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The Influence of N Rates on Maize Leaf Number and Senescence in Nigeria

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Abstract: Leaf senescence greatly affects photosynthetic capacity, dry matter production and allocation in plants. Death of leaves as a result of senescence ends or limits dry matter production and allocation in plants. If more leaves are retained on the plants by delaying senescence, dry matter production may be maintained for a longer period leading to higher grain yield. Since redistribution of nutrients like nitrogen is the major reason for leaf senescence, adequate supply of N may delay senescence. Field experiments were therefore conducted in 1996 and 1998 in Mokwa (in the Southern Guinea savanna of Nigeria) on a sandy-loam (Tropeptic Haplustox) to determine the effects of different N rates (0, 30, 60, 90 and 120 kg N ha^{-1}) on leaf number per plant and leaf senescence of nine maize (*Zea mays* L.) varieties. The highest number of leaves per plant (20.5) at anthesis was obtained from the 120 kg N ha^{-1} in both seasons while the lowest percentage leaf senescence was obtained from 120 kg N ha^{-1} at all the sampled periods. The highest grain yield was also recorded at the 120 kg N ha^{-1} in both seasons. Varieties 8644-27 and TZLCOMP4C1 that had the highest grain yield also produced the highest number of leaves and lowest percentage leaf senescence. This shows that N rates increased leaf number and delayed leaf senescence. Maintaining more green leaves for a longer period through higher N application resulted in higher grain yield. Maize varieties that produce more leaves and maintain them longer may yield higher.

Key words: Leaf number · leaf senescence · green leaves · yield · nitrogen rates · varieties

INTRODUCTION

Senescence is a developmental stage in crop plants, which marks the end of growth and commencement of deterioration of the organs of a plant or the entire plant. Grabau [1] defined senescence in maize as the collective processes resulting in metabolic and anatomic disassembly of photosynthetic plant organs, with the ultimate purpose of providing nutrients needed to support the growth of grains for the ensuing generation. Thimann [2], metabolic changes associated with senescence include chlorophyll loss, proteolysis, changes in nucleic acid levels and altered respiration. He further reported that the prominent anatomically visible change is decrease in chlorophyll. Several factors known to influence senescence include genetic characteristics, N stress, radiation, temperature, drought and pathogens [1, 3]. The role of N stress in initiating senescence is still a subject of debate in research. Nitrogen depletion in the soil during crop growth period is however reported to greatly influence senescence [1]. Penarrubia and Moreno [4] reported that senescence in plants is a very pervasive phenomenon that has been encountered in all plants and at all stages of the life cycle. It shows a variety of patterns ranging from the death of specific cells to the most extreme case of decline of the entire plant. The view of Grabau [1] is that if the senescence code is broken, leaves may be forced to remain green longer thereby carrying out photosynthesis and maintaining dry matter allocation for a longer period, which can lead to higher crop yield.

Increase in N supply within limits are associated with increase in leaf area and weight, carboxylases and chlorophyll content, all of which determine the photosynthetic activity of the leaf and ultimately dry matter production and allocation to the various organs

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of plants [5]. This shows that adequate N supply can be used to delay leaf senescence in maize thereby maintaining the leaves green and functional for a longer period. Photosynthetic rate, leaf surface area, size of the sink all increase with increase in nitrogen levels [6]. Increase in leaf area and photosynthetic capacity with increased N levels was attributed to the effects of N on cell and tissue growth [7].

The effects of N on leaf number and senescence in maize has however, not been fully investigated and it is not clear how leaf senescence will behave under low or high N conditions. What is also not so clear is whether the effects of N rates on leaf senescence and leaf number will vary with maize varieties. The objective of this research work therefore was to investigate the effects of different N rates on leaf number and leaf senescence in maize.

MATERIALS AND METHODS

Field experiments were conducted in Mokwa (a location in the Southern Guinea Savanna ecological zone of Nigeria) during the 1996 and 1998 cropping seasons. Mokwa is located on latitude 9° 18'N and longitude 5° 04'E. Rainfall distribution, minimum and maximum temperatures of the experimental site during the two seasons are presented in Table 1. The soil at the experimental site is a sandy-loam (Tropeptic Haplustox). A split plot design with four replications was used for the experiment. Five N rates (0, 30, 60 90 and 120 kg ha^{-1}) were assigned to the main plots while the subplots consisted of nine late maturing maize varieties - S9325-SR, TZLCOMP3C1, TZLCOMP4C1, TZB-SR, AK9328-DMRSR, IK9129-SR, AC93TZLCOMP1W and ACR9222-SR and 8644-27. Each sub-plot had 8 rows which were 5 m long and separated from each other by a distance of 0.75 m.

Planting was done on the 21st June in the 1996, while in 1998, the crops were planted on the 4th July when rainfall was sufficient. Two seeds were planted per hill at a spacing of 75 cm x 25 cm, which were thinned to one plant per stand at 2 weeks after planting thus giving a plant population of 53333 plants per hectare. Nitrogen was applied in two equal doses at 7 and 28 Days after Planting (DAP), while P and K were applied in a single dose along with the first application of N at the rate of 26.22 and 49.80 kg ha^{-1}, respectively. Nitrogen was obtained from urea fertilizer, P was obtained from single super phosphate fertilizer, while K was obtained from muriate of potash. Fertilizer application was by incorporation.

Table 1: Rainfall distribution and temperatures during the 1996 and 1998 cropping seasons in the site

	1996 season			1998 season		
Months	TMAX (°C)	TMIN (°C)	RAIN (mm)	TMAX (°C)	TMIN (°C)	RAIN (mm)
January	35.2	16.9	0.0	35.1	15.6	0.0
February	38.6	21.2	0.8	37.5	21.1	0.0
March	39.5	23.4	0.0	38.3	23.9	0.0
April	38.5	26.8	38.0	38.6	25.1	39.0
May	34.4	24.5	178.0	34.2	23.2	153.0
June	33.6	23.7	230.0	32.4	22.4	334.0
July	31.6	23.5	114.0	31.3	22.8	203.0
August	30.5	23.6	262.0	30.3	22.3	64.0
September	31.3	23.5	151.5	31.4	21.4	318.0
October	33.1	23.5	27.8	33.0	21.1	117.0
November	35.8	20.5	0.0	35.1	16.0	0.0
December	34.8	17.3	0.0	37.0	16.9	0.0

TMAX = maximum temperature and TMIN = minimum temperature

Total number of leaves per plant was determined by tagging the 5th leaf of ten plants per plot at 14 DAP before the germination leaves senesced. When senescence had progressed, the tags were adjusted to the 10th leaf. Total number of leaves per plant were counted from 23 DAP to anthesis while number of green leaves were counted up to physiological maturity [3]. Green leaves refer to leaves not senesced according to Ottman and Welch [3], who defined a senesced leaf as one with necrosis or brown color on more than 50% of the leaf area. Ten counts from each plot were averaged to obtain the mean value per plot. Leaf senescence was calculated as the percentage of the difference between total number of leaves produced per plant and number of green leaves at any particular time, expressed over the total number of leaves produced per plant. At maturity, all the plants from the two middle rows of each plot were harvested except two plants at the beginning and end of each row which were considered as border plants. The harvested ears were dried and shelled to determine the grain yield from each plot, which were standardized at 15% moisture content. Data collected were subjected to analysis of variance using the mixed model procedure of Statistical Analysis System (SAS [8]) and means were compared using LSD.

RESULTS

The mean squares from the analysis of variance for the total number of leaves and leaf senescence at different crop growth stages taken in 1996 and 1998 cropping seasons are presented in Table 2. In 1996 season, the total number of leaves per plant significantly varied with N rates at $p = 0.05$ at 37 DAP, which was the

Table 2: Analysis of variance table showing mean squares of leaf number, leaf senescence and grain yield of maize in 1996 and 1998 seasons

Source of variation	df	Total number of leaves per plant at: 23DAP	37DAP	50% AN	Percentage leaf senescence (%) at: 37DAP	50% AN	MSK	88 DAP	95 DAP	Grain yield
1996										
N	4	9.267**	9.536*	9.536*	925.913**	335.869**	217.569*	170.590ns	268.878ns	54.797**
Error a	12	1.007	2.612	2.612	153.911	31.528	69.589	83.566	208.031	0.417
Varieties	8	1.175**	2.025**	2.025**	135.161**	36.517**	61.746**	149.002**	286.435**	2.859**
N x Varieties	32	0.278ns	0.620**	0.620**	48.956*	12.690*	21.081ns	41.078ns	52.639ns	1.189**
Error b	120	0.333	0.326	0.326	29.320	7.514	19.322	28.883	59.678	0.222
1998										
N	4	0.962ns	4.646ns	22.241**	386.995**	323.119**	292.232**	161.005**	300.563*	13.880**
Error a	12	0.852	1.552	0.972	41.389	39.662	44.477	25.319	84.812	1.645
Varieties	8	0.375*	0.766ns	2.588**	43.742ns	42.412**	61.458**	55.690**	272.906**	1.464ns
N x Varieties	32	0.104ns	0.269ns	0.391ns	30.832ns	15.175ns	19.673	20.605ns	41.134ns	0.570ns
Error b	120	0.158	0.602	0.649	28.679	16.716	18.488	17.788	37.714	0.954

AN = Anthesis, MSK = Mid silking and DAP = Days after planting, * = significantly different at p = 0.05, ** = Significantly different at p = 0.01 and ns = Non significantly different at p = 0.05

Table 3: The effects of N rates on total number of leaves per plant at different growth stages, leaf senescence and grain yield of maize planted in 1996 and 1998 seasons

N rates	Total number of leaves per plant at: 23DAP		37DAP		50% anthesis		Leaf senescence (%): 23DAP		37DAP		50% anthesis		74 DAP		88 DAP		Grain yield mg ha^{-1}	
(kg ha^{-1})	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998
0	4.32	4.70	9.28	9.56	19.28	18.47	40.30	49.49	37.18	43.06	44.32	47.35	53.34	54.75	64.70	62.20	2.52	3.05
30	5.26	4.88	10.15	9.86	20.15	19.67	35.77	48.82	39.17	48.07	47.54	52.85	57.31	57.87	69.24	68.12	3.09	2.96
60	5.18	4.90	10.44	10.12	20.44	19.93	38.27	44.43	35.39	44.97	46.82	49.68	57.49	54.28	67.38	64.24	4.16	3.58
90	5.45	4.77	10.41	10.38	20.41	20.22	32.10	42.43	32.92	40.68	43.42	45.93	56.70	53.20	65.62	60.93	4.88	4.31
120	5.64	5.13	10.54	10.40	20.54	20.50	27.56	43.12	31.67	41.31	41.57	46.44	53.12	52.33	62.02	61.72	5.51	4.18
Mean	5.17	4.88	10.16	10.06	20.16	19.76	34.80	45.66	35.27	43.62	44.73	48.45	55.59	54.49	65.79	63.44	4.03	3.62
S.E	0.10	0.07	0.10	0.13	0.10	0.13	0.90	0.89	0.46	0.68	0.73	0.72	0.90	0.70	1.29	1.02	0.08	0.16
Prob. of F	0.01	ns	0.05	ns	0.05	0.01	0.01	0.01	0.01	0.01	0.05	0.01	ns	0.01	ns	0.05	0.01	0.01
LSD	0.356	0.185	0.267	0.362	0.267	0.497	3.341	3.304	1.691	2.522	2.051	2.653	2.508	2.602	3.605	2.866	0.291	0.602

DAP = Days after planting and ns = Non significantly different at p = 0.05

Active Stem Elongation period (ASE) and at 50% anthesis period. However, at 23 DAP, the number of leaves varied with N rates at p = 0.01. In the 1998 season, there were no significant differences between N rates for number of leaves per plant (p = 0.05) except at 50% anthesis period, where highly significant difference between N rates (p = 0.01) was observed.

In 1996 season, leaf senescence significantly differed with N rates at p = 0.01 at 37 DAP and 50% anthesis periods (Table 2). At mid silking stage, leaf senescence significantly varied with N rates at p = 0.05, while at 88 and 95 DAP, there were no significant differences among the N rates for leaf senescence. In 1998 season, however, highly significant differences were observed in leaf senescence among the N rates at p = 0.01 except at 95 DAP that the level of significance was p = 0.05.

There were significant differences among the varieties for all the periods data were recorded for either total number of leaves per plant or leaf senescence in both seasons except at 37 DAP in 1998. The interaction between N rates and varieties for number of leaves per plant and leaf senescence was significantly different only at 23 and 37 DAP in both seasons.

Mean values of the total number of leaves per plant for the 1996 season at all the periods observed were highest at 120 kg N ha^{-1} although there were no significant differences between 120 and 90 kg N ha^{-1} (Table 3). The lowest values were obtained at the 0 kg N ha^{-1}. Although statistical differences among the means were observed only at 50% anthesis period (p = 0.01) in 1998 season, the same trend was observed at all the periods data were taken.

In both seasons, varieties TZLCOMP4C1, ACR9222-SR and the hybrid-8644-27 had more number of leaves than the other varieties. On the other hand, TZLCOMP3C1 and AC93TZLCOMP1W had less number of leaves per plant compared to the other varieties (Table 4).

Leaf senescence was highest at the 0 kg N ha^{-1} at all the sampled periods in both seasons (Table 3). In most cases, leaf senescence was lowest at 120 kg N ha^{-1} although, there were no statistical differences between

Table 4: Total number of leaves per plant at different growth stages, leaf senescence and grain yield of nine maize varieties planted in 1996 and 1998 seasons

	Total number of leaves per plant at						Leaf senescence (%)										Grain yield mg ha^{-1}	
	23DAP		37DAP		50% anthesis		23DAP		37DAP		50% anthesis		74 DAP		88 DAP			
Varieties	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998
S 9325-SR	5.10	4.85	9.90	9.93	19.90	19.34	37.02	45.83	35.82	46.16	46.24	50.63	61.36	57.61	74.03	69.49	3.76	3.12
TZL COMP3 C1	4.95	4.91	9.85	9.86	19.85	19.35	33.11	44.02	32.88	42.22	42.50	45.92	52.21	53.22	61.78	59.66	4.67	3.98
TZL COMP4 C1	5.04	4.89	10.39	10.36	20.39	20.22	35.11	46.45	34.83	42.62	46.16	47.41	56.18	53.38	63.95	57.43	4.17	3.93
TZB-SR	4.92	4.80	10.11	9.98	20.11	19.95	35.15	46.67	35.72	44.05	42.86	49.45	54.31	55.73	62.39	65.28	4.17	3.67
AK9328DMRSR	5.08	4.77	10.68	9.99	20.68	19.99	37.23	47.44	35.91	43.91	44.90	49.92	55.83	53.00	66.66	62.83	3.79	3.43
AC93TZLCOMP1W	5.11	4.68	9.77	9.95	19.77	19.54	34.47	43.63	35.68	42.52	45.44	48.75	56.69	55.70	66.13	66.57	3.75	3.58
IK9129-SR	5.29	4.85	9.97	10.06	19.97	20.02	34.54	47.22	34.45	45.03	42.94	48.14	52.93	53.62	63.81	60.86	3.58	3.41
ACR 9222-SR	5.36	5.13	10.39	10.43	20.39	20.08	37.49	45.85	37.74	44.34	47.51	49.95	56.92	55.35	68.83	64.38	3.87	3.79
8644-27	5.70	5.04	10.44	10.04	20.44	19.35	29.08	43.81	34.37	41.73	44.06	45.86	53.91	52.77	64.55	64.47	4.54	3.64
Means	5.17	4.88	10.16	10.06	20.16	19.76	34.80	45.66	35.27	43.62	44.73	48.45	55.59	54.49	65.79	63.44	4.03	3.62
S.E	0.13	0.09	0.13	0.17	0.13	0.18	1.21	1.20	0.61	0.91	0.98	0.96	1.20	0.94	1.73	1.37	0.11	0.22
Prob. of F	0.01	0.05	0.01	ns	0.01	0.01	0.01	ns	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	ns
LSD	0.478	0.248	0.473	0.486	0.473	0.667	4.482	3.353	2.269	3.384	3.638	3.559	4.448	3.491	6.394	5.083	0.390	0.611

DAP = Days after planting and ns = non significantly different at P=0.05.

means of leaf senescence at 90 and 120 kg N ha^{-1}. Varieties TZLCOMP3C1, TZLCOMP4C1, IK9129-SR and 8644-27 had lower percentage leaf senescence while S1325-SR and ACR9222-SR had the highest percentage leaf senescence in both seasons (Table 4).

In 1996 there were significant ($p = 0.01$) increase in grain yields with increase N rates with the highest mean value of 5.5 Mg ha^{-1} at 120 kg N ha^{-1} (Table 3). In 1998 however, there were no differences between the 0 and 30 kg N ha^{-1} also 90 and 120 kg N ha^{-1} did not differ at $p = 0.05$. In both years, the highest mean values of grain yield was obtained from TZL COMP3 C1, TZL COMP4 C1, TZB-SR, AK9328DMRSR and 8644-27, while IK9129-SR and S 9325-SR had the lowest mean values of yield.

DISCUSSION

The significant differences observed in total leaf number among N rates are indications that the number of leaves produced by maize plants is affected by N rates. The non significant difference observed between N rates in 1998 season at 23 and 37 DAP could be due to low amount of rain at that period which made the plants to underutilize the applied N at the earlier stages of growth of the plants. Senescence is known to increase with stress factors, which include drought or near drought conditions and low levels of soil nutrients [2, 9].

Increasing the N rates resulted in more leaves produced per plant with the highest mean values in most cases at 120 kg N ha^{-1}. This shows that higher N rates enhanced the vegetative growth of the maize and increased the source capacity of the plants by the number of leaves produced per plant. This agrees with Aluko and Fischer [6], who reported increased source capacity with increase in nitrogen levels. The differences observed among the varieties in leaf number per plant indicate that the varieties had different genetic potentials to utilize the applied N. Some were more efficient in utilizing the N to produce leaves than others.

The significant difference observed among the data on leaf number from the two seasons can be attributed to the difference in the amount of rainfall in the two seasons during the month of August, which was higher in the first season. Rainfall affects soil moisture which in turn affects N uptake and the distribution of N in plants [1, 3]. Utzurrum *et al*. [9], water stress leads to loss of green leaves and N is remobilized from leaves to grains. They reported that application of N just before anthesis may reduce leaf senescence, contribute to dry matter production during grain filling period and hence increase grain yield. The moisture stress experienced in the second season could be the reason for the significant interaction between the N rates and season. The significant interactions between N rates and varieties at 37 DAP and at 50% anthesis periods in 1996 when there was sufficient rainfall is an indication that under favorable conditions, the varieties may behave differently. The non significant interaction between N rates and varieties in 1998 season for both total number of leaves and leaf senescence shows that all the varieties performed in a similar pattern across the N rates. This implies that under unfavorable weather conditions, the varieties may behave in a similar pattern. Similarly, the performance of the varieties in terms of number of leaves across the two seasons was the same.

Significant differences between N rates for percentage leaf senescence as observed are indications that the amount of N in the soil affects the level of leaf senescence in maize [5]. This effect seems to be more at the earlier stages of the plant development but as the plants approach maturity, the effects of N stress on senescence are reduced. More stress factors tend to combine to produce more senescence as noticed in the second season, where both N and moisture stress factors acted to increase the level of leaf senescence from the juvenile stages of the plants up to maturity.

At all the sampled periods, percentage leaf senescence was highest at 30 kg N ha^{-1}, subsequent addition of N resulted in decline in the level of leaf senescence with the lowest percentage of leaf senescence at 120 kg N ha^{-1}. This agrees with Berchtold *et al*. [10], who observed higher senescence in plots with low nutrients rate. This shows that leaf senescence is higher at lower levels of N than at higher levels of N. Therefore by reducing N stress, leaf senescence can also be reduced. By increasing the level of N in the soil, there will be more green leaves maintained on the plants. Since there are more leaves produced at higher N rates and less leaf senescence at the higher N rates, those higher N rates will have higher photosynthetic capacity than the lower N rates. This may partly explain why grain yield are higher at higher N rates.

The differences in the percentage leaf senescence with maize varieties are indications that some varieties maintained their green leaves longer than others. Thus there are differences in photosynthetic capacity among the varieties. Such varieties as S9325-SR and ACR922-SR were among the varieties with the highest percentage leaf senescence but on the other hand, they were among the varieties with lowest grain yield. The higher photosynthetic capacity in varieties with lower percentage leaf senescence was further confirmed by the fact that varieties like 8644-27, TZLCOMP3C1 and TZLCOMP4C1, which were among varieties with the highest grain yield and which also had low percentage leaf senescence. This agrees with Guie and Wassom [11], who reported a negative correlation between leaf senescence and grain yield.

CONCLUSIONS

Both leaf number and percentage leaf senescence were affected by N rates. With increased N rates up to 120 kg N ha^{-1}, there was increased number of leaves and decrease in percentage leaf senescence at the different growth stages. This shows that increased N rates up to 120 kg N ha^{-1} resulted in higher source capacity. Therefore, higher N rates can help in maintaining green leaves longer on maize plants which can lead to higher yield as there may be longer period for growth and grain filling. These will ultimately lead to higher grain yield.

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