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Mineral Composition of Dry Season Maize (*Zea mays* L.) in Response to Varying Levels of Nitrogen, Phosphorus and Irrigation at Kadawa, Nigeria

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Abstract: A field experiment was conducted in the 1998 dry season at Kadawa, Nigeria to determine the effect of different levels of nitrogen (0, 60, 120 or 180 kg N ha^{-1}), phosphorus (0, 20 or 40 kg P ha^{-1}) and irrigation (0.6, 0.8 or 1.0 IW/CPE ratio) on nutrient concentration and accumulation in maize. The experiment was a split plot design with four replications, the main plot was nitrogen level x irrigation frequency and the sub-plot being phosphorus level. Varying levels of nitrogen and phosphorus influenced the concentration of nutrients in the grain and stover significantly. Nutrient concentration either increased or decreased with increasing N and P application levels. However, increasing levels of nitrogen and phosphorus application either significantly enhanced the accumulation of nutrients in the grain and stover or failed to influence nutrient accumulation and in the same vein the uptake of nutrients by the maize plant. Irrigation frequency influenced nutrient concentration and accumulation in maize very minimally but increase frequency significantly increased concentration and accumulation for certain nutrients. Nitrogen x phosphorus interactions were significant for P concentration and N accumulation in maize grain.

Key words: Dry season · Irrigation · Nitrogen · Phosphorus · Nutrient concentration · Nutrient · accumulation · *Zea mays* L

INTRODUCTION

The uptake of nutrients and their distribution to different parts of the maize plants have been found to vary primarily with the fertility of the native soil, application of chemical fertilizers, the growth stage of the plant and the environmental conditions [1]. Several workers found that fertilization with nitrogen, for example, increased the concentrations of nitrogen and phosphorus in the plant tissue [2], as well as increasing potassium concentration in the plant [3]. Chemical analysis of plant tissue is one of the most reliable tools for estimating fertilizer needs of plants. It suggests some relationship between nutrient supply and the chemical composition of the plant. Munson and Nelson [4] have since recognised leaf analysis as a valuable tool for diagnosing plant nutritional problems.

There is a close relationship between soil moisture and nutrient availability. It is generally believed that the greatest benefit from fertilizer application can be derived under irrigated conditions, where water supply is least likely to limit nutrient uptake. With adequate nutrient supply, plants that are limited in growth due to moisture stress would have a higher content of mineral nutrients than plants under comparable fertility but not limited in growth by moisture supply [5]. In the present investigation, the effects of different levels of nitrogen and phosphorus on nutrient concentration and accumulation in maize grain and stover were studied under varying irrigation regimes.

MATERIALS AND METHODS

The study was conducted in 1998 at Kadawa Irrigation Research Station of the Institute for Agricultural Research, Samaru-Zaria, Nigeria. Kadawa (lat. 11°39′ N; long. 08° 02′ E; 500m above sea level) is semi-arid location in the Sudan savanna zone.

An extra-early maize variety, TZEE-W, was used for the study. The experiment was a split-plot design with four replications. The main plot consisted of N-fertilizer rates (0, 60, 120 or 180 kg ha^{-1}) x irrigation regimes

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(0.6, 0.8 or 1.0; Irrigation Water (IW): Cumulative Pan Evaporation (CPE) ratios, while the sub-plot consisted of the P-fertilizer rates (0, 20 or 40 kg ha^{-1}). Planting was done on 19 March 1998 using three seeds per hill at a spacing of 75cm by 25cm and thinned to one plant per stand at 2 weeks after planting (WAP), to give a population of 53, 300 plants per hectare. The plot size was eight rows (75cm apart), which were 6m long. A basal dressing of potassium at the rate of 50 kg K ha^{-1} was given to all plots using muriate of potash (60 K_20) while N and P were applied in forms of urea (46% N) and single superphosphate (18% P_20_5), respectively. N was applied split, first half with all of P and K given at planting and the second half top-dressed at 4 WAP.

Irrigation was given weekly until 4 WAP before treatment was imposed. A uniform depth of irrigation water (IW) was taken to be 50% of the available moisture and an effective root zone depth of 75cm was assumed for maize for the purpose of the present study. A cut-throat flume calibrated to give the head was placed appropriately on the farm laterals. Ratios of 0.6, 0.8 and 1.0 would require CPE to build up to 78, 58 and 47mm, respectively. Harvesting was done about 85 days after sowing, after the husks had turned brownish.

Samples for plant tissue analysis were taken from each of the plots, dissected into grains, cobs and stover; and oven-dried at 70oC to constant weight before grinding with a Wiley mill to pass through a 0.5mm sieve. The samples were chemically analysed to determine their contents of nitrogen, phosphorus, potassium, calcium, magnesium and sodium. Concentrations of all nutrients were expressed on a dry weight basis and the nutrient uptake and accumulation were calculated using the respective plant dry weights.

The total nitrogen concentration was determined by the micro-Kjeldahl method [6]. For the determination of the remaining elements, plant samples were first subjected to wet digestion[7]. From the digest various elements were read using the relevant procedures. P contents were determined colorimetrically using a spectrophotometer. The procedure involved the use of Vanado-molybdate yellow method [8]. A flame photometer was used for the determination of K and Na in plant tissue [9]. Atomic adsorption spectrophotometer was used to determine Ca, Mg and Na [10]. All the data collected were subjected to analysis of variance in order to test for the significance of the treatment effects and where found to be significant; the means were partitioned using the Duncan's Multiple Range Test [11].

RESULTS

Fertilizer N application up to 60 kg N ha^{-1} significantly increased the concentrations of N, P, Ca and Mg in maize grain, but beyond this application level, the concentration of each of these nutrients either declined or remained unchanged (Table 1). Grain N concentration increased by 13.8 % with application of 60 kg N ha^{-1}. In the case of K concentration in the grain, it declined significantly by 8.3 % as N application level increased from the lowest level up to 120 kg N ha^{-1}. Nutrient concentrations in the grain responded differently to

Table 1: Nutrient concentration (g kg^{-1}) in maize grain as influenced by nitrogen, phosphorus and irrigation levels at Kadawa, Nigeria, 1998 dry season

Treatment	N	P	K	Ca	Mg
Nitrogen (kg N ha^{-1})					
0	15.9b[1]	2.4d	3.6a	0.35b	1.06b
60	18.1a	3.3a	3.4b	0.36ab	1.08a
120	18.3a	2.9b	3.3bc	0.38a	1.04bc
180	18.2a	2.7c	3.3bc	0.24c	1.03c
SE±	0.53	0.06	0.06	0.01	0.009
Phosphorus (kg P ha^{-1})					
0	16.9b	2.7b	3.4	0.36a	1.12a
20	17.5ab	2.8b	3.4	0.33b	1.04b
40	18.5a	3.1a	3.4	0.31b	0.99c
SE ±	0.35	0.04	0.03	0.007	0.006
Irrigation (IW/CPE ratio)					
0.6	16.7b	3.0a	3.5	0.39a	1.03b
0.8	17.8ab	3.1a	3.4	0.32b	1.11a
1.0	18.3a	2.5b	3.4	0.29c	1.02b
SE ±	0.46	0.05	0.05	0.009	0.008

[1]Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 2: Nutrient concentration (g kg^{-1}) in maize stover as influenced by nitrogen, phosphorus and irrigation levels at Kadawa, Nigeria, 1998 dry season

Treatment	N	P	K	Ca	Mg
Nitrogen (kg N ha^{-1})					
0	0.47b[1]	0.22	1.53	0.15c	0.14
60	0.47b	0.15	1.45	0.29b	0.15
120	0.49b	0.18	1.51	0.31ab	0.18
180	0.64a	0.16	1.43	0.33a	0.16
SE±	0.018	0.028	0.07	0.011	0.018
Phosphorus (kg P ha^{-1})					
0	0.49b	0.18	1.56a	0.257b	0.16
20	0.49b	0.19	1.42b	0.279a	0.16
40	0.57a	0.18	1.46b	0.276a	0.16
SE ±	0.014	0.011	0.012	0.0028	0.005
Irrigation (IW/CPE ratio)					
0.6	0.47b	0.15	1.47	0.266	0.16
0.8	0.53a	0.18	1.46	0.273	0.16
1.0	0.54a	0.21	1.51	0.274	0.15
SE ±	0.016	0.024	0.061	0.0095	0.016

[1]Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test

fertilizer P application. N and P concentrations in the grain increased 9.5 % each when 40 kg P ha^{-1} was applied. Ca and Mg concentrations declined significantly with P application up to 20 and 40 kg P ha^{-1}, respectively. Increased irrigation up to 1.0 IW/CPE ratio increase N concentration by 9.6 % while P concentration declined by 20.0 %.

Increased fertilizer N application caused 36.2 % and 120.0 % increases in N and Ca concentrations in maize stover up to 180 and 120 kg N ha^{-1}, respectively (Table 2). There were no changes in P, K and Mg concentrations in the stover. Stover N did not increase until the highest N level (i.e. 180 kg N ha^{-1}) was applied. Application of 40 kg P ha^{-1} increased N and Ca concentrations in the stover by 16.3 % and 7.4 %, respectively; while the same P application decreased K concentration in stover by 9.0 %. Stover N was increased significantly by 12.7 % by irrigation frequency up to 0.8 IW/CPE ratio but P, K, Ca and Mg in the stover did not respond to irrigation frequency.

Nutrient accumulation in the grain was influenced by nitrogen and phosphorus application; just as irrigation frequency influenced N uptake in the grain (Table 3). Increasing levels of N application significantly increase the accumulation of N, P, K and Mg in the grain up to 180 kg N ha^{-1}. Accumulation of N, P, K and Mg in maize grain was increased substantially by 237.3, 228.9, 162.7 and 178.2 % respectively when the highest level of N was applied. Application of 40 kg P ha^{-1} increased N and K accumulation in the grain by 22.5 and 21.2 %, respectively. An irrigation frequency of 1.0 IW/CPE ratio caused increased accumulation of N in the grain by 26.0 %.

Increased N application caused significant increase in accumulation of N, P, K, Ca and Mg in the stover (Table 4). Accumulation of N in the stover was increased 228.6 % when 180 kg N ha^{-1} was applied while the accumulation of P, K, Ca and Mg markedly increased 70.9, 102.1, 306.2 and 165.9 % respectively when 120 kg N ha^{-1} was applied. Application of 40 kg P ha^{-1} produing the highest accumulation of N in the maize stover, which increased 28.5%. There was no variation in the accumulation of each of the other nutrients in the stover with P application. It was only the accumulation of P in the stover that was significantly influenced by irrigation frequency; with the highest irrigation frequency producing 40.5% increase in P accumulation in the stover.

Total uptake of nutrients by the maize plant was influenced by nitrogen application (Table 5). Uptake of N, P, K, Ca and Na by the plant increased significantly with increasing in N application. Application of 180 kg N ha^{-1} increased N, K and Na uptake by 217.1, 127.9 and 222.7 % respectively; while in the case of P, Ca and Mg, application of 120 kg N ha^{-1} increased uptake by 143.3, 282.9 and 145.0 % respectively. Total plant N uptake increased 23.3 % with P application of 40 kg P ha^{-1}, while the uptake of the other nutrients was not influenced by P application. An irrigation frequency of 1.0 IW/CPE ratio gave the highest uptake of N, K and Na by the maize plant.

There was significant ($p<0.05$) nitrogen x phosphorus interaction for P concentration in maize plant (Table 6). In

Table 3: Nutrient accumulation (kg ha^{-1}) in maize grain as influenced by nitrogen, phosphorus and irrigation levels at Kadawa, Nigeria, 1998 dry season

Treatment	N	P	K	Ca	Mg
Nitrogen (kg N ha^{-1})					
0	15.0d[1]	2.25c	3.43d	0.33c	1.01c
60	29.8c	5.43b	5.74c	0.59b	1.77b
120	44.2b	7.11a	7.73b	0.91a	2.52a
180	50.6a	7.40a	9.01a	0.63b	2.81a
SE±	1.53	0.51	0.421	0.063	0.246
Phosphorus (kg P ha^{-1})					
0	31.1c	5.36	5.85b	0.611	2.01
20	35.5b	5.71	6.50ab	0.613	2.04
40	38.1a	5.58	7.09a	0.620	2.02
SE ±	0.74	0.46	0.283	0.0035	0.014
Irrigation (IW/CPE ratio)					
0.6	31.2b	5.27	6.16	0.68	1.88
0.8	34.2b	5.86	6.32	0.59	2.10
1.0	39.3a	5.52	6.96	0.57	2.10
SE ±	1.33	0.44	0.364	0.055	0.213

[1]Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 4: Nutrient accumulation (kg ha^{-1}) in maize stover as influenced by nitrogen, phosphorus and irrigation levels at Kadawa, Nigeria, 1998 dry season

Treatment	N	P	K	Ca	Mg
Nitrogen (kg N ha^{-1})					
0	5.87c[1]	2.78b	18.8c	1.92c	1.67c
60	9.46b	3.21b	30.1b	6.22b	3.11b
120	12.66b	4.75a	38.0a	7.80ab	4.44a
180	19.29a	4.64a	41.9a	9.72a	4.78a
SE±	1.19	0.298	1.61	0.877	0.421
Phosphorus (kg P ha^{-1})					
0	11.05b	3.96	34.8a	6.08	3.50
20	10.21b	3.56	28.1b	6.34	3.25
40	14.20a	4.02	33.7a	6.83	3.75
SE ±	0.992	0.211	1.72	0.316	0.246
Irrigation (IW/CPE ratio)					
0.6	10.98	3.28b	31.6	6.22	3.58
0.8	11.54	3.65b	30.9	6.27	3.42
1.0	12.95	4.61a	34.1	6.76	3.50
SE ±	1.03	0.258	1.40	0.76	0.365

[1]Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 5: Total above-ground nutrient uptake (kg ha^{-1}) as influenced by nitrogen, phosphorus and irrigation levels at Kadawa, Nigeria, 1998 dry season

Treatment	N	P	K	Ca	Mg	Na
Nitrogen (kg N ha^{-1})						
0	23.4d[1]	5.38c	24.7d	2.40c	3.13c	0.22c
60	43.7c	9.49b	39.7c	7.08b	5.42b	0.37b
120	61.2b	13.09a	51.3b	9.19a	7.67a	0.43b
180	74.2a	12.82a	56.3a	10.70a	8.65a	0.71a
SE±	3.58	0.807	1.29	0.632	0.404	0.028
Phosphorus (kg P ha^{-1})						
0 45.5c	9.98	44.5a	6.96	6.00	0.42	
20	50.2b	10.08	39.1b	7.24	6.25	0.43
40	56.1a	10.52	45.4a	7.84	6.41	0.44
SE ±	1.29	0.246	0.81	0.337	0.197	0.014
Irrigation (IW/CPE ratio)						
0.6	45.7b	9.23	41.67b	7.21	6.03	0.35c
0.8	49.8ab	10.37	41.69b	7.20	6.02	0.44b
1.0	56.3a	10.99	45.64a	7.62	6.61	0.51a
SE ±	3.10	0.699	1.12	0.548	0.35	0.024

[1]Values followed by the same letter(s) within the same column and treatment group are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 6: Interaction between nitrogen and phosphorus on P concentration (g kg^{-1}) in maize grain at Kadawa, Nigeria, 1998 dry season

	Phosphorus (kg P ha^{-1})		
Nitrogen (kg N ha^{-1})	0	20	40
0	2.0f[1]	2.3ef	3.0bc
60	3.2b	3.2b	3.6a
120	2.8cd	3.0bc	3.0bc
180	2.6de	2.8cd	2.7cd
SE ±	0.104		

[1]Values followed by the same letter(s) are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 7: Interaction between nitrogen and phosphorus on N accumulation (kg ha^{-1}) in maize grain at Kadawa, Nigeria, 1998 dry season

	Phosphorus (kg P ha^{-1})		
Nitrogen (kg N ha^{-1})	0	20	40
0	13.7g[1]	13.3g	17.9fg
60	25.3ef	27.3e	36.8d
120	40.6cd	45.5bc	46.4bc
160	44.8bcd	55.8a	51.3b
SE ±	5.652		

[1]Values followed by the same letter(s) are not significantly different at the 5% probability level according to the Duncan's multiple range test

Table 8: Interaction between nitrogen and irrigation on total accumulation of K (kg ha^{-1}) in maize plant at Kadawa, Nigeria, 1998 dry season

	Irrigation (IW/CPE ratios)		
Nitrogen (kg N ha^{-1})	0.6	0.8	1.0
0	25.4f[1]	21.0f	27.6f
60	38.0e	43.4de	37.9e
120	47.7cd	42.7de	63.5a
180	55.6b	59.7ab	53.6bc
SE ±	2.24		

[1]Values followed by the same letter(s) are not significantly different at the 5% probability level according to the Duncan's multiple range test

the absence of N application, P application did not quite influence P concentration in the grain. However, with application of 60 kg N ha^{-1}, response to P application was significant up to 40 kg P ha^{-1}; while with the two high N levels, P concentration responded up to 20 kg P ha^{-1} only.

Nitrogen x phosphorus interaction significantly ($p<0.01$) influenced N accumulation in the grain (Table 7). Under either 0 or 40 kg P ha^{-1}, response to N application was limited to 120 kg N ha^{-1}; whereas under the 20 kg P ha^{-1} level, response to N application was significant up to 180 kg N ha^{-1}. The highest N accumulation was from a combination of 180 kg N ha^{-1} and 20 kg P ha^{-1}.

Nitrogen x irrigation frequency interaction significantly ($p<0.01$) influenced total plant accumulation of K (Table 8). Under the 0 and 60 kg N ha^{-1} application levels, total plant accumulation of K did not respond to variation in irrigation frequency. But with the application of 120 and 180 kg N ha^{-1}, total plant accumulation of K was highest at 1.0 and 0.8 IW/CPE ratios, respectively.

DISCUSSION

Plant tissue analysis has been used to reveal the deficiency, adequacy or excessiveness status of various nutrient elements in a soil-plant system. Unfortunately, a serious limitation to its utility is the dynamic nature of nutrient concentration in plants in relation to their availability in the soil, either in the native state or through their addition to the soil in fertilizer form. Nevertheless, the important part that analyses of soil and plants play in decision-making regarding fertilizer type and rates of application cannot be ignored. Gibson [12] stressed the importance for the farmer of analyses being reliable, as is the need for well-based interpretation of analytical results, in order that the yield responses to fertilizer can be foreseen.

Dilution effect arising from substantial increase in grain dry weight would partly account for the observed lack of response or negative response of N, P, Ca and Mg concentration in maize grain to N application levels higher than 60 kg N ha^{-1}. We have earlier reported from another aspect of this investigation substantial increases in grain yield primarily arising from N application and secondarily from P application [13]. N and P application had a much greater impact on maize grain yield than on nutrient concentration in the grain. This would seem to explain the similarity in the response of nutrient concentrations in the stover, even though the N concentration was the highest for the highest level of N application. About a half century ago, Nelson [14] had reported that when nutrients such as N, P, or K were applied on maize, it is difficult to predict whether or not the concentration of a given element in the plant will increase, remain unchanged, or even decrease. What would take place would very much depend upon the influence of the other nutrients that are present in the soil and the direct or indirect effects of the applied nutrient has on increased growth and yield It is certain that the various factors are not likely to act independently, rather they will act in concert with each other to produce the observed effects either in antagonism or synergy. For instance, Grunes and Krantz [15] found that nitrogen fertilization of oats (*Avena sativa*) led to increased concentrations of N, P and K in the plant tissue. Russell [16] had noted that the concentration of cations in most plant tissues is a function of the crop and fairly independent of the soil or fertilization; even though Power [17] later asserted that dry soil conditions severely reduce the supply of mobile ions to roots and impede transformation of soil nutrients to plant-available form.

A certain degree of synergy between nitrogen and phosphorus has been reported for some field crops. Some workers have reported that the addition of nitrogen influenced the uptake by the plant of soil and fertilizer phosphorus sources. This phenomenon can be explained by the fact that the supply of nitrogen enhances the production of small roots and root hairs, which in turn facilitated the high absorbing capacity per unit of dry weight. N and P uptake by maize stover in response to N and P application was in close bearing with the response of total plant dry matter to these two nutrients as had recently been reported by Hussaini *et al.* [18].

Barber and Olson [19] found that with the application of fertilizer nitrogen, the yield, percent nitrogen content and the uptake of other nutrients were increased. Nutrient accumulation in the maize grain was greater than that in the other components of the plant. This can be attributed to the mobilization of large proportions of nitrogen and phosphorus and a small proportion of potash, from other parts of the plant to the grain as the grain developed. The levels of soil moisture supply or soil moisture stress exerted considerable influence on the efficiency of water use and also upon nutrient uptake and growth of the maize plant [14]. Soil moisture status thus has a strong influence on the accumulation of mineral nutrients in the plant.

It is pertinent to make reference to the work on okra (*Abelmoschus esculentus* L. Moench) at Samaru, Nigeria that was reported by Ogunlela *et al*. [20], who concluded that even though leaf analysis is now a more widely used research tool than hitherto, there is need to pay due cognizance to factors such as methods of plant sampling, plant age and varietal differences in result interpretation.

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