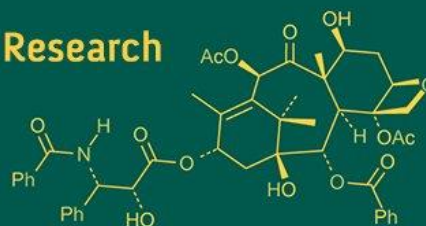


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(8): 2582-2585

www.biochemjournal.com

Received: 24-06-2026

Accepted: 27-07-2026

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Dynamics of maize dry matter accumulation: weather variability, population density, and genotypic impacts

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8Sac.9790>

Abstract

Dry matter accumulation of a plant serves as an essential indicator of crop growth and resource use efficiency. A field experiment was conducted during the 2021 and 2023 seasons to examine the impacts of weather variability, population density, and genotypes on the dry matter accumulation of maize. The results revealed that maize dry matter accumulation per plant increased progressively from 20 days after sowing (DAS) until harvest (8.24 to 183.80 g), with the highest rate of dry matter accumulation occurring between 40 and 60 DAS. Normal sowing, S₁ (2021: 211, 2023: 208g) and 10 days after normal sowing time, S₂ significantly optimized dry matter per plant (2021:206.55 2023:195.63g) by exploiting favourable weather regimes. Conversely, increasing population density from 83,333 plants ha⁻¹ (P₃) to 133,333 plants ha⁻¹ (P₁) significantly reduced individual plant dry matter accumulation due to severe inter-plant competition (2021: 186.79 to 181.75 and 2023: 174.72 to 168.36 g). Among the cultivars, the late-maturing genotype BIO-9682 (G₃) consistently excelled in dry matter accumulation from 40 DAS onwards (2021: 125.05 to 192.11 g and 2023: 34.16 to 178.61g). The interaction between normal sowing and the late-maturing genotype (S₁G₃) yielded the maximum dry matter per plant (212.82 g) at harvest during 2023.

Keywords: Maize, dry matter accumulation, population density and genotypes

Introduction

Maize as a major global crop for food, feed, and industry, maximizing its productivity requires a deep understanding of its physiological growth. Dry matter accumulation per plant serves as the most accurate index for evaluating true crop development and metabolic efficiency. Individual plant dry matter build-up is highly sensitive to management choices and seasonal environmental factors. Specifically, sowing dates determine the microclimates and weather variations encountered by the crop during its critical life stages. Planting maize during normal timelines or with minimal delay ensures optimal weather windows and longer growth periods, allowing the plants to maximize both vegetative and reproductive dry matter accumulation. Conversely, delayed sowings drastically shorten the active vegetative growth phase and push reproductive development into suboptimal, restrictive environmental conditions (Sab *et al.*, 2020; Tripathi *et al.*, 2025) [6, 9]. Concurrently, plant population density shapes the spatial arrangement of the field canopy, directly altering how effectively individual plants capture solar radiation, soil moisture, and essential soil nutrients. While high-density planting patterns can optimize net crop yields per unit area, they simultaneously trigger aggressive inter-plant competition that restricts single-plant development and reduces individual photo-assimilate accumulation (Rajesh Babu *et al.*, 2019; Sharanabasappa and Basavanneppa, 2019) [5, 7]. Lower planting densities minimize this inter-plant friction, granting each plant a larger share of vital growth components. This competition is further complicated by the unique genetic architecture of different maize hybrids, which exhibit varying resource conversion efficiencies and phenophase durations (Prasad *et al.*, 2017; Jat *et al.*, 2019) [2, 4]. Long-duration cultivars typically possess a superior baseline capacity to transform captured resources into standing dry matter compared to early-maturing variations. To address these challenges, a field study was conducted across the 2021 and 2023 growing seasons to track periodic maize dry matter accumulation from early growth through final harvest.

By evaluating a combined matrix of four sowing dates, plant population densities, and genotypes of early, mid-late, and late-maturing period, this research aims to identify optimal management setups. Ultimately, the findings seek to align spatial layouts with seasonal weather patterns to maximize individual plant growth and dry matter production efficiency.

Dry matter accumulation per plant

Dry matter accumulation plant⁻¹ is a key measure of plant growth, probably the best index of growth put forth by the crop. It shows the true growth and dry accumulation build-up of the crop over time. The data pertaining to total dry matter accumulation plant⁻¹ (g) as affected periodically by various treatments are presented in Table 1 and graphically depicted in Fig. 1(a), 1(b) and 1(c). Progressive increase in dry matter accumulation plant⁻¹ (g) was noticed with advancement of crop growth. The mean dry matter accumulation plant⁻¹ was found to increase from 20 DAS to at harvest, from 8.24 to 183.80 g during 2021 and from 8.12 to 170.49 g during 2023 season. The rate of increase was maximum between 40 to 60 DAS followed by 60 to 80 DAS and subsequently by harvest stage there was declined compared to the preceding phase.

Weather variability

During both the years at 20 DAS, normal sowing time (S₁) along with delayed sowings by 10 days (S₂) and 20 days (S₃) were statistically at par among themselves and superior over 30 days most delayed sowing (S₄). At 40 DAS in 2021, S₂ being marginally more was however at par with S₁ and both were significantly superior over S₃ and S₄. At subsequent stages from 60 DAS to at harvest in 2021 and from 40 DAS to harvest stage in 2023, normal sowing time S₁ recorded significantly higher dry matter weight plant⁻¹ being statistically at par with S₂, except at 40 DAS in 2023. 10 days after normal sowing (S₂) also recorded significantly higher dry matter weight plant⁻¹ than further delayed sowings S₃ and S₄. The most delayed sowing S₄ accumulated the lowest dry matter weight plant⁻¹ at all the observed stages showing statistical equivalence with S₃ only at 20 DAS in 2023.

The observed trend could be attributed to the fact that normal sowing (S₁) and a slight 10-day delay (S₂) might have captured more optimal weather regimes and longer growing periods that allowed the plants to gain more vegetative and reproductive growth and hence more dry matter accumulation. Delayed sowings (S₃ and S₄) likely shortened the active vegetative phase and shifted the reproductive phase into suboptimal environmental constraints, restricting dry matter production. This corroborates the findings of Leela Rani *et al.* (2013) [3], Jadhav *et al.* (2015) [1], Vikhe (2016) [10], Swetha Sree *et al.* (2018) [8], Sab *et al.* (2020) [6] and Tripathi *et al.* (2025) [9].

Population density

Dry matter weight plant⁻¹ at the earliest stage (20 DAS) did not differ significantly due to varying population densities during both the years. From 40 DAS onwards till the harvest stage in both years, maize plants under normal planting density P₃: 83333 plants ha⁻¹ (60 cm x 20 cm) accumulated significantly higher dry matter plant⁻¹ than both high planting densities of P₂: 111111 plants ha⁻¹ (60 cm x 15 cm) and P₁: 133333 plants ha⁻¹ (paired row planting at 60-90 x

10 cm). However, during 2021, population densities of P₃ and P₂ were at par at 40 DAS, similarly P₃ and P₁ were at par at 60 DAS in 2021. Both high planting densities of P₁ and P₂ were statistically at par except at 40 DAS in 2023.

The significantly higher dry matter weight plant⁻¹ under the normal planting density (83333 plants ha⁻¹) might be due to the reduction in inter-plant competition. Fewer plants per unit area comparative to high population density, mean less competition for vital growth factors (light, moisture, nutrients) and each plant has access to a larger volume of growth resources. In contrast, high population densities (111111 and 133333 plants ha⁻¹) force plants to compete aggressively for growth resources and with more competition for limited resources each plant in a dense stand receives less share of growth resources, which translate into reduced photo-assimilates and hence lower dry matter production plant⁻¹, even though the total dry matter yield per hectare might be higher., Rajesh Babu *et al.* (2019) [5] and, Sharanabasappa and Basavanneppa (2019) [7] opined on the same line.

Genotype

Differences in dry matter weight plant⁻¹ due to maize genotypes were statistically significant except at 20 days stage in 2023. Minimal differences in dry matter weight (8.10 to 8.41 g) were observed at 20 DAS in 2021 with G₁ (BIO-605) being significantly more but at par with G₂ (ADV-756) and the latter being at par with G₃ (BIO-9682). From 40 DAS to harvest stage during both the years, late maize genotype BIO-9682 (G₃) produced significantly higher dry matter weight plant⁻¹ and it was statistically equivalent to mid-late maize genotype ADV-756 (G₂) solely at 60 DAS in 2023. Mid-late genotype ADV-756 was significantly more over early genotype BIO-605 except at 40 DAS in 2021.

Dry matter accumulation differences among maize genotypes may primarily be attributed to their unique genetic traits rather than the major effect of external weather parameters though external weather encountered by different genotypes might have slightly differed during varied phenophase duration along the growing period of different maize genotypes. While environment plays a baseline role, distinct genetic traits dictate how efficiently each cultivar converts resources into dry matter. These results are in line with Prasad *et al.* (2017) [4], Jat *et al.* (2019) [2] and Sab *et al.* (2020) [6].

Interaction

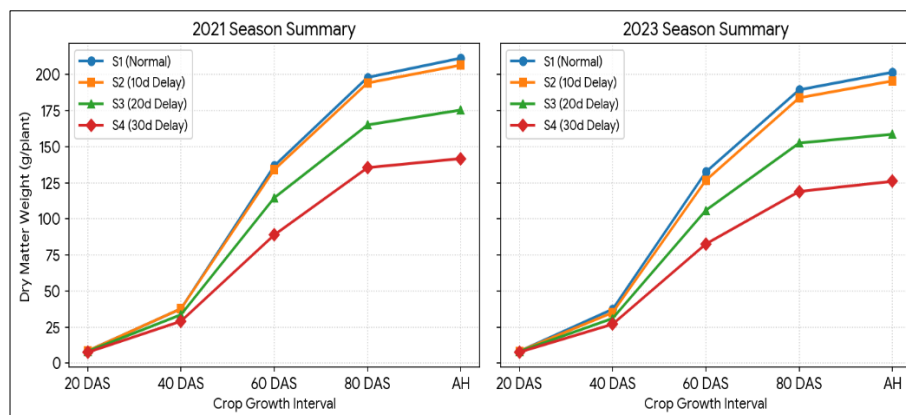
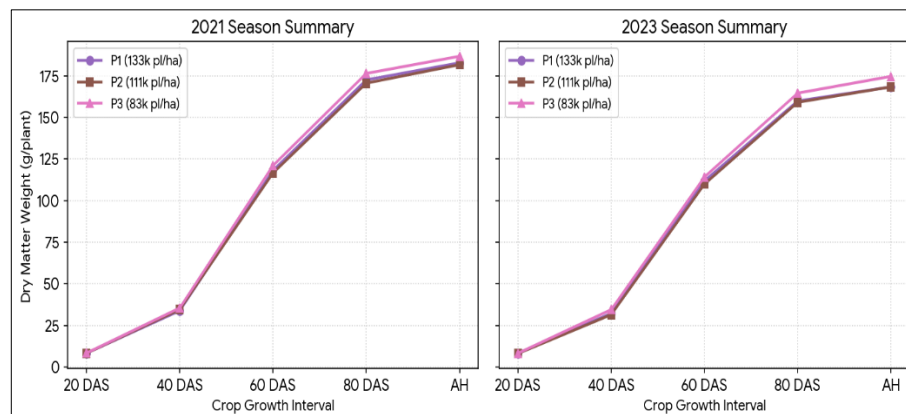
Interaction effect between weather variability and maize genotype at harvest stage was found significant in respect of dry matter weight plant⁻¹.

Weather variability and genotype (S X G) Interaction

Data on dry matter weight plant⁻¹ as influenced by SxG interaction at harvest stage during 2023 is presented in Table 1(a). Treatment combination of normal sowing and late-maturing genotype (S₁G₃) produced a significantly higher dry matter weight plant⁻¹ (212.82 g) compared to all other treatment combinations except that it was statistically at par with S₂G₃ interaction (205.88 g). Similarly, S₂G₃ interaction showed statistical equivalence with S₁G₂ interaction. Treatment interaction S₄G₁ recorded the least dry matter weight plant⁻¹ (122.59 g) being on par with interactions S₄G₂ and S₄G₃.

Table 1: Dry matter weight plant⁻¹ as influenced by different treatments during 2021 and 2023

Treatment	Dry matter weight plant ⁻¹ (g)									
	2021					2023				
	20 DAS	40 DAS	60 DAS	80 DAS	AH	20 DAS	40 DAS	60 DAS	80 DAS	AH
Weather variability										
S ₁ - Normal sowing time	8.54	37.74	136.77	198.05	211.38	8.29	37.47	132.56	189.44	201.61
S ₂ - 10 days after normal sowing	8.55	37.81	134.12	194.20	206.55	8.33	35.11	126.79	183.91	195.63
S ₃ - 20 days after normal sowing	8.27	33.65	114.63	165.12	175.46	8.19	31.09	106.01	152.56	158.69
S ₄ - 30 days after normal sowing	7.59	29.12	88.92	135.52	141.80	7.68	27.07	82.67	119.01	126.05
SE(m)+	0.14	0.50	1.35	2.66	1.29	0.15	0.63	1.72	2.10	1.98
CD (P=0.05)	0.48	1.71	4.69	9.21	4.46	0.52	2.19	5.94	7.28	6.87
Population density										
P ₁ - 60-90x10 (133333 pl ha ⁻¹)	8.22	33.79	118.16	172.57	182.86	8.17	32.20	111.87	159.93	168.36
P ₂ - 60X15 (111111 pl ha ⁻¹)	8.19	34.50	116.60	170.63	181.75	8.01	31.41	109.93	159.13	168.40
P ₃ - 60x20 (83333 pl ha ⁻¹)	8.30	35.45	121.08	176.47	186.79	8.19	34.45	114.22	164.63	174.72
SE(m)+	0.06	0.42	1.22	1.20	0.58	0.07	0.19	0.68	0.97	1.17
CD (P=0.05)	NS	1.27	3.65	3.58	1.75	NS	0.58	2.03	2.91	3.50
Genotype										
G ₁ - BIO - 605	8.41	33.51	112.87	166.81	174.76	8.18	31.31	107.30	156.51	161.14
G ₂ - ADV - 756	8.20	34.27	117.92	172.74	184.52	8.14	32.58	113.46	161.29	171.73
G ₃ - BIO - 9682	8.10	35.96	125.05	180.11	192.11	8.05	34.16	115.27	165.88	178.61
SE(m)+	0.08	0.43	1.24	1.73	0.86	0.09	0.40	0.75	1.39	1.23
CD (P=0.05)	0.22	1.23	3.53	4.91	2.44	NS	1.13	2.14	3.96	3.51
Interaction										
SxP										
SE(m)+	0.11	0.85	2.44	2.39	1.17	0.13	0.39	1.35	1.94	2.33
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SxG										
SE(m)+	0.15	0.86	2.48	3.45	1.71	0.17	0.79	1.50	2.79	2.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	7.02
PxG										
SE(m)+	0.13	0.75	2.15	2.99	1.48	0.15	0.69	1.30	2.41	2.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SxPxG										
SE(m)+	0.27	1.50	4.29	5.98	2.97	0.30	1.37	2.60	4.82	4.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	8.24	34.58	118.61	173.22	183.80	8.12	32.69	112.01	161.23	170.49

**Fig 1:** Weather variability impact on maize dry matter accumulation per plant**Fig 2:** Population density impact on maize dry matter accumulation per plant

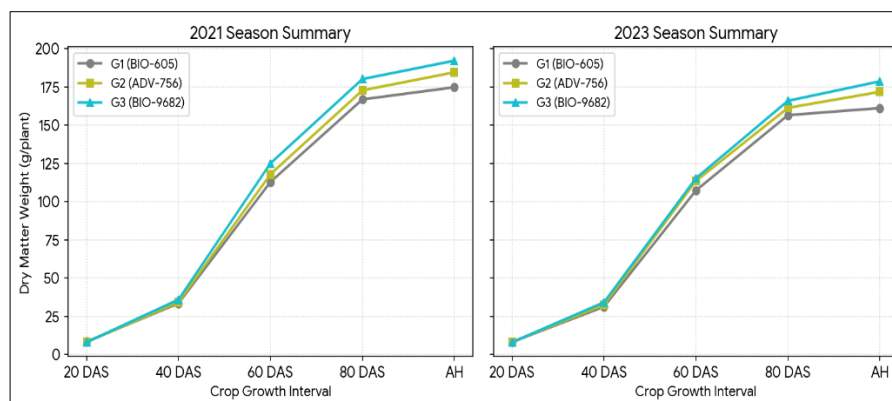


Fig 3: Genotypes impact on maize dry matter accumulation per plant

Conclusion

This study establishes that optimizing sowing windows, crop geometry, and genetic selection are critical drivers for maximizing maize productivity. Sowing at the normal sowing time (S_1) or within a 10 days after normal sowing time (S_2) aligns growth stages with favourable weather regimes, maximizing individual plant development. While high planting density (P_1) triggers intense intra-specific competition and reduces per-plant dry matter, a standard density of 83,333 plants ha^{-1} (P_3) optimizes resource capture. Cultivating the late-maturing genotype BIO-9682 (G_3) under normal sowing conditions ($S1G_3$) maximizes canopy resource use efficiency, yielding the highest individual dry matter accumulation at harvest, representing an ideal management strategy for high-yielding maize production.

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