Research Article
Open Access

Journal of Life Science and Applied Research (JLSAR)
E-ISSN: 2959-8036

OPTIMAL PLANT SPACING EFFECTS ON PHENOLOGY AND GROWTH METRICS OF CORN (Zea Mays L.)

A. **S. A. Dizayee***

University of Salahaddin - College of Agricultural Engineering Sciences.
* **Corresponding author:** Aryan Suad Ahmad Dizayee, Department of Field Crops and Medicinal Plants, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Kurdistan Region, Iraq. Email: aryan.ahmed@su.edu.krd

Article Info:

Received: Jul. 14, 2023
Revised: Aug. 17, 2023
Accepted: Sep. 06, 2023
Published: Dec. 31, 2023

DOI:
doi.org/10.59807/jlsar.v4i2.87

How to Cite:
A. S. A. . Dizayee, "OPTIMAL PLANT SPACING EFFECTS ON PHENOLOGY AND GROWTH METRICS OF CORN (Zea mays L.)", JLSAR, vol. 4, no. 2, pp. 68–74, Dec. 2023.

Available From:
https://www.jlsar.com/index.php/journal/article/view/87

Abstract: This experiment aimed to investigate the influence of different inter and intra-row spacing on phenology and plant growth metrics of corn (Zea mays L.). The experiment was conducted under field conditions at Qushtapa zones of northern Iraq in the main cropping season of 2020-2021. Three different inter and intra-row spacing treatments (45, 60 and 75 cm) and (10 and 15 cm) respectively, were applied in a Randomized Complete Block Design (RCBD) with three replications, the total plots were six, each plot on the field was measured 2m width by 3m length (6 m^2). The study assessed various plant growth parameters. The results found that inter-row spacing significantly influenced plant height and leaf area index (LAI) at inter-row spacing (45cm). In contrast, leaf area (LA) and leaf area ratio (LAR) significantly had the higher mean value at (75cm) inter-row spacing. Additionally, interaction treatments of inter-row spacing×intra-row spacing recorded highest mean values of plant height at treatment (inter 45cm × intra 15cm), while leaf area (LA) was higher mean value at interaction treatments of (inter 75cm × intra 15cm). As for leaf area index (LAI) this trait showed higher mean value at treatment interaction of (inter 45cm × intra 10cm), leaf area ratio (LAR) and leaf area duration (LAD) postulate higher mean at interaction (inter 75cm × intra 10cm) and (inter 60cm × intra 15cm) respectively. This study explores key growth indicators to comprehensively analyze the growth and productivity of corn plants, shedding light on their canopy development dynamics and overall performance.

Keywords: Corn, Plant Growth Metrics, Inter and Intra-Row Spacing's.

1. Introduction

Among cereals corn or maize (Zea mays L.) is one of the most important cereal in the world [1]. It is grown extensively with equal success in temperate, sub-tropical and tropical regions of the world, in addition, to meeting the food requirement of human and livestock, the yield potential of a crop is mainly dependent upon its genetic make-up as well as the environment in which it is grown [2]. The combination of plant height, leaf area, leaf area index, leaf area ratio and leaf area duration could collectively have referred to as "plant growth metrics" these parameters provide insights into the size, structure and productivity of a plants canopy during its growth cycle [3], [4]. Inter and intra-row spacing are critical factors in crop management that significantly influence the phenology and plant growth metrics of corn (Zea mays L.).

These spacing parameters determine the spatial arrangement of plants within a field, affecting plant architecture, light interception, competition for resources, and ultimately, crop yield [5]. Understanding the effects of inter and intra-row spacing on corn growth is essential for optimizing plant performance and achieving maximum productivity [6]. Inter row spacing refers to the distance between adjacent rows of corn crops, while intra-row spacing represents the distance between individual plants within a row, both spacing factors play vital roles in shaping the plant growth and development of sweet corn [7], [8]. Proper inter-row spacing is crucial for ensuring efficient use of available land and resources. Wider inter row spacing provides more space between rows, allowing individual corn crops to develop a broader canopy and expand horizontally [9].

This promotes optimal light interception, as each plant has access to sufficient sunlight, resulting in increased photosynthetic activity and biomass production [6]. On the other hand, narrower inter-row spacing can lead to higher planting densities, maximizing land utilization and potentially increasing overall crop yield [10]. However, closer spacing may result in increased competition among plants for light, nutrients, and water, potentially limiting individual plant growth and overall productivity [11]. Intra-row spacing, the distance between plants within a row, also affects corn growth. Wider intra-row spacing provides more room for individual plants to grow, allowing for larger leaf area and root development [12]. This can contribute to enhanced light interception, nutrient uptake, and overall plant performance [13].

This study aims to investigate the effects of different inter and intra-row spacing configurations on the vegetative growth and canopy development parameters of corn crop, by examining some parameters such as plant height, leaf area, leaf area index, leaf area ratio and leaf area duration, it can gain insights into the optimal spacing strategies for increasing sweet corn productivity.

2. Materials and Methods

Experimental Design: The experiment was designed according to a Randomized Complete Block Design (RCBD) with three replications at Qushtapa zones of northern Iraq in the main cropping season of 2020-2021. Treatments were three inter and two intra-row spacing's namely; Narrow (45cm×10cm), (45cm×15cm), Medium (60cm×10cm), (60cm×15cm) and Wide (75cm×10cm), (75cm×15cm), replicated three times making a total of six plots. The total plot size was 2.0 m × 3.0 m = 6.0 m^2 and accommodating 7, 5 and 4 rows for all 45 cm, 60 cm and 75 cm inter-rows, respectively. Number of plants 20 and 13 plant per row for all intra-row spacing 10 and 15 cm respectively.

Planting and Crop Management: Maize hybrid seeds (CASH F1) were sown uniformly according to the recommended plant density in the designated plots following standard agronomic practices. Adequate irrigation and pest control measures were implemented throughout the crop growth period. Table 1 shows analyze some physical and chemical properties for soil samples were taken at a depth 0 - 30 cm.

Table 1. Some physical and chemical properties for the soil of the experimental site.

Soil Properties	Sand%	Silt%	Clay%	Soil texture	Ec dSm^{-1}	pH	O.M (%)	N%	P (ppm)	K (ppm)
	16.2	43.1	40.7	Silty Clay	0.3	7.74	0.95	0.12	9.6	150

Data Collection: Some plant growth metrics and phenology traits including, plant height (cm), leaf area (LA), leaf area index (LAI), leaf area ratio (LAR) and leaf area duration (LAD) were recorded during the crop growth cycle at regular time intervals.

Leaf Area Ratio (LAR): Leaf area ratio reflects the leafiness of the plant or amount of leaf area formed per unit of biomass and expressed in cm^{-2} g^{-1} of plant dry weight [14].

LAR = Leaf area per plant / Plant dry weight Leaf Area Duration (LAD): To correlate dry matter yield with leaf area index (LAI) with time, called as Leaf Area Duration. LAD takes into account, both the duration and extent of photosynthetic tissue of the crop canopy [15].

$LAD = LAI_1 + LAI_2 / 2 \times (t_2 - t_1)$

LAI_1 = LAI at the first stage.

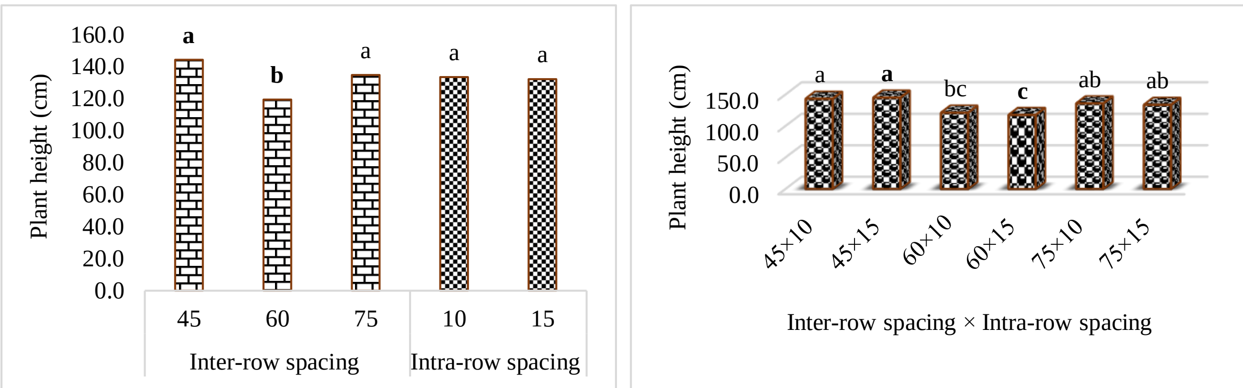
LAI_2 = LAI at the second stage, $(t_2 - t_1)$ = Time interval in day.

Statistical Analysis: Data collected and then subjected to analysis of variance (ANOVA) by using [16]. Significant differences between means were determined using [17] at a p-value of 0.05.

3. Results and Discussion

Plant growth metrics of (a) inter and intra-row spacing and (b) interactions of (inter-row spacing × intra-row spacing) of (*Zea mays* L.):

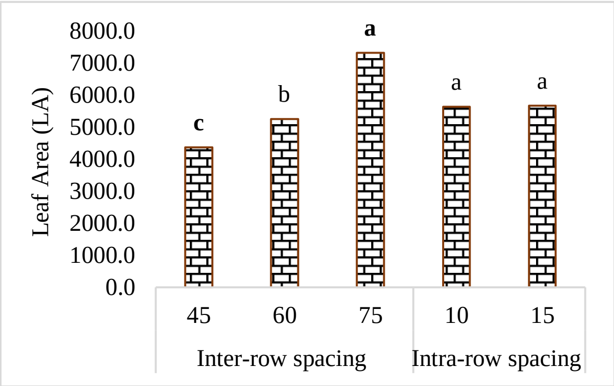
Plant height (cm): Plant height is an important agronomic trait in corn (*Zea mays* L.) that can influence crop performance and potential yield. The results showed significant variation of plant height across different inter-row spacing and interactions of inter and intra-row spacing. The highest and lowest plant height was occurred at inter-row spacing of 45cm and 60cm their mean values 144.3 and 119.5 cm respectively (Figure 1.a). In contrast interactions of inter-row spacing × intra-row spacing (Figure 1.b) showed that higher plant height was obtained from interaction narrow inter and intra-row spacing 45cm×15cm, while the lower plant height obtained from interaction medium inter and intra-row spacing 60cm×15cm with their mean values 145.2 and 117.7 cm respectively. The increase of plant height at narrower interactions of inter-row spacing × intra-row spacing might be due to comparatively lower solar that intercepted through crop canopy at narrower spacing, high plant density [18].

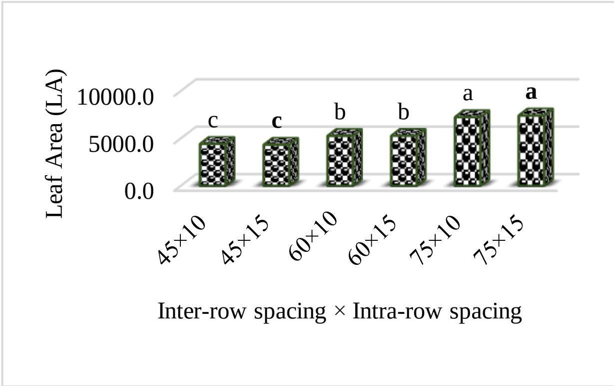


(a) **(b)**

Figure 1. Effect (a) inter and intra-row spacing and (b) interactions of (inter-row spacing×intra-row spacing) on plant height (cm) of (*Zea mays* L.).

Leaf Area (LA): Main effects of inter-row spacing and interaction effects of (inter-row spacing×intra-row spacing) on leaf area were highly significant (Figure 2.a.b). As for inter-row spacing the higher and lower leaf area was recorded at 75cm and 45cm their mean values 7330.0 and 4371.7 cm^2 respectively. In addition, the highest leaf area per plant 7414.4 cm^2 was recorded at interactions of inter-row spacing×intra-row spacing of 75cm×15cm, while the lowest 4327.4 cm^2 was at 45cm×15cm. In general leaf area per plant was increased with decreasing inter-row spacing from 45 cm to 75 cm. This result was in line with [19] where postulate that maximum leaf area of hybrid maize was at under wider row spacing 75 cm than in narrower 45 cm spacing.

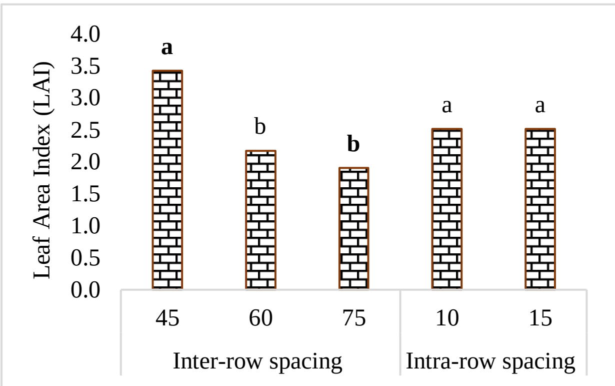


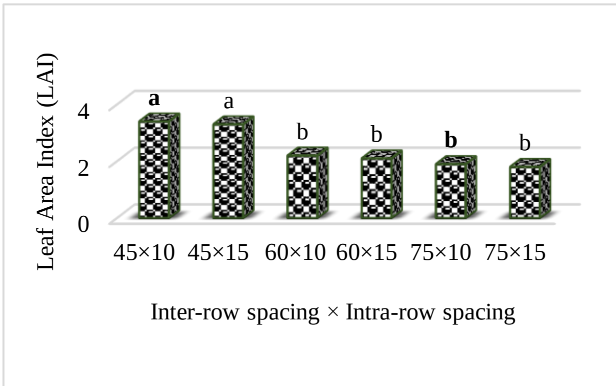


(a) (b)

Figure 2. Effect (a) inter and intra-row spacing and (b) interactions of (inter-row spacing×intra-row spacing) on leaf area (LA) of hybrid maize.

Leaf Area Index (LAI): Leaf area index was significantly affected by inter-row spacing and interactions of (inter-row spacing×intra-row spacing). Therefore, a combined analysis of variance depicted that the highest mean value of leaf area index 3.4 was recorded at 45cm inter-row spacing and the lowest mean value 1.9 was recorded at 75cm inter-row spacing (Figure 3.a). Additionally, the maximum leaf area index 3.4 was obtained at interaction closer inter 45cm×10cm intra-row spacing, whereas the minimum leaf area index 1.9 was attained at wider inter 75cm×10cm intra-row spacing (Figure 3.b). The possible reason for highest leaf area index at narrower inter-row spacing×intra-row spacing maybe due to produce more number of leaves and number of plants per unit area [20].





(a) (b)

Figure 3. Effect (a) inter and intra-row spacing and (b) interactions of (inter-row spacing×intra-row spacing) on leaf area index (LAI) of (*Zea mays* L.).

Leaf Area Ratio (LAR): Leaf area ratio (LAR) is a growth index that quantifies the leaf area per unit of plant biomass. LAR was measured to postulate the interaction impact of inter-row spacing and interactions of (inter-row spacing×intra-row spacing) on this important growth index. The mean LAR obtained from this study showed a significant difference between the different inter-row spacing the higher and lower mean value 175.87 and 108.06 cm^{-2} g^{-1} of this traits was recorded at 75cm and 45cm inter-row spacing respectively (Figure 4.a). In addition, interaction treatments (figure 4.b) showed that the higher mean LAR was found to be 189.13 cm^{-2} g^{-1} at interaction (inter 75cm×10cm intra-row spacing), in contrast lower mean LAR was found to be 91.33 cm^{-2} g^{-1} at interaction (inter 45cm×15cm intra-row spacing). These findings are in line with the previous research on the impact of spacing on LAR in sweet corn [21].

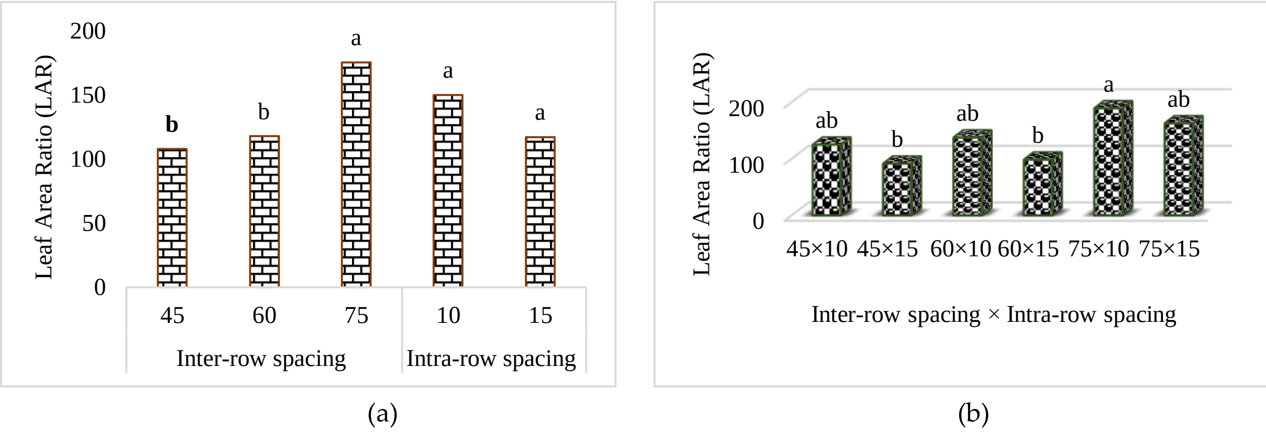


Figure 4. Effect (a) inter and intra-row spacing and (b) interactions of (inter-row spacing×intra-row spacing) on leaf area ratio (LAR) of (*Zea mays* L.).

Phenology traits of (a) inter and intra-row spacing and (b) interactions of (inter-row spacing × intra-row spacing) of (*Zea mays* L.):

Leaf Area Duration (LAD): Leaf area duration (LAD) is a term used to describe the cumulative period during which a plant maintains its leaf area over a given period of time. It is a crucial parameter in understanding the photosynthetic capacity and carbon assimilation of plants throughout their growth cycle. Inter-row spacing and interaction between inter and intra-row spacing gave significantly positive effects on leaf area duration. Inter-row spacing at 60cm and 45cm showed maximum and minimum mean values 42.85 and 27.35 day (Figure 5.a). Additionally, leaf area duration possessed higher and lower mean value at interaction (inter 60cm×15cm intra-row spacing) and narrower interaction (inter 45cm×10cm intra-row spacing) their mean values 44.76 and 27.10 day respectively (Figure 5.b) a longer leaf area duration generally indicates more extended period of active photosynthesis, allowing the plant to capture solar energy and convert it into chemical energy for growth and development [22].

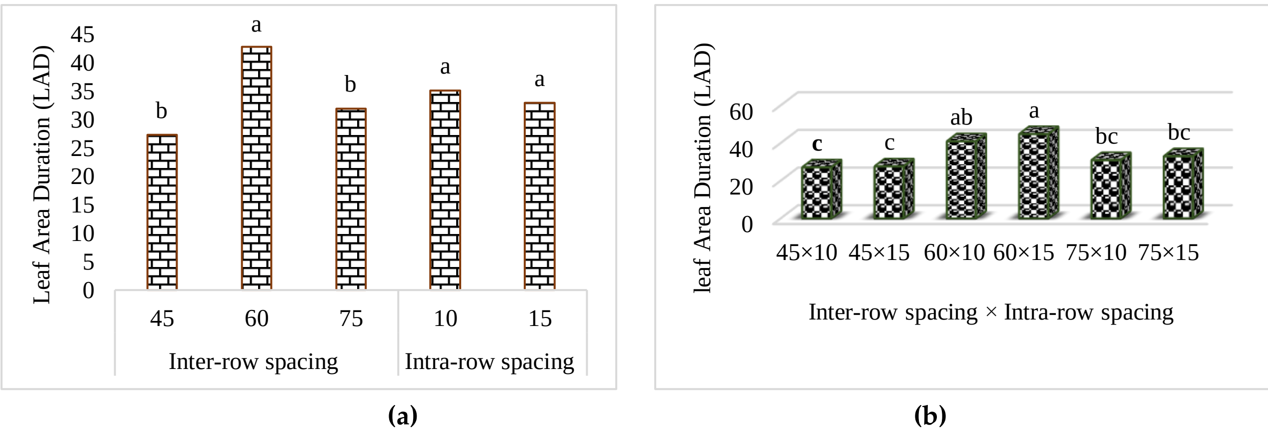


Figure 5. Effect (a) inter and intra-row spacing and (b) interactions of (inter-row spacing×intra-row spacing) on leaf area duration (LAD) of (*Zea mays* L.).

4. Conclusion

The findings of this study will contribute to our understanding of how inter and intra-row spacing influence sweet corn growth and provide valuable information for farmers to make informed decisions regarding spacing management in their sweet corn crops. Further research is needed to explore the specific interactions between spacing and environmental factors to develop precise recommendations for different production systems.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

A. S. A. Dizayee; methodology, writing—original draft preparation, A. S. A. Dizayee; writing—review and editing, A. S. A. Dizayee; paraphrasing. The author has read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted in accordance with the protocol authorized by the University of Salahaddin - College of Agricultural Engineering Sciences.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The author declare no conflict of interest.

Acknowledgments:

The authors are greatly indebted to the University of Salahaddin - College of Agricultural Engineering Sciences.

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