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Kiwi Plant Growth Monitoring with Soil and Climatic Conditions in the Semi-Arid Region of Pakistan †

Muhammad Umair Arif Khan [1], Muhammad Azam Khan [1,*], Usman Ali Abbasi [1], Muhammad Amin [2], Tahira Kalsoom [1], Abdul Basit [3] and Basit Shahzad [1]

1 Department of Horticulture, PMAS-Arid Agriculture University, Rawalpindi 46000, Pakistan
2 Institute of Geo-Information & Earth Observation, PMAS-Arid Agriculture University, Rawalpindi 46000, Pakistan
3 Green AI, Center of Precision Agriculture, PMAS-Arid Agriculture University, Rawalpindi 46000, Pakistan
* Correspondence: drazam1980@uaar.edu.pk; Tel.: +92-300-6884470

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Abstract: Crop growth and yield are influenced by the genetic potential of the cultivar, soil, weather, and cultivation practices, i.e., sowing date, irrigation and fertilizer amount, and biotic stresses. Temporal variation in yield and growth has been largely forecasted using climate as a predictor, which can be achieved by using either an empirical or crop simulation approach for a given location. Climate and soil data collected over agricultural land regularly aid in crop growth monitoring, as well as crop vitality assessment. Crop simulation models (CSM) that have been successful in field-scale applications are now being implemented in GIS framework to simulate and monitor crop growth with remote sensing inputs, allowing for sensitive evaluations of seasonal weather conditions, local variability, and crop management signals. This research was designed to monitor the growth of three varieties of kiwifruit, i.e., Hayward grafted, Green-flesh, and Hayward, in four different localities: Hazaro (Attock), Simli Dam (Pind Begwal), GPU (germ plasm unit) Arid Agriculture University Rawalpindi and ZTBL (Zarai Taraqiati Bank Limited) Farm Islamabad, each of which has different soil and weather conditions. Soil proximal sensors were used to measure soil characteristics, and data loggers were installed in each field to monitor the weather parameters to collect data that influences crops. In this study, we used a quantitative method and GIS-integrated data to assess the impact of soil and climate on kiwifruit growth. It can help policy makers and researchers to identify new agro-climatic zones in Pakistan's semi-arid regions for kiwifruit farming based on this data. In this study, we found that kiwi is very susceptible to temperatures above 40 °C, which cause mortality in kiwifruits plants. Morphological data with respect to soil and climate results showed that green-fleshed and Hayward varieties performed slightly better than Hayward grafted, which was most susceptible to diseases and heat damage.

Keywords: crop simulation models; crop monitoring; remote sensing; soil and climate

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1. Introduction

Kiwifruit is a deciduous perennial climber plant that originated from eastern and southern Asia [1]. Kiwifruit seeds and peels are an excellent source of beneficial compounds, including carotenoids, terpenoids, and polyphenols, and have anti-inflammatory, antimicrobial, antidiabetic, and antioxidant properties; therefore, this fruit has excellent industrial and pharmaceutical potential [2]. Commercial cultivation of kiwifruit started in New Zealand and later spread all over the world [3]. This plant is susceptible to extreme temperatures and frost and requires an optimum temperature ranging from 22 °C to 30 °C for better fruit production [4]. A total of 70 varieties of kiwifruit are grown worldwide, among which only green and golden kiwifruit are used for commercial purposes [5]. In 2020, China had the highest kiwifruit exports, valued at USD 454 million [6].

Approximately 4.41 million metric tons of kiwifruit were produced worldwide in 2020—an increase from the 1.87 million metric tons produced in 2000. In 2020, China and New Zealand produced 2.2 and 0.6 million metric tons, respectively [5]. Commercial kiwi cultivars, including Arctic, Abbott, Allison, Bruno, Hayward, Monty, and Tomuri, are significant globally and are imported into Pakistan from China and other producers. The Pakistan Agricultural Research Council has been testing the Hayward type of kiwi plants in the Hazara belt in past few years. The fruit has also been grown in Battagram, Abbottabad, and Havalian [7].

In Pakistan, kiwi is an exotic plant that is not cultivated at a commercial level. However, research is being conducted to determine suitable climatic zones for fruit production. Climate and soil variability are the two most important factors in plant growth and are essential for determining suitable climatic zones for fruit crop production. Soil characteristics and climatic suitability are the primary factors affecting optimal plant growth and fruit quality [8–10].

The growth cycle of kiwifruit (including budburst, blooming, and fruit maturity) is affected by environmental and soil conditions [9], which determine the occurrence of phenological phases, i.e., lower temperatures in late autumn and winter cease dormancy. Rainfall affects fruit development, and cooler mean temperatures in the fall seem to boost brix. Accordingly, warmer temperatures accelerate phenological phases from budburst through early fruit development, whereas cooler mean temperatures encourage faster maturation rates in autumn and the end of dormancy in winter. In this way, kiwifruit vine is sensitive to frost and high temperatures and cannot withstand harsh weather [2,11].

Soil nutrient status also affects plant productivity, as excess or deficient N, P, and K can represent potential risks, reducing fruit quality, quantity, and plant growth [12,13]. Like soil nutrient status, pH and electric conductivity can also affect kiwifruit crop productivity, as high pH can significantly constrain nutrient availability [14].

As the world population is increasing daily and modern technologies are progressing rapidly, agriculture interventions to monitor crop growth need time to fulfill nutritional requirements. In the current research, GIS and sensor-based approaches were applied to monitor the growth of kiwifruit, considering climate and soil parameters [15,16]. It is a well-established practice to employ GIS and RS data for crop monitoring during all stages of activity, i.e., planning, analysis, and output [17]. For this purpose, different sensors are used to determine fertilizer requirements, water availability, and pest infestations. Precision agriculture provides explicit real-time estimations through satellite systems. This technology provides accurate field data [18], reduces labor costs and input resources, and boosts agricultural productivity [17,19,20].

It is essential to study the two crucial factors of climate and soil to monitor the growth of kiwifruit. Using proximal sensors, in this study, we intended to evaluate the morphological response of kiwifruit in a semi-arid region, determine the influence of climate and soil variability on kiwifruit, and compare the growth of different kiwifruit varieties in terms of climate and soil suitability.

2. Materials and Methods

2.1. Experimental Site

The research experiment was carried out at 4 different locations in the semi-arid region of Potohar, Pakistan. These locations included Simli Dam (Pind Begwal; 33°41′57″ N 73°15′52″ E), Zarai Taraqiati Bank Limited (Farm Islamabad; 13°39′59″ N 73°06′01″ E), Attock (Tehsil Hazaro; 33°56′55″ N 72°24′52″ E), and the Germ Plasm Unit (Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi; 13°38′48″ N 73°04′50″ E). Three varieties were selected for this research, i.e., green-fleshed, Hayward grafted, and Hayward. Satellite imagery of the above-mentioned locations via GPS logger are illustrated in Figure 1:

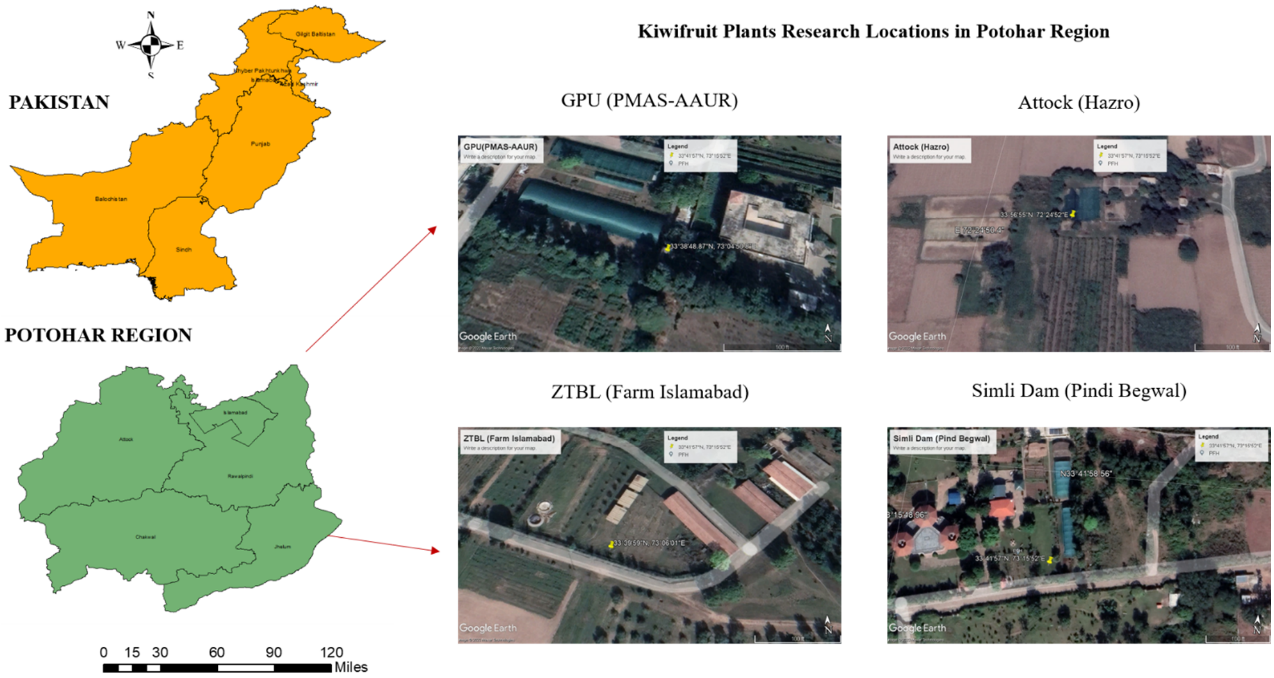

Figure 1. Kiwifruit plant research locations in Pothohar region.

2.2. Study Parameters

Morphological growth parameters include the number of leaves, number of shoots, stem diameter (cm), plant height (cm), inter-nodal distance (cm), and leaf area (cm). To monitor the growth of kiwifruit plants, soil (NPK concentration, pH, electrical conductivity, and organic matter) and climate (temperature, rainfall, and relative humidity) parameters were measured. Soil and climate data were utilized to estimate agroclimatic appropriateness their effect on plant morphological growth.

2.3. Monitoring Parameters

Rainfall data were collected from the Pakistan Meteorological Department. Temperature data were collected using a data logger installed at the research locations. Soil parameter results from the lab and proximal sensors were compared. A calibrated scale was used to assess morphological growth from March 2022 to August 2022.

2.4. Data Evaluation and Analysis

RCBD analysis was used to evaluate data. By considering the soil and climatic parameters, varieties for a specific location were planned for the next growing season, and the influence of these parameters on morphological growth were also considered.

3. Results and Discussion

The chemical properties of the soil used for experiments at the four locations are shown in Table 1. This test indicated the nutrient status of soil in which kiwifruit plants were grown.

Temperature data were collected through a data logger, and rainfall data were collected from the Pakistan Meteorological Department, as shown in Table 2. These data, which were observed during a six-month period from March to August, show the average rainfall, minimum temperature, and maximum temperature during each month.

Table 1. Average data of chemical properties and nutrient status of soil collected through proximate soil sensors and soil fertility tests.

	Attock	Simly	GPU	ZTBL
Nitrogen (mg/kg)	14	16	16	12
Phosphorous (ppm)	0.919	0.615	1.046	0.288
Potassium (ppm)	3.5	1.3	3.9	2.1
EC (us/cm)	0.4	0.1	0.1	0.1
pH	6.4	6.19	6	6.5
Organic matter (%)	0.93	1.28	0.24	0.59

Table 2. Climatic factors recorded at different locations.

Location	Month	Climatic Factors				
		T °C (Average Min)	T °C (Min)	T °C (Average Max)	T °C (Max)	Rainfall (mm)
Attock	March	20	8.1	36	37	66.3
	April	21.2	17.2	37.2	38	50.7
	May	24.6	19.5	40	43	33
	June	31	22.5	45	49	32.7
	July	31.5	24.3	45.5	47	99.5
	August	29.5	23.1	43	46	97.1
ZTBL	March	17	7.1	33	34.5	73.8
	April	18	14.3	34.3	35.1	59.7
	May	21.5	16.1	37	40	39.2
	June	28.2	19.5	42.3	46	62.2
	July	27.5	19.8	42	44	267
	August	22.9	20	39.2	42	309.9
Simly	March	16.5	7.0	32	33.5	140.39
	April	17.2	13.2	33.5	34.5	94.23
	May	20.8	14.8	36	39.1	55.02
	June	27.5	18.1	41.2	43.5	63.55
	July	26.6	19.3	41	43.1	261.5
	August	21.5	19.5	38.5	41	240.31
GPU	March	18	7.5	34	35	71.8
	April	19.6	15.5	35.1	36	57.7
	May	22	17.5	38	41	30
	June	29	20.2	43.2	47.3	53.3
	July	29.5	21.1	43.3	45.2	237
	August	27.5	20.3	41.8	43.8	236

As shown in Table 3, different growth patterns were observed among the three varieties at each location. For each variety, stem diameter was almost constant at every location, but the highest stem diameter was recorded (0.85 cm) in the green-fleshed variety at Simly Dam (Pind Begwal). Minute variation in stem diameter is due to variations in soil chemical composition. An increases in stem diameter often followed canopy responses and soil chemical composition, as described in [7]. Collected data show a major difference in the plant height of each variety at different locations. This variation is due to weather conditions; rainfall of more than 150 mm in June and July caused water flooding in the root zone, affecting the root zone's oxygen ratio. In terms of plant height, the Hayward kiwi plant reached a height of 126.4 cm in Attock, followed by 125.32 cm in GPU, 125.67 cm in ZTBL, and 75.5 cm in the Simly Dam kiwifruit orchard. The height of the Hayward grafted variety was 128.83 cm at the Simly Dam location. The third variety, green-fleshed, was most heightened at each location as compared to other varieties, with a maximum height of 246.17 cm at the Simly Dam location, followed by 228.17 cm at ZTBL, 219.3 cm at GPU, and 173.35 cm at Attock. Tree growth and development are determined by the plant's height in the local climate [21]. The genetic makeup of the variety and the impact of environmental factors lead to diversity in plant height among olive types, which behave differently in various climatic situations. The efficient use of plant nutrients and water at various locations is the cause of the variance in plant height in kiwifruit [12].

Table 3. Growth parameter analysis of three varieties (Hayward, Hayward grafted, and green-fleshed) at Attock, GPU, ZTBL, and Simly Dam.

Variety	Location	Parameters						
		Stem Dia. (cm)	Plant Height (cm)	Internodal Distance (cm)	No. of Shoots	No. of Leaves	Disease (%)	Heat Damage (%)
Hayward	Attock	0.755	126.4	8.625	10	50.167	2.933	23.833
	GPU	0.5867	125.32	8.6267	9.8333	50.5	4.6667	5.5
	ZTBL	0.5467	125.67	8.63	12	52	5	8.833
	Simly Dam	0.8333	75.5	4.8167	10.5	46.667	3.8333	3.3333
Hayward grafted	Attock	0.6083	94.2	5.7167	5.667	54	7.133	25.633
	GPU	0.5583	101.67	6.6	8.3333	52	5.8333	10
	ZTBL	0.515	111.67	8.6267	11.667	52.5	5.3333	12.167
	Simly Dam	0.8367	128.83	6.5133	10.167	64.833	4.5	4.8333
Green-fleshed	Attock	0.6283	173.35	7.5167	6.333	53.833	4.555	4.23
	GPU	0.56	219.28	8.15	7.8333	57.333	5.1667	5.167
	ZTBL	0.5133	228.17	8.2167	9	72.833	4.5	5.667
	Simly Dam	0.8533	246.17	8.2167	10.333	82.667	3.5	3.5

The climate data at all locations are shown in Figure 2, this climatic data affects kiwifruit morphological growth as shown in Table 3. The data on climatic factors shown in Table 2 indicate that rainfall and temperature variation affected plant growth, as reflected by internodal distance, the number of shoots, and the number of leaves. The internodal distance reached a maximum value (8.62 cm) in the Hayward grafted variety at ZTBL and a minimum value (4.82 cm) in the Hayward variety at Simly Dam. Internodal distance determines the morphology of the canopy and the porosity of the branches, which favors light and air permeability [22]. All vegetative tissues of plants share metabolites, so their effects on intermodal tissues vary [22,23]. The maximum number of shoots was 11.7 in the Hayward grafted variety, and the maximum number of leaves was 82.7 in the green-fleshed variety. When the internode size of native spearmint tissues is increased, the number of shoots decreases [24].

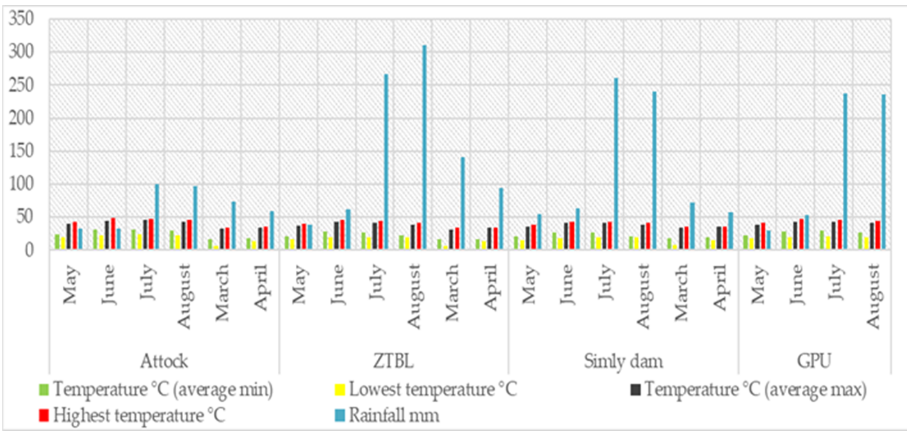

Figure 2. Climatic factors recorded at different locations.

The percentage of disease caused by genera *Sphingobium* and *Phytophthora* was 7.133% in the Hayward grafted variety and 2.93% in the Hayward variety at Attock kiwi orchard. These pathogens are responsible for the loss of kiwifruit vine [25]. In June and July, temperatures above 40 °C adversely affect kiwifruit plants, making them more vulnerable to sudden and extreme weather events, such as very high, quickly rising temperatures and rains, which occur more frequently in the summer and cause intense and abrupt water stress [26]. Heat damage percentage was also recorded as highest in the Hayward grafted and lowest in the Hayward and green-fleshed varieties at Simly Dam. These data show that green-fleshed and Hayward varieties are the most suited to the local climate, and the Hayward grafted variety is the most susceptible to diseases and heat damage (Table 3), which can have long-term effects on the growth of the kiwifruit plant. The physiological responses of the kiwifruit vine to environmental stress can indicate for opportunities that can be overcome through breeding and, cultural techniques. Spatial variation in leaf arrangement and temporal variation in irradiance conditions lead to highly dynamic irradiance of individual leaves within the canopy [26]. Overall, the green-fleshed kiwi variety performed better than the Hayward and Hayward grafted varieties in terms of morphological parameters at all research locations. The climatic conditions at Simly Dam are most suitable for kiwi plants. Because kiwi plants like humidity, they are widely adopted in humid areas of China and New Zealand [27]. Rainfall of more than 150 mm causes flooding in the root zoon of kiwi plant, and the physiology of plants and the anatomical characteristics of the xylem point to a potential involvement of weather. This role might be highly harmful to kiwifruit, which is known as an anisohydric plant [28].

4. Conclusions

Identifying new agro-climatic zones in Pakistan's semi-arid regions for kiwifruit farming is possible. This plant is being introduced in Pakistan to attain significant benefits. For this purpose, a number of kiwifruit varieties were grown in different areas to determine suitable soil and climate conditions for growth and commercial production. The morphological characteristics of three varieties were recorded at four locations, and the effects of climate and soil were observed. Crop simulation models (CSMs) are now being applied in GIS framework to simulate and monitor crop growth with remote sensing inputs, allowing for sensitive evaluation of seasonal weather conditions, local variability, and crop management. In this study, we found that kiwi is very susceptible to warm weather, is sensitive to frost and high temperatures, and cannot bear harsh weather; specifically, temperatures above 40 °C cause mortality in kiwifruit plants. Morphological results show that green-fleshed and Hayward varieties performed slightly better than the Hayward grafted variety, which was found to be the most susceptible to diseases and heat damage, which can have long-term effects on the fruiting of kiwi plants.

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