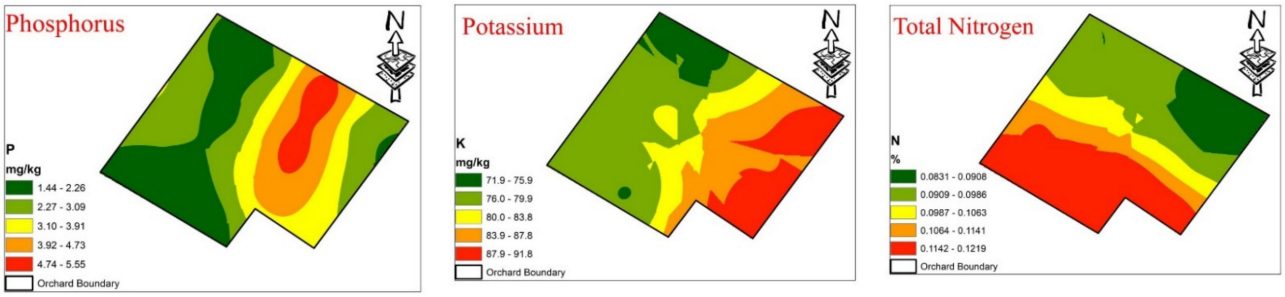
Table 3. Analysis of variance of the stem girth at 50% (2021).

Canopy Volume (ft^3)	Sample	N	Mean	*p*-Value	Mean	**p*-Value
			July 2021			**July 2022**
300–450	VRF	3	15.66	0.400985	17.10	0.116486
	URF	3	15.33		0.52	
450–600	VRF	3	20.17	0.095855	1.60	0.113882
	URF	3	19.00		3.00	
600–750	VRF	3	18.50	0.044226	1.25	0.263621
	URF	3	18.67		2.12	

***p*-value** less than 0.05 shows significant results.

3.3. Interpolation of the Soil Nutrients

In Figure 2, the maps show the current nutrient status of the nitrogen, phosphorous, and potassium in the citrus orchards after the application of fertilizers with the VRT methods. Soil data were taken from 15 different stations by soil proximal sensors after the application of fertilizer with the VRT method. The maps show that the soil contained a reliable concentration of all primary nutrients.



(**a**) (**b**) (**c**)

Figure 2. Kriged interpolated maps of (**a**) potassium, (**b**) nitrogen, and (**c**) phosphorous.

3.4. Fruit Yield

It is essential to note that the impact of the VRF and URF on citrus yield depends on a variety of considerations, including the type of citrus being cultivated and the soil conditions. The fruit yield of the plants under the VRF treatment was higher than the plants under the URF treatment, as shown in Figure 3. Moreover, there were fewer disease attacks on the fruits after maturity in the plants under the VRF treatment.

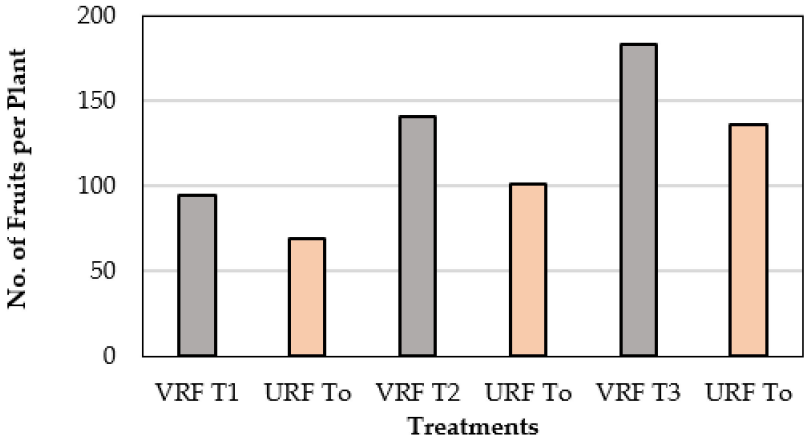


Figure 3. Number of fruits per plant vs. treatments based on the canopy volume.

4. Conclusions

A calculated amount of fertilizer was applied to the plants under the VRF treatment as compared to the plants under the uniform-rate fertilization (URF) treatment. The random or excessive use of fertilizers increases the risk of soil toxicity. It is also considered an unsustainable practice. The preliminary results showed that the VRT method reduced the fertilizer quantity, which also reduced the cost of fertilization for the farmer. Due to the abovementioned benefits, VRT has the potential to increase the production of crops as well as their quality by enhancing their physiology.

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