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DIURNAL AND SEASONAL VARIATION IN LEAF WATER CONTENT OF VIGNA UMBELLATA IN KARMANA AND TASHKENT, UZBEKISTAN

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ABSTRACT This study compared diurnal and seasonal changes in leaf water content of *Vigna umbellata* grown in Karmana District, Navoi Region, and Tashkent City during 2024–2025. Leaf water content, expressed as a percentage of fresh mass, was measured every two hours from 08:00 to 20:00 on observation dates from May to August in Karmana and May to September in Tashkent. Data were analysed descriptively, with site comparisons based on matching months and observation times. Tashkent showed higher water content at every matched time point in both years. The largest differences occurred at 20:00 in June: 6.5 percentage points in 2024 and 6.7 in 2025. Diurnal variation was greater in Karmana, except in June 2025, when the range was 2.9 percentage points compared with 4.0 in Tashkent. Evening water content remained below morning levels on all eight observation dates in Karmana but equalled or exceeded them in May and June in Tashkent. These findings highlight the importance of considering observation time, daytime minima, and evening recovery when comparing leaf water status between sites.

KEYWORDS *Vigna umbellata*, leaf water content, plant introduction, diurnal variation, seasonal variation, water balance, Karmana, Tashkent.

Introduction. *Vigna umbellata* (Thunb.) Ohwi & H.Ohashi, commonly known as rice bean, is a legume grown for food and forage. Guan et al. conducted a genomic analysis of 440 landraces and identified genetic resources with potential for improving adaptation and yield traits [1]. Assessing the prospects for cultivation in different regions also requires physiological observations under local growing conditions to complement genomic evidence.

Water content in leaf tissue reflects changes in water supply and loss over time. Its interpretation depends on the mass basis used in the measurement. Water content expressed relative to fresh mass describes the proportion of water in the leaf, whereas relative water content (RWC) is based on the water held by the leaf at full turgor [2]. Although both are expressed as percentages, their physiological meaning and calculation differ. Controlled

experiments with *V. umbellata* seedlings have shown that drought and salinity stress affect RWC, chlorophyll, and other biochemical traits [3]. Responses to oxidative stress also varied with stress intensity [4]. Such experiments help explain stress mechanisms, while field observations describe plant water status under particular growing conditions. Stress levels imposed in laboratory experiments should therefore not be equated directly with leaf water percentages recorded in the field. A sample collected at a single time captures only one point in the diurnal pattern. A plant with high morning water content may undergo a pronounced decline during the day or show incomplete recovery by evening. Over the growing season, observation date, leaf physiological age, and weather conditions also change together. A central question in comparing Karmana and Tashkent is whether mean leaf water content and the pattern of diurnal variation show the same differences between sites. To address this question, diurnal profiles and seasonal sequences recorded in 2024–2025 were analysed together.

Materials and methods. The analysis examined leaf water content in *V. umbellata* grown in Karmana District, Navoi Region, and Tashkent City. Observations were made in May, June, July, and August in Karmana and from May to September in Tashkent in both 2024 and 2025. Values recorded at 08:00, 10:00, 12:00, 14:00, 16:00, 18:00, and 20:00 were compared for each observation date. The analysis comprised 126 time-specific summary values from 18 observation dates. Observation dates and meteorological data for the corresponding months are presented in Table 1. Comparisons between sites were restricted to May–August, the period covered at both sites. September results from Tashkent were considered separately to describe the continuation of the seasonal pattern at that site. Leaf water content values for each month represent a single observation day within that month. Because sampling dates differed between sites, comparisons were interpreted as descriptive differences between observations made in the same month.

Leaf water content (W) was expressed as a percentage of fresh mass. Its gravimetric expression is the difference between fresh and dry mass divided by fresh mass [5]:

$$W = \frac{m_{fresh} - m_{dry}}{m_{fresh}} \times 100$$

Here, m_{fresh} and m_{dry} denote the fresh and dry masses of the leaf sample, respectively. Diurnal variation was described using the seven time-specific values recorded on each observation date. The diurnal range was calculated as the difference between the highest and lowest values recorded on that day. Evening recovery was assessed by comparing the values at 20:00 and 08:00; a negative difference indicated that water content had not returned to its morning level by evening. Differences between sites were calculated separately for each year and month by subtracting the Karmana value from the Tashkent value at the same observation time. Diurnal ranges were likewise compared between observations from the same month and year. Seasonal variation was described using observations from successive months. Absolute differences between percentage values were expressed in percentage points. The analysis was intended to provide descriptive conclusions for the sites and observation dates studied.

Results. Mean leaf water content on the observation days declined over the season at both sites (Table 1; Figure 1). In Karmana in 2024, it decreased from 79.1 ± 0.78% in May to 73.7 ± 0.39% in August, a difference of 5.4 percentage points. In 2025, the corresponding

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values were 77.2 ± 0.97% and 72.6 ± 0.48%, a decline of 4.6 percentage points. In Tashkent, the decrease between May and August was 4.1 percentage points in both years. By September, the total decline from May had reached 5.1 percentage points in 2024 and 4.9 in 2025.

Table 1. Mean leaf water content on observation days and meteorological data for the corresponding months

Site	Year	Date	Leaf water content (%)	Air temperature (°C)	Precipitation (mm)	Relative humidity (%)
Karmana	2024	18.V	79.1 ± 0.78	21.4	50.5	46.4
Karmana	2024	14.VI	75.1 ± 0.52	29.0	3.0	29.4
Karmana	2024	16.VII	74.8 ± 0.53	29.9	3.4	29.5
Karmana	2024	08.VIII	73.7 ± 0.39	28.8	0.0	26.6
Karmana	2025	13.V	77.2 ± 0.97	26.0	0.7	29.8
Karmana	2025	16.VI	74.7 ± 0.37	29.0	0.0	28.8
Karmana	2025	8.VII	74.4 ± 0.79	31.9	0.0	23.2
Karmana	2025	4.VIII	72.6 ± 0.48	28.8	0.0	28.5
Tashkent	2024	24.V	81.3 ± 0.46	20.8	85.1	56.0
Tashkent	2024	20.VI	80.7 ± 0.43	28.8	0.0	35.0
Tashkent	2024	19.VII	78.1 ± 0.41	29.7	1.1	32.0
Tashkent	2024	15.VIII	77.2 ± 0.47	28.4	0.0	34.0
Tashkent	2024	06.IX	76.2 ± 0.40	21.4	3.3	38.0
Tashkent	2025	16.V	80.7 ± 0.70	25.4	14.0	37.0
Tashkent	2025	14.VI	80.1 ± 0.50	28.7	2.0	33.0
Tashkent	2025	6.VII	77.9 ± 0.64	31.2	0.0	27.0
Tashkent	2025	5.VIII	76.6 ± 0.27	28.3	0.0	31.0
Tashkent	2025	6.IX	75.8 ± 0.58	23.2	0.4	35.0

Leaf water content refers to the observation day. Air temperature and relative humidity are monthly means; precipitation is the total for the corresponding month.

The differences between the May observations in the two years coincided with changes in meteorological conditions. In Karmana, mean May temperature rose from 21.4 °C in 2024 to 26.0 °C in 2025, while precipitation decreased from 50.5 to 0.7 mm and relative humidity from 46.4% to 29.8%. Leaf water content was 1.9 percentage points lower in the second May observation. In Tashkent, May temperature increased from 20.8 to 25.4 °C, precipitation declined from 85.1 to 14 mm, and relative humidity decreased from 56% to 37%; leaf water content differed by 0.6 percentage points.

July was the warmest month at both sites in 2025, with mean temperatures of 31.9 °C in Karmana and 31.2 °C in Tashkent. The lowest mean leaf water content on an observation day occurred later, however: in August in Karmana and in September in Tashkent.

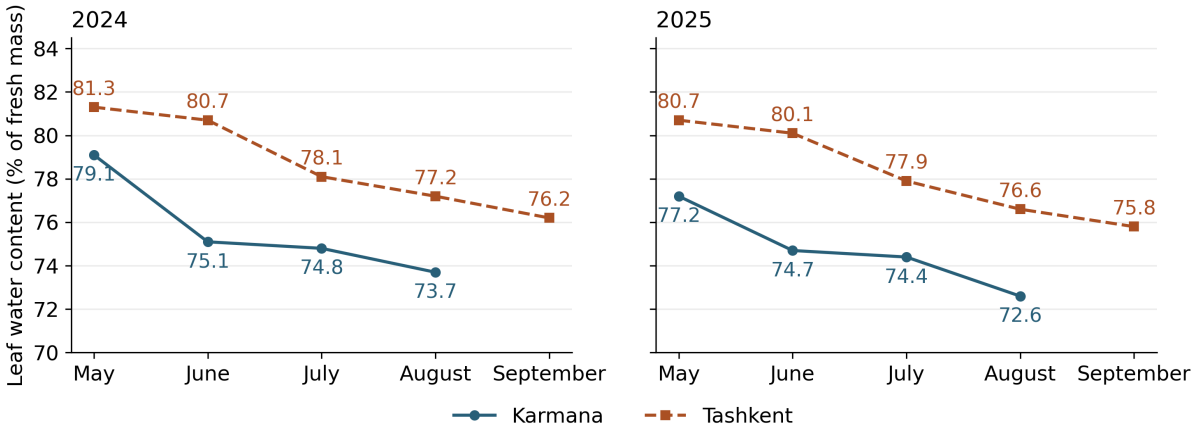


Figure 1. Seasonal variation in leaf water content. Points represent the mean for the observation day in each month; lines connect successive observations.

In Karmana, the highest water content was recorded at 08:00 on every observation date (Figure 2). In 2024, the minimum occurred at 14:00 in May and July and at 12:00 in June and August. In 2025, the May minimum occurred at 16:00, while the minima in the other three months occurred at 14:00. Across all time-specific observations in Karmana, the highest value was 82.2 ± 0.24% in May 2024 and the lowest was 70.9 ± 0.41% at 14:00 in August 2025.

The largest diurnal range in Karmana occurred in May 2025, when water content fell from 80.8 ± 0.36% at 08:00 to 73.4 ± 0.86% at 16:00, a difference of 7.4 percentage points. By 20:00, it had risen to 80.2 ± 0.39% but remained 0.6 percentage points below the morning value. Evening values also remained below morning values during the other observations in Karmana. The shortfall ranged from 1.6 to 2.6 percentage points in 2024 and from 0.6 to 1.4 percentage points in 2025.

In Tashkent, the minimum occurred at 12:00 on all observation dates in 2024. In 2025, it occurred at 14:00 from May to August and at 16:00 in September. Evening water content in May and June differed from the pattern in Karmana. In May 2024, the values at 08:00 and 20:00 were identical at 83.1%; in June, the evening value exceeded the morning value by 0.3 percentage points. In May and June 2025, evening values were higher by 1.8 and 1.5 percentage points, respectively. From July onwards, evening values in Tashkent also remained below morning values.

Figure 2. Diurnal profiles of leaf water content in Karmana and Tashkent. Each line shows the seven time-specific values for the corresponding date in Table 1. All panels use the same vertical scale; uncertainty intervals are not shown.

Comparisons at matching observation times within each month and year from May to August showed higher leaf water content in Tashkent in every case (Table 2). The magnitude of the difference nevertheless varied with month and time of day. During the June observations, differences between sites ranged from 4.6 to 6.5 percentage points in 2024 and from 4.4 to 6.7 percentage points in 2025. The largest time-specific difference in each year occurred in June at 20:00. At that time, water content in 2024 was 75.8% in Karmana and 82.3% in Tashkent; the corresponding values in 2025 were 75.5% and 82.2%.

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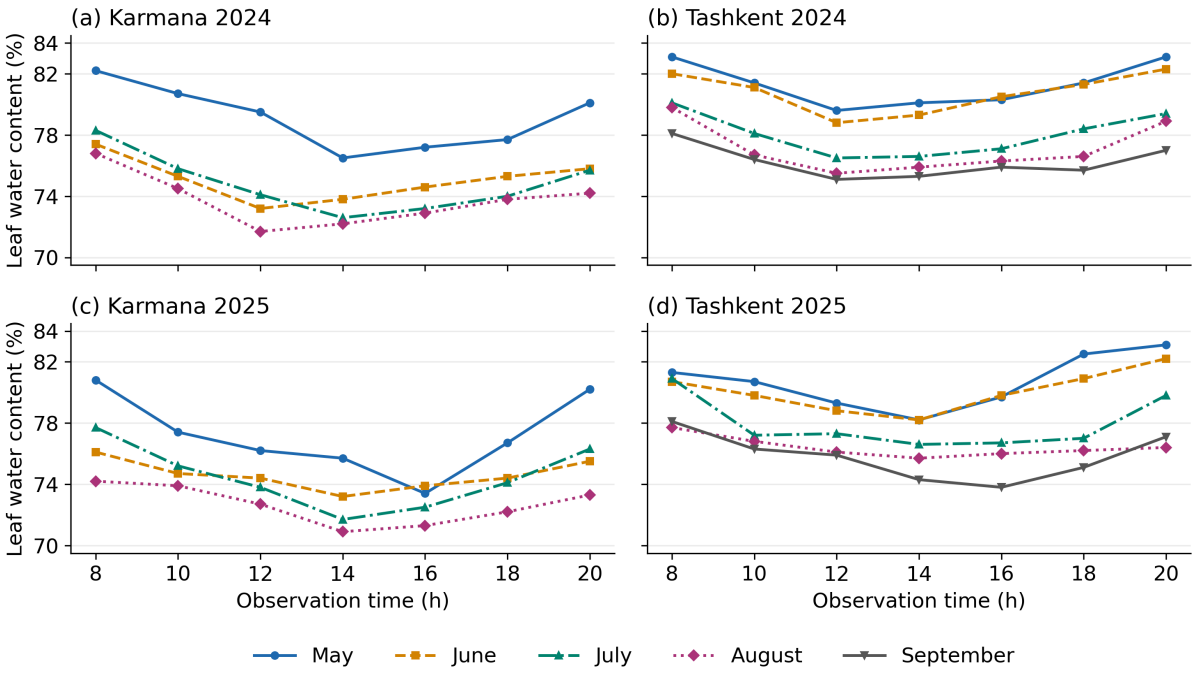


Table 2. Leaf water content differences between sites by month and observation time, in percentage points

Year	Month	08:00	10:00	12:00	14:00	16:00	18:00	20:00
2024	May	0.9	0.7	0.1	3.6	3.1	3.7	3.0
2024	June	4.6	5.8	5.6	5.5	5.9	6.0	6.5
2024	July	1.8	2.3	2.4	4.0	3.9	4.4	3.7
2024	August	3.0	2.2	3.8	3.7	3.4	2.8	4.7
2025	May	0.5	3.3	3.1	2.5	6.3	5.8	2.9
2025	June	4.6	5.1	4.4	5.0	5.9	6.5	6.7
2025	July	3.2	2.0	3.5	4.9	4.2	2.9	3.5
2025	August	3.5	2.9	3.4	4.8	4.7	4.0	3.1

Values are Tashkent − Karmana in percentage points. Rows compare the same month and year; columns show observation times. Sampling dates are given in Table 1.

Differences between sites also varied during the day. For example, in May 2025, the difference was 0.5 percentage points at 08:00 but reached 6.3 percentage points at 16:00. In May 2024, the difference at 12:00 was only 0.1 percentage points. Examining time-specific differences separately for each month identified when the contrast between sites was most pronounced.

Table 3. Diurnal ranges in leaf water content by month and site

Year	Month	Diurnal range in Karmana (pp)	Diurnal range in Tashkent (pp)	Difference in diurnal range (Karmana − Tashkent) (pp)
2024	May	5.7	3.5	2.2
2024	June	4.2	3.5	0.7
2024	July	5.7	3.6	2.1
2024	August	5.1	4.3	0.8
2025	May	7.4	4.9	2.5

2025	June	2.9	4.0	-1.1
2025	July	6.0	4.3	1.7
2025	August	3.3	2.0	1.3

pp, percentage points. The diurnal range is the difference between the highest and lowest values recorded between 08:00 and 20:00 on each observation date.

Month-by-month comparisons showed that the diurnal range was greater in Karmana during all May–August observations in 2024 (Table 3). The same pattern occurred in May, July, and August 2025. In June, however, the range was 2.9 percentage points in Karmana and 4.0 in Tashkent, making the Tashkent range 1.1 percentage points greater. Thus, the direction of the difference between sites in water content was not consistently reflected in the diurnal range across all months. Because sampling dates differed between sites, these results were interpreted as descriptive comparisons of observations from the corresponding months.

Conclusion. Leaf water content in *V. umbellata* declined over the season in Karmana and Tashkent during the 2024–2025 observations. Values compared at matching times within each month from May to August were consistently higher in Tashkent. The largest time-specific differences between sites occurred at 20:00 during the June observations, reaching 6.5 percentage points in 2024 and 6.7 percentage points in 2025. The diurnal range was greater in Karmana during all May–August observations in 2024 and in May, July, and August 2025, whereas it was greater in Tashkent in June 2025. Evening values remained below morning values on every observation date in Karmana. In Tashkent, evening values equalled or exceeded morning values during the May and June observations. These findings show that evaluating leaf water content within individual months and observation times, together with daytime minima and evening recovery, provides a more detailed description of physiological differences between sites. The results offer a comparative basis for planning further controlled water-deficit experiments and introduction trials.

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