Relationship Between Leaf Area Index and Lysimetric Crop Coefficients of Pigeonpea (Cajanus Cajan L.) under local climatic conditions of Vidarbha

ABSTRACT

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| --- |
| **The experiment was conducted to determine the crop coefficients and leaf area index of pigeonpea, using a digital weighing type lysimeters. The research was conducted under Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola for kharif season of year 2024. The meteorological data was collected from the weather station installed at the experimental site to determine the reference crop evapotranspiration (ETo) using Penman-Montieth method. The crop evapotranspiration (ETc) was measured using water balance method by using weighing type lysimeters. Crop coefficients were determined for pigeonpea as ratio of daily ETc and ETo. Simultaneously, leaf area index was measured monthly using a leaf area meter. The study reveals that Kc values and LAI increased with crop development, reaching maximum during the mid-season stage and showed a strong positive correlation with each other with an R-square value of 0.78. The results highlight the importance of stage-specific Kc and LAI values for accurate irrigation scheduling and for improving water use efficiency in pigeonpea cultivation.** |

*Keywords: Pigeonpea, Crop Coefficients, Leaf Area Index, Lysimeter*.

1. INTRODUCTION

Pigeonpea (*Cajanus cajan*), a grain legume widely cultivated in tropical and subtropical regions, holds significant agronomic and economic importance, particularly in countries like India, where it is a major source of dietary protein and plays a central role in sustainable farming systems. Its adaptability to rainfed conditions, deep root system and nitrogen-fixing ability make pigeonpea an ideal crop for enhancing soil fertility and ensuring food security in marginal environments. As agriculture increasingly faces the twin challenges of water scarcity and climate variability, optimizing water use in crops like pigeonpea has become a crucial research priority.

Accurate estimation of crop water requirements is fundamental to achieving efficient irrigation management and maximizing water productivity. In this context, the crop coefficient (Kc) serves as a critical parameter in quantifying crop evapotranspiration (ETc) through the FAO-56 approach, which relates ETc to reference evapotranspiration (ETo). While the FAO provides generalized Kc values for many crops (Allen et.al., 1994), these are often inadequate for site-specific conditions, especially in regions with varying climatic, soil and crop management practices. Thus, the experimental determination of Kc under local agro-climatic conditions becomes essential.

In parallel, the Leaf Area Index (LAI) has emerged as a pivotal canopy parameter that directly influences crop water use. LAI, defined as the total leaf area per unit ground surface area, reflects the plant's capacity for light interception, photosynthesis, and transpiration. For pigeonpea, understanding the variation of LAI during the growth stages provides valuable insights into the physiological status of the crop and its potential water demand. Theoretically, Kc values should correlate closely with LAI, especially during the crop development and mid-season stages when canopy cover and transpiration are at their peak (Allen et.al., 1994). Establishing a quantitative relationship between LAI and Kc could facilitate the prediction of crop water use using simple LAI measurements, potentially reducing the reliance on resource-intensive lysimeter experiments. This is particularly valuable for regions lacking access to advanced infrastructure for direct evapotranspiration measurement.

This study aims to investigate the relationship between Leaf Area Index and crop coefficients in pigeonpea by integrating direct measurements from weighing-type lysimeters and leaf area meters. The primary objective includes finding the relationship between LAI and Kc values. The findings of this research are expected to improve the accuracy of Kc estimation for pigeonpea, support efficient irrigation planning and contribute to a deeper understanding of crop water use under field conditions.

2. material and methods

**2.1 Location of the experimental site**

The field experiment was carried out under Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola for kharif season of year 2024. Two digital lysimeters with soil type of heavy black soil were used to determine the crop coefficients. The study area is situated in Akola district in Vidarbha region of Maharashtra. Akola is situated at 20.7° N latitude and 77.0° E longitude. The climate of this district is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season.

**2.2 Data collection**

To carry out the study, daily meteorological data like minimum and maximum temperature, solar radiation or sunshine hours, wind speed and relative humidity was collected from the Automatic Weather Station installed at the experimental site.

**2.3 Plant Growth Observations**

The plant growth observations like height of plant, number of leaves, flowers, branches, pods and leaf area were recorded at 30, 60, 90,120,150 days after sowing (DAS) and at the time of harvest of pigeonpea crop.

**2.4 Calculation of crop coefficient (Kc)**

Crop coefficient values calculated as the ratio of crop evapotranspiration obtained from water balance expression to that of reference crop evapotranspiration obtained from FAO Penman Monteith equation. The calculation of the crop coefficient (Kc) is based on the following equation:

$$Kc = \frac{ETc}{ETo}$$

where,

Kc is crop coefficient

ETc is the actual crop evapotranspiration (mm day-1)

ETo is the reference crop evapotranspiration (mm day-1)

**2.5 Leaf area index (LAI)**

Leaf area was measured at 30, 60, 90, 120, 150 DAS and at the time of harvest. Leaf samples of different sizes from bottom to top of the branch were taken to measure average leaf area. The total leaf area was calculated by multiplying average leaf area by average number of leaves per plant. The leaf area index was determined using following formula,

$$LAI=\frac{Total Leaf Area}{Ground Area}$$

1. results and discussion

**3.1 Growth and Yield Observations**

Table 1 shows the average plant growth parameters recorded during the experiment.

**Table 1. Average plant growth parameters of pigeonpea crop**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameters | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | At Harvest |
| Height (cm) | 28.90 | 76.13 | 125.00 | 170.83 | 204.23 | 207.35 |
| Branches | 0.00 | 7.70 | 17.45 | 22.98 | 25.53 | 24.90 |
| Leaves | 22.33 | 162.45 | 183.40 | 375.98 | 525.00 | 544.75 |
| Flowers | 0.00 | 0.00 | 0.00 | 15.05 | 44.55 | 27.35 |
| Pods | 0.00 | 0.00 | 0.00 | 0.00 | 158.90 | 157.50 |
| LAI | 0.05 | 0.48 | 0.61 | 1.03 | 1.10 | 0.66 |
| Yield | 24.21 q/ha |

**3.3 Comparison between Kc and LAI of pigeonpea crop**

 Table 2 shows the average leaf area across all sizes for each growth stage. Total leaf area was determined by multiplying the average leaf area by average number of leaves of the plant for the respective stage.

**Table 2 Leaf Area (cm2) of Pigeonpea**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| DAS | Big | Medium | Small | Average |
| 30 | 8.84 | 5.20 | 3.23 | 5.76 |
| 60 | 15.92 | 5.41 | 2.57 | 7.97 |
| 90 | 15.19 | 7.56 | 4.00 | 8.92 |
| 120 | 12.47 | 5.86 | 3.78 | 7.37 |
| 150 | 8.70 | 5.20 | 3.04 | 5.65 |
| 182 | 9.29 | 6.53 | 5.20 | 7.01 |

The leaf area index measured using leaf area meter and crop coefficient values calculated using ratio of ETc by ETo at respective growth stage, as derived from the water balance equation are given below in the Table.3.

**Table 3 Leaf Area Index of Pigeonpea**

|  |  |  |
| --- | --- | --- |
| **DAS** | **Average Kc** | **Average LAI** |
| 0-30 | 0.62 | 0.05 |
| 31-60 | 0.84 | 0.48 |
| 61-90 | 1.06 | 0.61 |
| 91-120 | 1.16 | 1.03 |
| 121-150 | 1.08 | 1.10 |
| 151-182 | 0.81 | 0.66 |

From Table 3, it was observed that the LAI was lowest during initial growth stage and gradually increased, reaching its maximum value of 1.10 during mid-season stage, which represents the peak vegetative growth period. Following this stage, the LAI declined steadily toward crop maturity during late season stage

The data indicates a consistent increase in the crop coefficient (Kc) during the early to mid-growth stages, corresponding to an increase in LAI and crop evapotranspiration. The highest crop coefficient value was observed during the mid-season stage about 1.16, meanwhile the LAI was found to be 1.03.

**Fig. 1. Comparison between Kc and LAI**

**Fig. 2. Correlation Between Kc and LAI for Pigeonpea Crop**

The study of the leaf area index (LAI) and crop coefficient (Kc) in pigeonpea indicates a strong correlation between leaf growth and crop water use. LAI increases from 0.05 at 30 days after sowing (DAS) to a peak of 1.10 at 150 DAS. Kc rises from 0.67 at 30 days after sowing to 1.16 at 120 days after sowing. This suggests increased evapotranspiration and water needs during the active growth stage. After 150 DAS LAI and after 120 DAS Kc decline, indicating reduced water demand as the crop matures.

Figures 1 and 2 illustrates this pattern, showing a decrease in Kc and LAI from mid-season to later stages. A statistical analysis of Kc and LAI data throughout the growing season highlights a clear relationship between canopy growth and water use. The equation derived from this comparison is:

Kc = 0.4733 \* LAI + 0.6163

with an R² value of 0.78, confirming strong and significant correlation between Kc and LAI.

1. Conclusion

The study monitored the Leaf Area Index (LAI) to assess the development of the crop canopy and its effect on water usage. The findings indicated a steady rise in the LAI from 0.05 at 30 days after sowing (DAS) to a peak of 1.10 at 150 DAS, corresponding to the Kc recorded. A strong positive correlation was observed between Kc and LAI, with an R-squared value of 0.78. This correlation underscores the importance of leaf area expansion in determining the crop water requirements, providing crucial insights for optimizing irrigation schedules.

Disclaimer (Artificial intelligence)

Authors hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and no text-to-image generators have been used during the writing or editing of this manuscript.

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