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Dry Matter Accumulation and Physiological Growth Parameters of Maize as Influenced by Different Nutrient Management Practices

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ABSTRACT

Background: Maize, which is an important cereal for its yield potential and it can be influenced by various agronomic factors. In hybrid maize, dry matter accumulation and leaf area index are strongly affected due to applied nutrients. The amount of dry matter accumulation is directly related to the grain yield. The present study has been conducted with a focus on the effect of nutrient management on dry matter accumulation and other physiological parameters for quantifying the growth of maize.

Methods: The present study was conducted during *rabi* season for two consecutive years of 2021-2022 and 2022-23 at the P.G. Experimental Farm of Centurion University of Technology and Management, Odisha. The experiment was laid out in randomized block design with 14 treatments and three replications. The treatment details include different recommended doses of nutrients, leaf colour chart and sufficiency index-based nitrogen management and nutrient expert based nutrient management in maize.

Result: The study revealed that application of ample dose of nitrogen, *i.e.*, 200-60-60 kg/ha of N-P_2O_5-K_2O resulted in obtaining the highest dry matter accumulation and leaf area index of maize throughout the growth periods for both the years of maize. Further, the treatments 150% RDF and SI-based N management (N-60-60 kg/ha) at SI 90-95% also performed at par in terms of growth attributes of maize.

Key words: Dry matter, Maize, Physiological indices, Precision nutrient management.

INTRODUCTION

Maize plays an important role in food security in the world (Maitra *et al*., 2019). In India, maize is cultivated in wide range of agroclimatic conditions (Panda *et al*., 2021). Maize produces a large volume of biomass including economic yield within a short period of time. Proper vegetative growth of the crop and conversion of dry matter into seed yield is important physiological phenomenon to obtain a good productivity.

The above ground DMA is directly related to the quantity of grain yield production (Sairam *et al*., 2021). To contribution of dry matter to grain yield was up to 70%, indicating the vital role of DMA in grain filling and higher productivity (Rivera-Amado *et al*., 2019; Liu *et al.,* 2021). The DMA is mainly dependent on the potential of the genotype and agronomic practices. The leaf area index (LAI) is a genotypic character which can affect the DMA (Rivera-Amado *et al*., 2019). Among the agronomic management practices, the nutrient management can affect the DMA in a large extent (Sairam *et al*., 2020). Nutrient management in cereals can be well optimized by observing the crop demand and supply during critical stages of the crop based on site-specific management. Balanced nutrient application can increase the DMA and source to sink ratio; hence, enhances the overall leaf area and photosynthetic rate (Sagar *et al*., 2021).

The maize hybrids, presently cultivated in India, are nutrient responsive and nutrient uptake which ultimately enhances the biomass production (Szulc *et al*., 2021). Maize hybrids can produce huge leaf area and canopy, thereby, allocating the photo assimilates to different parts of the plants including grain at different growth stages (Midya *et al*., 2021). In this context, application of optimum nutrients with more specific application of nitrogen through real time crop requirement can enhance the growth and productivity of the crop. Application of nutrients by site specific approach can be managed through sensors like chlorophyll content meter and decision support systems like nutrient expert (Singh *et al*., 2021).

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Considering the above, there is a need to assess the DMA of maize at different growth stages and the response of the crop towards different nutrient management practices with a special emphasis to nitrogen application (Zewide *et al*., 2023). In maize hybrids, nutrient management has a significant impact on both growth and yield of the crop (Midya *et al*., 2021). The quantification of the growth can be calculated by using different physiological growth indices such as leaf area index (LAI), crop growth rate (CGR), relative growth rate (RAR) and net assimilation ration (NAR) (Azeem *et al*., 2015). These physiological indices can clearly show the photosynthates produced per unit area in a time interval and thereby, calculate the actual amount of stored dry matter in the plant parts (Azeem *et al*., 2015). By analyzing the physiological growth indices, the DMA can be assessed in a better way for quantifying the production of biomass and yield. Based on the above, the present study has been planned to assess the influence of nutrient management on growth parameters, relationship between DMA of maize and LAI and the role of physiological growth indices in quantifying the growth rate of maize.

MATERIALS AND METHODS

The study was conducted during *rabi* season for two consecutive years (2021-2022 and 2022-2023) at the P. G. Research Farm of Centurion University of Technology and Management, Odisha, India (18°48′18″N and 84°10′45″E). The cropping period was 20th November to 20th March in 2021-22 and 15th November to 17th March in 2022-23. The agrometeorological data was collected from the Meteorological Observatory, Centurion University of Technology and Management. The mean maximum temperature varied from 27°C-37°C and 28°C-36°C during both the years, respectively. The mean minimum temperature for two years ranged from 12°C-23°C and 14°C-21°C respectively. The mean maximum and minimum relative humidity ranged from 88%-96% and 39%-80% for 2021-22 and 79%-91% and 37%-68% during 2022-23, respectively. The crop received 145.9 mm and 71.8 mm rainfall during both the years, respectively. The mean bright sun shine hours recorded/day was between 7-9 hrs/day. The soil was sandy loam and the chemical properties of the initial soil are mentioned in Table 1.

The experiment was laid out in randomized block design. The treatments were, T_1: well fertilized N, T_2: recommended dose of fertilizer (RDF), T_3:125% RDF, T_4:75% RDF, T_5: 150% RDF, T_6: RDF + nano urea, T_7: 75% RDF + nano urea, T_8: leaf colour chart (LCC) 4-based nitrogen management, T_9: LCC 5-based nitrogen management, T_{10}: sufficiency index(SI)-based nitrogen management at SI 85-90%, T_{11}: SI-based N management at SI 90-95% T_{12}: nutrient expert (NE) based nutrient recommendation for targeted yield of 7t/ha, T_{13}: nutrient expert based nutrient recommendation for targeted yield of 9t/ha and T_{14}: control. The details of the treatments are mentioned in Table 2. The dent corn hybrid Pioneer P3396 was considered for the experiment during both the years. The net plot size for each treatment was 6.2 m × 4.8 m which was replicated thrice.

The DMA and leaf area were collected at 20 days interval during both the years and the physiological growth indices, namely, LAI, CGR, NAR and RGR were calculated by the equations provided by Williams (1946) and Watson (1947). The data was statistically analysed by using analysis of variance (ANOVA), standard error of means (S.Em. ±) and critical difference (C.D.) at 5% probability level of significance (Gomez and Gomez, 1984). Further, the Excel software (Microsoft Office Home and Student version 2021-en-us, Microsoft Inc was used for statistical analysis.

RESULTS AND DISCUSSION

Dry matter accumulation

The highest DMA was noted at harvesting and there was a gradual increase in DMA from 20 days after sowing (DAS) to harvest as noted during both the years (Table 3). The highest DMA during all the growth stages of maize was observed in ample dose of nitrogen application (T_1). At 20 DAS, the treatment T_5 (150%RDF) recorded significantly at par DMA with ample dose of nitrogen application (T_1); however, at 100 DAS and harvest the treatment T_5 and T_{11} (SI-based N management at SI 90-95%) remained on par with T_1 during both the years. Some other precision nutrient management practices such as LCC and NE were also performed marginally well when compared with 100 % RDF and other treatments. The results showed the significant role of nitrogen in attaining maximum DMA of maize. Application of ample N might increase the nutrient availability and uptake and maintained better canopy. Further, split applications of N through SI-based nutrient management practice resulted in a promising effect on DMA. The results are similar with the findings of Zhang *et al*., (2023), Liu *et al*. (2023) and Mohapatro *et al*. (2021).

Table 1: Physico-chemical properties of the experimental soil for both the years.

Parameters	2021-22	2022-23
pH	6.72	6.78
Electrical conductivity (dS/m)	0.24	0.21
Soil organic carbon (%)	0.41	0.46
Available nitrogen (kg/ha)	236	241
Available phosphorous (kg/ha)	12.6	12.8
Available potassium (kg/ha)	132.4	141.3

Leaf area index

The LAI of maize was increased from germination to 60DAS and later gradual decrease was observed due to senescence of older leaves towards maturity (Table 4). The highest leaf area in all the growth stages was recorded in ample dose of nitrogen application (T_1); whereas, the lowest leaf area index was observed in control (T_{14}). At 20 DAS, the treatments T_5 and T_{11} performed well and remained statistically at par with T_1; whereas, the remaining treatments did not perform well during initial stages of growth. During the peak growth stage at 60DAS, the maximum LAI was observed with the treatment T_1 and some other treatments such as T_5 (150%RDF), T_{11} (SI-based N management at SI 90-95%), T_2 (125%RDF) and T_9 (LCC 5) remained on par with T_1. During the harvest, the LAI was decreased to a higher extent and the maximum LAI was observed in T_1. Moreover, the treatment T_1 remained on par with T_5 and T_{11}. The application of sufficient nitrogen and optimum phosphorous and potassium resulted in obtaining higher leaf area. Also, the timely application nitrogen by using precision tools enhanced the leaf area compared to 200% nitrogen application. The results are confirmatory with the findings of Cao *et al*. (2021) and Swamy *et al*. (2022).

Table 2: Treatment details of the experiment.

Treatment details	Nitrogen (kg/ha)	Nitrogen splits	Phosphorous (kg/ha)	Potassium (kg/ha)
T_1	240	3	60	60
T_2	120	3	60	60
T_3	150	3	75	75
T_4	90	3	45	45
T_5	180	3	90	90
T_6	120	3	60	60
T_7	90	3	45	45
T_8	115	3	60	60
T_9	140	4	60	60
T_{10}	140	4	60	60
T_{11}	165	5	60	60
T_{12}	142	3	49	71
T_{13}	153	3	56	78
T_{14}	0	0	0	0

For all the treatments, potassium and phosphorous were applied in a single split as basal dose. However, in case of nitrogen, for RDF and Nutrient expert Treatments, 50% was applied as basal and remaining 50% applied in two equal splits at 40 and 65 DAS. For treatments like leaf colour chart and sufficiency index 40 kg N/ha was applied as basal and 25 kg N/ha was applied as top dressing as per treatment specifications. For nano urea treatments (T_6 and T_7), 4ml/L of IFFCO nano urea was foliar sprayed twice during 40 and 65 DAS.

Table 3: Dry matter accumulation (g/m^2) of maize as influenced by nutrient management practices.

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		100 DAS		At harvest	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	267	282	418	446	942	982	1685	1724	1948	2012	2117	2154
T_2	164	178	251	266	523	534	912	856	1056	1089	1114	1123
T_3	214	242	326	351	713	744	1356	1411	1592	1604	1863	1819
T_4	148	151	241	247	425	436	502	543	632	672	850	890
T_5	261	275	413	444	927	971	1623	1647	1855	1872	2066	2144
T_6	177	186	285	313	586	602	845	931	1023	1141	1152	1237
T_7	127	133	211	219	515	521	765	782	812	843	993	1004
T_8	112	119	195	206	455	462	878	882	1078	1085	1240	1247
T_9	119	129	206	231	547	574	966	1013	1175	1201	1453	1469
T_{10}	138	155	243	271	632	684	1127	1162	1313	1333	1598	1607
T_{11}	223	227	399	402	889	416	1617	1637	1892	1872	2043	2149
T_{12}	121	125	198	209	514	524	923	941	1126	1157	1327	1345
T_{13}	215	181	387	336	751	607	1362	1149	1578	1345	1826	1552
T_{14}	105	111	162	168	256	267	379	415	412	501	591	651
S.Em. (±)	6.1	9.3	13.5	13.4	29.9	25.8	49.3	41.0	43.8	53.8	65.1	92.2
C.D. (P=0.05)	17.7	27.1	39.4	38.9	87.1	75.0	143.5	119.3	127.4	156.4	189.3	268.2

Crop growth rate

During both the years, at the initial growth stage of 20-40 DAS and 40-80 DAS, the maximum CGR was observed in T_5 (150% RDF) and during 60-80 DAS and 80-100 DAS, the treatment T_1 (ample dose of nitrogen) resulted in the maximum CGR (Table 5). At harvesting stage, the treatment T_{11} (SI-based N management at SI 90-95%) recorded the maximum CGR. At the initial growth stage of maize, due do ample dose application of nitrogen and phosphorous and potassium together resulted in obtaining better CGR. However, during tasseling and silking stage, ample dose of nitrogen might result in better leaf area as well as a greater photosynthate assimilation. Increasing the nitrogen splits also improved the CGR of maize at later stage when nitrogen was applied through SI-based management, the CGR was improved than other treatments (Hu *et al*., 2023; Cao *et al*., 2021).

Net assimilation rate

The NAR revealed that there was a constant accumulation of dry matter from initial stage to grain filling (Table 6). However, a little increase in the NAR was recorded during 40-80DAS in all the treatments. During both years, at initial stages (20-40 DAS and 40-60 DAS), the treatment T_5 performed to show the NAR. Similarly, during 60-80DAS and 80-100DAS, the treatment T_1 produced the maximum NAR. At harvest, the treatment T_{11} (SI-based N management

Table 4: Leaf area index of maize as influenced by nutrient management practices.

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		100 DAS		At harvest	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	1.86	1.91	2.61	2.94	5.86	6.08	5.71	6.11	2.81	2.91	2.54	2.72
T_2	1.60	1.57	2.25	2.31	4.10	4.28	4.17	4.15	2.28	2.56	2.18	2.34
T_3	1.64	1.63	2.43	2.57	5.28	5.56	5.24	5.59	2.77	2.74	2.37	2.51
T_4	1.44	1.31	2.14	2.22	3.85	3.96	4.03	3.67	2.21	2.41	2.07	2.28
T_5	1.76	1.88	2.51	2.81	5.74	5.98	5.61	6.03	2.79	3.33	2.49	2.64
T_6	1.31	1.37	2.27	2.35	4.18	4.32	4.23	4.41	2.25	2.57	2.13	2.31
T_7	1.47	1.28	2.09	2.27	3.94	4.02	4.07	3.94	2.19	2.29	1.95	2.11
T_8	1.39	1.23	2.22	2.34	4.69	4.82	4.61	4.73	2.33	2.25	2.15	2.08
T_9	1.59	1.44	2.48	2.61	5.43	5.66	5.47	5.55	2.69	2.78	2.22	2.39
T_{10}	1.62	1.15	2.26	2.24	4.72	4.94	4.75	5.06	2.43	2.69	2.18	2.38
T_{11}	1.78	1.83	2.52	2.67	5.72	5.88	5.66	5.69	2.64	2.61	2.33	2.46
T_{12}	1.37	1.36	2.28	2.38	4.42	4.68	4.39	4.71	2.29	2.48	2.14	2.24
T_{13}	1.63	1.39	2.37	2.44	4.98	5.04	5.01	4.94	2.58	2.53	2.29	2.36
T_{14}	1.21	1.07	2.11	2.16	3.06	3.18	3.11	3.22	2.16	2.19	1.87	2.01
S.Em. (±)	0.06	0.09	0.08	0.12	0.17	0.24	0.20	0.25	0.15	0.13	0.09	0.10
C.D. (P=0.05)	0.18	0.25	0.24	0.34	0.49	0.61	0.57	0.71	0.43	0.37	0.26	0.29

Table 5: Crop growth rate (g/m²/day) of maize as influenced by nutrient management practices.

Treatments	20-40 DAS		40-60 DAS		60-80 DAS		80-100 DAS		100 DAS-harvest	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	6.02	7.20	29.53	26.32	37.17	39.62	16.48	14.40	10.12	7.08
T_2	4.37	4.43	9.82	13.37	19.45	16.10	7.22	11.68	5.92	6.70
T_3	5.62	5.48	23.60	19.62	32.17	33.37	12.12	9.65	13.57	10.75
T_4	4.67	4.83	5.62	9.45	6.83	7.55	6.48	6.43	10.92	10.90
T_5	7.62	8.42	32.10	26.37	34.80	33.78	11.60	11.25	10.53	10.10
T_6	5.40	6.33	18.75	14.43	12.97	16.45	8.88	10.52	6.47	4.82
T_7	4.22	4.28	16.02	15.08	12.48	13.08	2.38	3.03	9.05	8.07
T_8	4.13	4.33	12.45	12.83	21.13	20.98	10.02	10.13	8.12	8.13
T_9	4.33	5.08	15.20	17.18	20.95	21.93	10.43	9.38	13.90	13.43
T_{10}	5.28	5.78	14.67	20.63	24.73	23.93	9.30	8.53	14.27	14.35
T_{11}	5.80	6.78	29.55	23.70	33.40	32.03	11.75	14.33	14.88	8.85
T_{12}	3.87	4.18	6.37	15.77	20.45	20.87	10.17	10.78	10.03	9.38
T_{13}	7.57	7.75	29.45	13.53	30.52	27.12	10.82	9.77	12.40	10.35
T_{14}	2.85	2.87	9.78	8.95	6.17	7.40	1.67	4.30	9.17	7.48
S.Em. (±)	0.73	0.49	1.46	1.19	2.08	2.59	0.66	0.57	0.81	0.80
C.D. (P=0.05)	2.11	1.41	4.25	3.45	6.03	7.54	1.91	1.66	2.35	2.32

at SI 90-95%) obtained the highest NAR during both the years. However, during all the growth stages for both the years, the lowest NAR was observed in T_{14} (control) and T_4 (75%RDF) probably because of insufficient application of nutrients. The NAR followed a similar trend as it was noticed in the CGR and such results were obtained due to variation of growth and assimilates production as influenced by different treatments. The results corroborate with the findings of Azeem *et al*. (2015) and Cai *et al*. (2023).

Relative growth rate

The experimental data for both the years proved that the RGR of maize showed the highest values during 20-60DAS and there was a sharp decline in the RGR as the crop progressed towards maturity (Table 7). During the initial growth stage of 20-40DAS, the treatment T_{13} recorded the maximum RGR and the minimum was noted with the treatment T_1 (ample dose of nitrogen). During 40-60 DAS and 60-80DAS, the treatments T_9 and T_3 obtained the maximum RGR for two consecutive years and the treatment T_{14} as well as T_4 recorded the least RGR. However, during 80-100DAS and 100DAS to harvest, the treatment T_4 recorded the maximum RGR of maize. As the RGR a significant physiological index for determination of growth, the results clearly mentioned that the nutrient management

Table 6: Net assimilation rate (g/m^2/day) of maize as influenced by nutrient management Practices.

Treatments	20-40 DAS		40-60 DAS		60-80 DAS		80-100 DAS		100 DAS-harvest	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	1.12	1.09	3.19	2.54	2.81	2.84	1.76	1.54	1.66	0.93
T_2	0.97	0.93	1.38	1.81	2.05	1.66	1.00	1.44	0.57	0.31
T_3	1.18	1.03	2.76	2.21	2.62	2.65	1.37	1.05	2.26	1.77
T_4	1.15	1.21	1.09	1.39	0.43	0.64	0.93	0.96	2.22	2.05
T_5	1.66	1.68	3.63	2.76	2.67	2.47	1.25	1.08	1.76	1.41
T_6	1.34	1.51	2.61	1.94	1.35	1.67	1.23	1.35	1.28	0.86
T_7	1.04	1.09	2.39	2.14	1.35	1.44	0.34	0.44	1.92	1.63
T_8	1.01	1.09	1.65	1.64	1.98	1.91	1.31	1.33	1.57	1.65
T_9	0.94	1.13	1.76	1.89	1.67	1.71	1.16	1.02	2.38	2.25
T_{10}	1.20	1.54	1.92	2.64	2.28	2.07	1.18	0.99	2.60	2.47
T_{11}	1.21	1.45	3.35	2.54	2.57	3.16	1.29	1.52	2.71	2.53
T_{12}	0.95	1.00	1.86	2.02	2.01	1.93	1.37	1.35	1.99	1.73
T_{13}	1.89	1.81	3.25	2.64	2.68	2.36	1.29	1.18	2.21	1.84
T_{14}	0.77	0.80	1.18	0.82	0.86	1.01	0.28	0.69	1.98	1.55
S.Em. (±)	0.17	0.11	0.19	0.18	0.20	0.27	0.10	0.09	0.18	0.18
C.D. (P=0.05)	0.49	0.32	0.56	0.52	0.58	0.78	0.28	0.25	0.52	0.53
C.V. (%)	24.72	15.45	14.80	15.45	17.84	23.79	14.67	13.14	16.15	20.16

Table 7: Relative growth rate (mg/g/day) of maize as influenced by nutrient management practices.

Treatments	20-40 DAS		40-60 DAS		60-80 DAS		80-100 DAS		100 DAS-harvest	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	19.14	19.97	40.19	41.62	31.56	30.78	9.47	7.74	5.00	3.41
T_2	21.28	20.32	36.42	34.72	28.07	23.72	7.41	11.22	3.58	2.42
T_3	21.07	21.73	38.87	37.51	32.20	34.00	8.17	4.37	7.90	8.28
T_4	24.59	24.80	28.45	28.35	8.28	10.95	11.28	10.58	16.86	13.72
T_5	23.06	23.89	40.32	39.20	28.10	26.38	6.66	3.07	5.39	8.36
T_6	23.78	25.94	36.08	32.69	17.91	21.92	9.72	9.99	6.18	4.17
T_7	25.19	24.85	44.93	43.38	19.71	20.14	3.08	3.78	9.98	8.64
T_8	27.72	27.55	42.26	40.37	31.12	32.29	10.29	10.51	6.96	6.63
T_9	27.57	29.09	48.66	46.42	28.62	28.54	9.76	8.54	10.60	10.06
T_{10}	28.40	28.29	47.55	46.18	29.00	26.62	7.83	6.85	9.72	9.25
T_{11}	20.89	23.40	42.30	41.86	30.66	32.77	7.48	6.83	7.87	5.45
T_{12}	24.70	25.58	47.78	46.09	29.10	29.23	10.12	10.33	8.16	7.20
T_{13}	29.03	30.61	33.49	29.80	29.71	31.93	7.35	7.49	7.23	7.29
T_{14}	21.28	20.69	22.84	22.86	19.80	22.32	4.31	9.58	15.98	13.05
S.Em. (±)	2.15	2.37	2.84	2.48	3.42	3.43	0.52	0.79	1.03	0.54
C.D. (P=0.05)	6.24	6.90	8.26	7.22	9.96	9.96	1.50	2.31	2.99	1.58

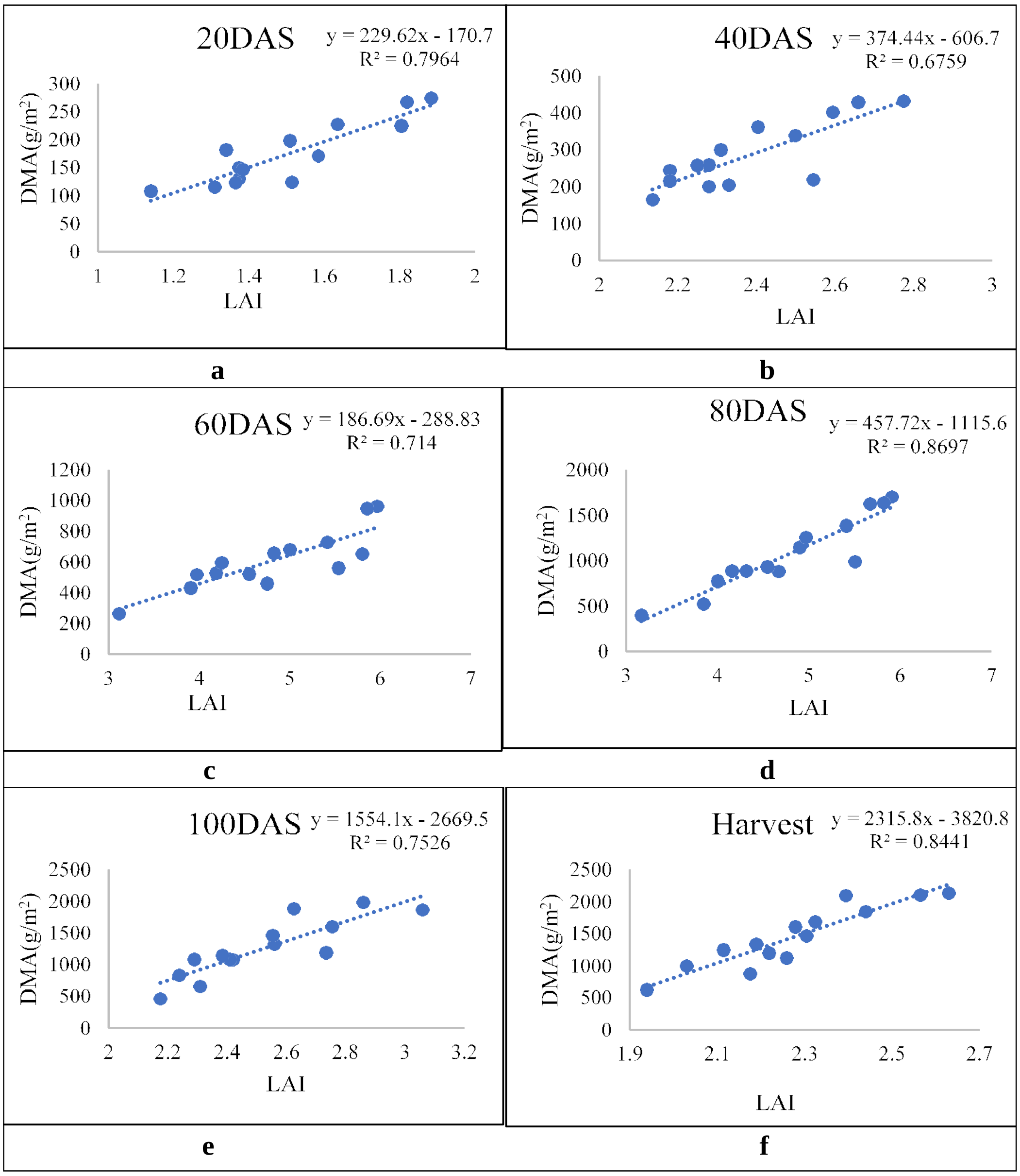

Fig 1: Regression analysis of two year mean dry matter accumulation (DMA) with mean leaf area index (LAI) of maize for different days after sowing (DAS).

practices had a significant impact on RGR of maize (Koca and Erekul, 2016).

Regression analysis of dry matter accumulation with leaf area index

The regression analysis of two-year mean data of DMA with mean data of LAI are plotted and presented in Fig 1. The LAI of maize had a direct proportion to total dry matter accumulation. The more the leaf area of maize, the higher the photosynthates assimilation resulting in higher dry matter production. The analysis showed that there was a moderate to strong correlation between the DMA and the LAI. The relation of the LAI and DMA was found to be strongly correlated during 20 DAS, 80 DAS, 100 DAS and harvest with a mean R^2 value ranged from 0.75 to 0.86. However, during 40 and 60 DAS, the correlation was found to be moderate with a R^2 value of 0.69 and 0.71, respectively.

CONCLUSION

The present study revealed that various nutrient management practices played a significant role in growth as well as physiological indices of maize throughout the growing season. This experiment concludes that ample dose of nitrogen (200%N) along with optimum amount of phosphorous and potassium can be recommended for obtaining better growth and physiological indices in maize. Further, the split application of optimized nitrogen application through sufficiency index-based nitrogen management can also be considered to enhance crop growth rate and better leaf area index at later stage of maize, which may result in optimum grain filling and improved dry matter accumulation for enhancing productivity.

Conflict of interest: None.

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