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NUTRIENT BALANCE AND INTERACTION BETWEEN Fe, Mn, Zn OR Cu MICRONUTRIENTS AND (N + P) MACRONUTRIENTS ON FORAGE SORGHUM

By

Abd El-Salam, A.A.* and El-Sheikh, F.T.Z.M.**

* Dept. of Soil Science and Agricultural Chemistry; ** Dept. of Agronomy; Fac. of Agriculture Moshtohor, Zagazig Univ., Egypt.

ABSTRACT

Experiments were conducted in Moshtohor Research and Experimental Center during 1992 and 1993 seasons to assess four NP macronutrient treatments (N_0P_0, N_1P_1 "30 kg N + 3.5 kg P", N_2P_2 "60 kg N + 7 kg P" and N_3P_3 "90 kg N + 10.5 kg P"/fad.) applied in soil, and five micronutrient treatments (0, 72 g Fe, 60 g Mn, 48 g Zn and 18 g Cu/fad.) sprayed in chelated forms dissolved in 600 l./fad.

Macronutrients (N+P) increased plant height, fresh and dry weight of plant organs, number of stems/m^2 and green and dry forage yields in the 1st and 2nd cuts. The highest values resulted from (N_3P_3). All positive effects were reflected in increased total forage yield of up to 66% green and 67% dry forage.

All parameters of growth or yield were increased by up to 24% by Zn application. Forage yield and some growth parameters were increased in some cases by 14% due to Fe application and 15% due to Mn. No response occurred to Cu application.

There were cases of interaction when Fe or Mn showed response only in presence of high levels of NP. The practical implication refers the necessity to apply Zn under all conditions of macronutrients; and Fe or Mn only where high levels macronutrients are applied. With no need for Cu application. In all cases, consideration should be given to the actual available contents of nutrients in the soil itself.

INTRODUCTION

One of the limitations in efficient livestock production in Egypt is the lack of adequate amounts of high quality forage in summer. Forage sorghum is an important summer forage crop. Balanced fertilization is important to increase forage yield and quality of sorghum. Nitrogen is the most limiting nutrient for grass forage production. Many investigators found that N application increased forage yield of sorghum (El-Keredy *et al.*, 1986; Geweifel and El-Khawaga, 1991; Ali and Sarhan, 1992 and Abdel-Gawad, 1993).

Phosphorus is the second important nutrient and is not easily lost from the soil like nitrogen. Large amounts of P are applied to the old arable soils of Egypt. Nasr *et al.* (1984) found that applying P gave no positive results in increasing forage yields of Sudan grass. According to Olsen *et al.* (1954) contents of more than 10 $\mu g\ P\ g^{-1}$ in soil indicate no difinite need to P application. Follett *et al.* (1991) reported that Colorado loams having about 11 $\mu g\ P\ g^{-1}$ (extractable by ammonium bicarbonate -DTPA) may need small application of P for sorghum. However, applying P in combination with N gave more positive results with millet forage, compared with N only (Ghobrial *et al.*, 1984). Sharaan and Abdel-Gawad (1986) applied the 3 main macronutrients N, P and K to forage sorghum and obtained positive yield increases.

Application of micronutrients such as Fe, Mn, Zn or Cu has become an important aspect of crop production. This is mainly due to the high intensive patterns of crop production in the old established arable soils in Egypt and to expansion in reclaiming and putting new desert lands under agriculture. Foliar application of micronutrients is widely used by many farmers and reported by a number of scientists (Ohki, 1984; Khadr *et al.*, 1988; Barsoum and Abdel-Gawad, 1989; Wahdan, 1989 and Khalil *et al.*, 1991).

The purpose of this study was to evaluate the interaction effect of macro and micronutrients on growth and forage yield of sorghum..

MATERIALS AND METHODS

Two field experiments were carried out at the Agricultural Research and Experimental Center, Faculty of Agriculture Moshtohor, Zagazig University, during 1992 and 1993. The aim was to assess the effect of foliar application of micronutrients Fe, Mn, Zn or Cu with or without the macronutrients N+P, on the forage yield of sorghum [*Sorghum bicolor* (L.) Moench].

The soil was a clay having an alkaline reaction. Its properties are listed in Table (1).

Table (1): Characteristics of the Moshtohor clay soil of the experiment.

EC. (of saturated paste extract d Sm^{-1})*	3.0
pH (1:2.5 soil water suspension)	8.1
Organic matter (%)	2.0
Available nutrients (µg g^{-1}):	
N (Nitrate-N) KCl-extractable	17.0
P ($NaHCO_3$-extractable)	12.0
K (neutral NH_4-acetate extractable)	200.0
Fe (DTPA - extractable)	10.0
Mn (DTPA - extractable)	8.5
Zn (DTPA - extractable)	2.0
Cu (DTPA - extractable)	2.2

* : EC : electric conductivity measured as d Sm^{-1} "decisiemens/m i.e. mmhos/cm/25°C".

The experimental design was a randomized complete block with three replications. Two factors, and their interaction were under study in such a design.

Factor A: Macronutrient soil application: being 4 NP formulas as follows: None (N0P0); N_1P_1 (30 kg N + 3.5 kg P $fad.^{-1}$); N_2P_2 (60 kg N + 7.0 kg P $fad.^{-1}$) and N_3P_3 (90 kg N + 10.5 kg P $fad.^{-1}$).

(Fertilizer sources were urea 46% N and Ca. superphosphate 6.3% P or 15% P_2O_5 applied through soil).

Factor B: Micronutrient foliar application: being 5 treatments as follows:

1- None (spray with tap water).
2- Fe at 72 g Fe/cut/fad. (60 mg Fe $l.^{-1}$ spray solution).
3- Mn at 60 g Mn/cut/fad. (50 mg Mn $l.^{-1}$ spray solution).
4- Zn at 48 g Zn/cut/fad. (40 mg Zn $l.^{-1}$ spray solution).
5- Cu at 18 g Cu/cut/fad. (15 mg Cu $l.^{-1}$ spray solution).

Micronutrients were in forms of chelated (organic) materials (Fe-EDDHA, 6% Fe; Mn-EDTA, 15% Mn; Zn-EDTA, 14% Zn and Cu-EDTA, 14% Cu). Sprays were done twice (one for each cut), each at 600 L. fad^{-1}. The first spray was 4 weeks after planting and the second was 3 weeks after the 1st cut. Phosphorus was applied before seeding. Nitrogen was applied in 2 equal doses; the first when plants were 5-10 cm tall the second was after the 1st cut (62 days after seeding).

Sorghum cultivar was Sudan grass hybrid cv pioneer 988. Seeding was done by drilling on June 14th and 18th in 1992 and 1993 season, respectively at a rate of 20 kg fad^{-1}. The plot area was 10.5 m^2 (3.0x3.5 m^2) having 15 rows of 3.5 m length and 20 cm width. In both seasons, the preceding crop was wheat. The usual cultural practices were used. Two cuts were taken. the first was 8½ weeks after planting, the second was 7½ weeks later. With each cut, ten plants were randomely taken to estimate the followings: plant height (cm), fresh and dry weight of leaves and stems/plant (g), total fresh and dry weight/plant (g) leaves : plant ratio, number of stems/m^2 and dry matter content (%). Green and dry forage yields per faddan were measured (ton).

Statistically analysis were done according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

1- Plant height and fresh and dry weight/plant:

a) Response to macronutrients application:

There were significant responses to N + P with all characters and in both cuts asserting the decisive need for N and P to sorghum production in this soil (Table, 2). Regarding the 1st cut, increases in plant height due to adding (N+P) ranged from 13% to 45%. Increases in fresh or dry weight/plant were much higher. The range of increase in fresh weight of leaves/plant was 21% to 64%. Comparable range of increase for stems weight was 17% to 70%; and for total fresh weight it was 18% to 70%.

A similar pattern of response to (N+P) application occurred in the 2nd cut. Ranges of increase were 19% to 47% for plant height; 13% to 46% for leaves fresh weight/plant; 13% to 68% for stems fresh weight/plant and 13 to 69% for total fresh weight/plant.

The pattern of response of dry weight of plant organs was generally similar to that regarding fresh weight in both cuts (Table, 2). The response indicates a progressive increase in plant growth to rates as high as N_3P_3 showing significant increments of height and weight. This reflects a need for high (N+P) to obtain higher and greater forage yield. Increased plant growth shown by increased yield, is most certainly a function of increased root network which helps uptake of more nutrients. Such a condition helps in minimizing N loss by leaching. Increased weight per plants due to application of high (N+P) or N to other soils were reported by Ashoub *et al.* (1987) with maize and El-Khawaga and Geweifel (1991) working with sorghum.

b) Response to micronutrients application:

There was a number of significant responses in the 1st cut. Applying Zn caused 8, 22, 24, 24, 26, 24 and 24% increases in plant height, leaves fresh weight, stems fresh weight, total fresh weight/plant, leaves dry weight, stems dry weight and total dry weight/plant, respectively. Comparable increases for the same respective characters in the 2nd cut were 9, 22, 17, 18, 17, 14 and 14%. With all characters, and in both cuts, Zn effect was significant, asserting a

Table (2): Interaction of macronutrients (N + P) and some micronutrients on growth characters and yield components of sorghum in two cuts, combined over 1992 and 1993 growing seasons.

Characters	Cuts / Macro-nutrients*	1st cut: Micronutrients** (g/cut/fad.) 0	72 Fe	60 Mn	48 Zn	18 Cu	Mean	2nd cut: Micronutrients** (g/cut/fad.) 0	72 Fe	60 Mn	48 Zn	18 Cu	Mean
1- Plant height (cm)	N_0P_0	143.3	146.7	145.0	151.7	143.3	146.0	135.0	139.3	139.3	147.5	137.7	139.8
	N_1P_1	160.3	165.8	169.2	172.7	160.7	165.7	159.2	171.7	168.3	171.8	161.7	166.5
	N_2P_2	189.5	194.3	199.2	209.2	192.5	196.9	183.3	195.0	195.8	203.3	187.5	193.0
	N_3P_3	205.8	208.5	217.5	221.0	204.2	211.4	200.8	205.0	207.5	215.0	201.7	206.0
	Mean	174.7	178.8	182.7	188.6	175.2	180.0	169.6	177.8	177.7	184.4	172.1	176.3
	L.S.D. at 0.05 for:	Macronutrients = 3.69 Micronutrients = 3.10 Interaction = N.S.						Macronutrients = 4.94 Micronutrients = 3.60 Interaction = N.S.					
2- Fresh weight of leaves/ plant (g)	N_0P_0	13.47	13.27	15.75	15.63	13.32	14.29	13.63	16.70	17.55	17.70	16.50	16.42
	N_1P_1	15.63	17.17	18.08	19.67	16.00	17.31	18.17	18.93	18.00	19.67	18.12	18.58
	N_2P_2	18.50	18.92	20.82	24.92	18.92	20.41	22.25	26.50	29.00	29.67	24.75	26.43
	N_3P_3	22.00	23.25	23.92	25.00	22.80	23.39	26.67	29.17	30.00	31.30	27.58	28.94
	Mean	17.40	18.15	19.64	21.30	17.76	18.85	20.18	22.83	23.64	24.58	21.74	22.59
	L.S.D. at 0.05 for:	Macronutrients = 1.28 Micronutrients = 0.79 Interaction = N.S.						Macronutrients = 0.82 Micronutrients = 0.88 Interaction = 1.76					
3- Fresh weight of stems/ plant (g)	N_0P_0	62.50	61.83	74.50	76.17	62.17	67.43	64.48	77.15	80.58	80.97	75.18	75.67
	N_1P_1	69.83	79.33	83.00	90.33	72.00	78.90	84.75	85.90	83.67	90.80	83.97	85.82
	N_2P_2	85.00	85.83	99.50	117.17	86.83	94.87	101.67	116.00	125.67	128.33	107.75	115.88
	N_3P_3	109.50	113.50	117.83	122.67	112.00	115.10	119.67	127.50	131.67	134.53	121.67	127.01
	Mean	81.71	85.13	93.71	101.58	83.25	89.08	92.64	101.64	105.40	108.66	97.14	101.10
	L.S.D. at 0.05 for:	Macronutrients = 6.02 Micronutrients = 5.20 Interaction = N.S						Macronutrients = 3.52 Micronutrients = 2.96 Interaction = 5.93					
4- Total fresh weight/ plant (g)	N_0P_0	75.95	75.10	90.25	91.80	75.48	81.72	78.12	93.85	98.13	98.67	91.68	92.09
	N_1P_1	85.47	96.50	101.08	110.00	88.00	96.21	102.92	104.80	101.70	110.50	102.10	104.39
	N_2P_2	103.50	104.25	120.32	142.10	105.75	115.18	123.90	142.50	154.70	158.00	132.50	142.32
	N_3P_3	131.50	136.92	141.75	147.67	134.80	138.53	146.30	156.70	161.70	165.80	149.25	155.95
	Mean	99.10	103.19	113.35	122.89	101.01	107.91	112.82	124.46	129.03	133.24	118.88	123.69
	L.S.D. at 0.05 for:	Macronutrients = 7.26 Micronutrients = 6.13 Interaction = N.S						Macronutrients = 4.30 Micronutrients = 3.70 Interaction = 7.39					

* Macronutrients were N_0P_0 (zero), N_1P_1 (30 kg N + 3.5 kg P/fad.), N_2P_2 (60 kg N + 7 kg P/fad.) and N_3P_3 (90 kg N + 10.5 kg P/fad.), respectively.
** Spray rate was 600 L/fad. (fad. = faddan = 4200 m^2).

Table (2): Cont.

Characters	Cuts / Macro-nutrients	1st cut: Micronutrients** (g/cut/fad.)						2nd cut: Micronutrients** (g/cut/fad.)					
		0	72 Fe	60 Mn	48 Zn	18 Cu	Mean	0	72 Fe	60 Mn	48 Zn	18 Cu	Mean
5- Dry weight of leaves/ plant (g)	N_0P_0	3.58	3.62	4.28	4.17	3.47	3.82	3.41	4.07	4.33	4.43	4.05	4.07
	N_1P_1	4.22	4.52	4.97	5.43	4.22	4.67	4.72	4.65	4.48	5.03	4.73	4.72
	N_2P_2	4.93	5.18	5.95	6.73	4.93	5.55	5.50	6.97	7.12	7.15	6.40	6.63
	N_3P_3	5.78	6.25	6.15	7.02	6.03	6.25	7.05	7.52	7.57	7.53	7.08	7.35
	Mean	4.63	4.89	5.34	5.84	4.66	5.07	5.17	5.80	5.89	6.04	5.57	5.69
	L.S.D. at 0.05 for:	Macronutrients = 0.34 Micronutrients = 0.33 Interaction = N.S.						Macronutrients = 0.19 Micronutrients = 0.17 Interaction = 0.35					
6- Dry weight of stems/ plant (g)	N_0P_0	15.55	15.83	18.50	18.50	15.62	16.80	16.10	19.41	20.10	20.29	18.86	18.95
	N_1P_1	17.83	18.75	20.00	21.33	17.47	19.08	21.37	20.62	20.52	22.37	21.01	21.18
	N_2P_2	19.13	19.50	22.85	26.97	19.98	21.69	26.12	29.93	31.35	31.18	27.87	29.29
	N_3P_3	22.92	24.28	25.00	26.45	24.52	24.63	29.98	32.37	32.73	32.83	32.73	31.64
	Mean	18.86	19.59	21.59	23.31	19.40	20.55	23.39	25.58	26.18	26.67	24.51	25.26
	L.S.D. at 0.05 for:	Macronutrients = 1.30 Micronutrients = 1.11 Interaction = 2.22						Macronutrients = 0.92 Micronutrients = 0.85 Interaction = 1.70					
7- Total dry weight/ plant (g)	N_0P_0	19.13	19.45	22.78	22.67	19.08	20.62	19.50	23.48	24.48	24.72	22.92	23.02
	N_1P_1	22.05	23.27	24.97	26.77	21.68	23.75	26.08	25.27	25.00	27.40	25.77	25.90
	N_2P_2	24.15	24.68	28.80	33.70	24.92	27.25	38.33	36.90	38.47	38.33	34.27	35.92
	N_3P_3	28.70	30.53	31.15	33.47	30.22	30.81	37.03	39.88	40.28	40.37	37.38	38.99
	Mean	23.51	24.48	26.93	29.15	23.98	25.61	28.56	31.38	32.06	32.70	30.08	30.96
	L.S.D. at 0.05 for:	Macronutrients = 1.56 Micronutrients = 1.41 Interaction = N.S.						Macronutrients = 1.08 Micronutrients = 1.00 Interaction = 1.90					
8- Fresh weight of leaves : plant ratio	N_0P_0	0.175	0.177	0.173	0.175	0.178	0.176	0.175	0.178	0.178	0.180	0.180	0.178
	N_1P_1	0.180	0.177	0.180	0.177	0.182	0.179	0.175	0.180	0.175	0.178	0.177	0.177
	N_2P_2	0.177	0.180	0.175	0.178	0.183	0.179	0.180	0.187	0.188	0.190	0.185	0.186
	N_3P_3	0.172	0.175	0.173	0.173	0.177	0.174	0.182	0.187	0.187	0.192	0.185	0.186
	Mean	0.176	0.177	0.175	0.176	0.180	0.177	0.178	0.183	0.182	0.185	0.182	0.182
	L.S.D. at 0.05 for:	Macronutrients = N.S. Micronutrients = N.S. Interaction = N.S.						Macronutrients = 0.003 Micronutrients = N.S. Interaction = N.S.					

* Macronutrients were N_0P_0 (zero), N_1P_1 (30 kg N + 3.5 kg P/fad.), N_2P_2 (60 kg N + 7 kg P/fad.) and N_3P_3 (90 kg N + 10.5 kg P/fad.), respectively.

** Spray rate was 600 L/fad. (fad. = faddan = 4200 m^2).

Table (2): Cont.

Characters	Cuts / Macro-nutrients	1st cut — Micronutrients** (g/cut/fad.)						2nd cut — Micronutrients** (g/cut/fad.)					
		0	72 Fe	60 Mn	48 Zn	18 Cu	Mean	0	72 Fe	60 Mn	48 Zn	18 Cu	Mean
9-Dry weight of leaves : plant ratio	N_0P_0	0.187	0.185	0.188	0.185	0.183	0.186	0.177	0.172	0.182	0.180	0.178	0.178
	N_1P_1	0.195	0.197	0.202	0.207	0.197	0.199	0.180	0.183	0.180	0.183	0.182	0.182
	N_2P_2	0.208	0.213	0.208	0.205	0.200	0.207	0.177	0.190	0.185	0.187	0.187	0.185
	N_3P_3	0.205	0.208	0.202	0.212	0.205	0.206	0.192	0.190	0.188	0.185	0.192	0.189
	Mean	0.199	0.201	0.200	0.202	0.196	0.199	0.181	0.185	0.184	0.184	0.185	0.184
	L.S.D. at 0.05 for:	Macronutrients = 0.006 Micronutrients = N.S. Interaction = N.S.						Macronutrients = 0.004 Micronutrients = N.S. Interaction = N.S.					
10- No. of stems/ m^2	N_0P_0	34.3	30.8	34.0	36.3	30.8	33.6	26.0	28.8	28.5	28.0	27.7	27.8
	N_1P_1	41.3	41.5	42.3	41.5	40.5	41.4	33.5	33.7	31.0	32.5	29.7	32.1
	N_2P_2	42.3	44.7	45.7	46.5	43.0	44.9	33.8	35.2	36.3	37.5	35.3	35.6
	N_3P_3	46.3	48.2	48.0	49.3	47.8	47.4	36.8	36.7	36.7	37.2	36.7	36.8
	Mean	41.1	41.3	42.5	43.4	40.5	41.9	32.5	33.6	33.1	33.8	32.3	33.1
	L.S.D. at 0.05 for:	Macronutrients = 2.1 Micronutrients = N.S. Interaction = N.S.						Macronutrients = 1.7 Micronutrients = N.S. Interaction = N.S.					
11- Dry matter content (%)	N_0P_0	23.83	24.50	24.50	24.33	23.92	24.22	24.88	24.97	24.78	24.88	24.90	24.90
	N_1P_1	24.93	24.28	24.57	24.63	24.83	24.65	24.72	24.33	24.60	24.72	25.17	24.70
	N_2P_2	23.60	23.88	24.23	23.73	24.03	23.90	25.45	25.77	24.80	24.17	25.77	25.20
	N_3P_3	24.28	24.05	24.05	24.77	24.98	24.43	25.03	25.47	24.93	24.27	24.88	24.90
	Mean	24.20	24.20	24.30	24.40	24.40	24.30	25.00	25.10	24.80	24.50	25.20	24.90
	L.S.D. at 0.05 for:	Macronutrients = 0.48 Micronutrients = N.S. Interaction = N.S.						Macronutrients = N.S. Micronutrients = 0.17 Interaction = 0.34					

* Macronutrients were N_0P_0 (zero), N_1P_1 (30 kg N + 3.5 kg P/fad.), N_2P_2 (60 kg N + 7 kg P/fad.) and N_3P_3 (90 kg N + 10.5 kg P/fad.), respectively.

** Spray rate was 600 L/fad. (fad. = faddan = 4200 m^2).

definite necessity for its application in order to obtain enhanced plant growth. Since the soil contained 2 µg Zn g^{-1} (DTPA-extractable). as shown in Table (1), this may be considered inadequate. Khadr *et al.* (1988) reported similar results obtaining no response to Zn application to some Egyptian calcareous soils. However, contents of a similar magnitude may be considered adequate for sorghum in some other soils (Follett *et al.*, 1991).

Applying Mn caused 5, 13, 15, 14, 15, 9 and 9% for plant height, fresh weight of leaves, stems and total weight/plant, dry weight of leaves, stems and total weight/plant, respectively in the 1st cut. In the 2nd cut, increases were 5, 17, 13, 13, 14, 12 and 12%, respectively.

Fe significantly increased all growth characters in the 2nd cut, and plant height only in the 1st cut. It seems that the effect of Fe application requires a longer time to show, as compared with Zn or Mn. Similar results were obtained by Khadr *et al.* (1988) and Barsoum and Abdel-Gawad (1989) regarding Fe and Mn on sordan. Applying Cu caused slight and insignificant increases in all growth characters in the 1st cut. However, like Fe, it gave significant increases in the 2nd cut regarding all weights/plant. Follett *et al.* (1991) reported that as low as 0.2 µg Cu g^{-1} in soil is adequate for sorghum growth.

c) The interaction effects:

In the 1st cut, there was no interaction, regarding plant height and fresh weight/plant since the pattern of their response to (N+P) was not affected by the presence or absence of any of the micronutrients. However, for dry weight, there was an interaction; the N_2P_2 was superior to N_1P_1 except where Fe was present; or where no other micronutrients were present. Also, the superiority of N_3P_3 over N_2P_2 was not significant where Zn was present. This indicates that the balanced formula of macro and micronutrients is essential to enhance plant growth.

In the 2nd cut, there was an interaction effect regarding the fresh and dry weight/plant. Applying N_1P_1 was superior to N_0P_0 except where Mn (and in some cases also Fe) was present. It seems that the presence of Mn did not allow the full effect of N_1P_1 to take place. Also, applying micronutrients was affected by application of macronutrients. This is shown when application of each micronutrient gave significant increases in weights/plant only where N_0P_0 or N_2P_2 or N_3P_3 was applied. It did not induce any significant increase where N_1P_1 were applied. This indicates that, with the rate of N_1P_1, the limited increased growth caused by this particular treatment did not allow plants to utilize applied micronutrients effectively. It also indicates that the rates of N_2P_2 or N_3P_3 plus rates of micronutrients represent a more balanced formula for macro- and micronutrients.

2- Leaves : plant ratio:

The ratio of fresh weight of leaves : plant weight showed a significant increase, in the 2nd cut only, to applied macronutrients up to N_2P_2. The same rate significantly increased dry weight of leaves : plant ratio in both cuts. The present results indicate that N+P encouraged growth of leaves/plant. Bakheit (1990) found that leafiness increased by increasing N rate, but Abdel-Gawad (1993) found no apparent trend on leaf/stem ratio.

Fresh and dry weight of leaves : plant ratios were not affected by micronutrients. Thus micronutrients encouraged growth of both organs in a similar manner.

3- Number of stems/m^2:

There was an increase reaching as high as 41% in the number of stems/m^2 as a result of macronutrient application (Table, 2). The high number of stems/m^2 resulting from application of N+P is a logic result of increasing tillering of forage sorghum. With micronutrients, there were insignificant increases particularly with Zn addition, with no interaction occurring between macro- and micronutrients. Thus the effect of some micronutrients was more effective on plant height and fresh and dry weight of different plant organs than on the number of stems/m^2. Since Zn is important in synthesis of tryptophan and indol acetic acid (I.A.A.), as well as protein metabolism (Epstein 1972 and Marschner, 1986), it affected these characters most.

4- Dry matter content:

Dry matter content was largely not affected by treatments except in some cases, where there was a decrease by N_2P_2 in the 1st cut, and by Zn in the 2nd cut (Table, 2).

5- Forage yield (ton/fad.):

In general, forage yields followed the same pattern of response as that of the growth characters (Table, 3).

a) Response to macronutrient application:

Green and dry forage yields were increased by applying N+P in both cuts. The increases ranged between 23% to 66% and 24% to 67% in the total green and dry forage yields, respectively. Increases were rather similar in both cuts and the response was rather similar to that of the weight/plant (Table, 2). The increase in forage yield due to N+P application was obtained whether in presence or absence of micronutrients. This stresses the importance of applying N+P. Lesile (1981), Ghobrial *et al.* (1984) and Sharaan and Abdel-Gawad (1986) reported similar results. Follett *et al.* (1991) reported that Colorado loams having about 11 μg P g^{-1} (extractable by ammonium bicarbonate-DTPA) may need small application of P for sorghum. On the other hand, Nasr *et al.*

Table (3): Effect of macro- (N+P) nutrients and some micronutrients on green and dry forage yields in both cuts and total forage yield of sorghum, combined analysis of 1992 and 1993 growing seasons.

Cuts macro-nutrients	1st cut Micronutrients (g/cut/fad)**						2nd cut Micronutrients (g/cut/fad.)						Total forage yield (ton/fad.) Micronutrients (g/cut/fad.)					
	0	72 Fe	60 Mn	48 Zn	18 Cu	Mean	0	72 Fe	60 Mn	48 Zn	18 Cu	Mean	0	72 Fe	60 Mn	48 Zn	18 Cu	Mean
I- Green forage yield (ton/fad.)																		
N_0P_0	6.900	7.073	7.153	7.740	6.933	7.160	4.295	4.297	4.277	4.400	4.310	4.310	11.195	11.370	11.430	12.140	11.243	11.476
N_1P_1	8.233	8.467	8.633	9.713	8.467	8.703	4.800	5.600	5.317	6.050	5.117	5.373	13.033	14.067	13.950	15.763	13.583	14.079
N_2P_2	9.600	10.200	10.200	11.067	9.867	10.187	6.217	6.450	6.517	7.000	6.233	6.483	15.817	16.650	16.717	18.067	16.100	16.670
N_3P_3	10.667	11.800	12.467	13.733	10.867	11.907	6.608	7.025	7.467	8.083	6.708	7.178	17.275	18.825	19.933	21.817	17.575	19.085
Mean	8.850	9.385	9.613	10.563	9.034	9.489	5.480	5.843	5.894	6.383	5.592	5.836	14.330	15.228	15.508	16.947	14.625	15.328
L.S.D. at 0.05 for:	Macronutrients = 0.400 Micronutrients = 0.351 Interaction = 0.700						Macronutrients = 0.205 Micronutrients = 0.175 Interaction = 0.350						Macronutrients = 0.450 Micronutrients = 0.391 Interaction = 0.782					
II- Dry forage yield (ton/fad.)																		
N_0P_0	1.634	1.726	1.746	1.880	1.659	1.729	1.070	1.073	1.060	1.095	1.072	1.074	2.704	2.800	2.806	2.975	2.731	2.803
N_1P_1	2.044	2.056	2.113	2.377	2.091	2.136	1.184	1.361	1.309	1.498	1.283	1.327	3.229	3.415	3.422	3.875	3.374	3.463
N_2P_2	2.240	2.412	2.458	2.589	2.340	2.408	1.581	1.654	1.617	1.688	1.602	1.629	3.821	4.067	4.075	4.277	3.942	4.036
N_3P_3	2.577	2.828	2.975	3.383	2.683	2.889	1.650	1.789	1.862	1.958	1.660	1.784	4.227	4.617	4.837	5.341	4.343	4.673
Mean	2.124	2.255	2.323	2.557	2.193	2.291	1.371	1.470	1.462	1.560	1.404	1.454	3.495	3.725	3.785	4.117	3.597	3.744
L.S.D. at 0.05 for:	Macronutrients = 0.069 Micronutrients = 0.083 Interaction = 0.166						Macronutrients = 0.053 Micronutrients = 0.044 Interaction = 0.087						Macronutrients = 0.087 Micronutrients = 0.103 Interaction = 0.200					

* Macronutrients were N_0P_0 (zero), N_1P_1 (30 kg N + 3.5 kg P/fad.), N_2P_2 (60 kg N + 7 kg P/fad.) and N_3P_3 (90 kg N + 10.5 kg P/fad.), respectively.

** Spray rate was 600 L/fad. (fad = faddan = 4200 m^2).

(1984) reported no response by forage yield to application of P. In Nigeria average of dry matter yield of millet decreased with increasing N up to 62.5 kg N/fad. (Oji and Ugherughe, 1993).

b) Response to micronutrients application:

Applying Zn caused significant green yield increases of 19 and 18% in the 1st and 2nd cuts, respectively. Comparable significant increases due to Mn were 9% and 8%, and those due to Fe were 6% and 7%. Applying Cu gave only 2% increase which was not statistically significant. The same trend was obtained in dry forage yield in both cuts. Foliar application with Zn, Mn, Fe and Cu increased total dry forage yield by 18, 8, 7 and 3%, respectively compared with the control. This shows the importance of Zn, Mn and Fe on plant growth and forage yield of sorghum.

c) The interaction effects:

For Zn, there was no interaction effect: its application showed positive effects whether N+P were applied or not. This illustrates the dire necessity for its application. Also, no interaction occurred with regard to Cu: it showed no significant effect with or without any presence of macronutrients asserting the non-necessity of its application since the 2.2 $\mu g\ g^{-1}$ contents of indigenous soil available Cu are most certainly adequate.

However, Fe as well as Mn increased yield, only where the soil was supplied with the high (N_2P_2) or (N_3P_3) and either of them was of no significance where soil received little or no (N+P). Khade *et al.* (1988) and Wahdan (1989) who found that foliar application with Fe, Mn and Zn alone or in combinations significantly increased total green and dry forage yields of sorghum. Therefore, in soils with Zn content similar to or lower than that of the current study (i.e. 2 $\mu g\ g^{-1}$), fertilizing sorghum with Zn should be considered.

GENERAL CONCLUSION

Applying N together with P is certainly necessary for sorghum to produce high forage yields. The marked increase in plant fresh weight, and dry weight as well as plant height confirms such a necessity. The contents of soluble mineral N of 17 $\mu g\ g^{-1}$ shown by soil of the present study are most certainly not adequate for enhanced plant growth, therefore the significant response to N+P occurred. Applying N+P increased root system, hence more absorbance of nutrients. According to Olsen *et al.* (1954), contents of more than 10 μg P g^{-1} in soil indicate that applying P may or may not yield significant increases. Soil of the present study contained 12 μg P g^{-1}.

Of the four micronutrients Zn was the only one which gave significant response in nearly all situations, whether or not there were N and P present. Epstein (1972) stated that, Zn difficency in particular retards plant growth with "dramatic impact", since it is a constituent as well as an activator of several enzymes vital in metabolism, and is necessary for synthesis of optimal levels of amino acids. Therefore, it is important to add Zn to sorghum grown in such a soil with 2.0 μg Zn (DTPA-extractable). Applying Fe or Mn gave significant increases only where macronutrients N+P were given at a high rate. Therefore the soil's 10 μg Fe and 8.0 μg Mn/g soil (DTPA-extractable) indicate enough of both for moderate growth of sorghum. When growth was further stimulated by applying high rates of N+P, the response to Fe occurred. These results due to the positive effect of higher rates of N+P and Fe or Mn element on vegetative growth and most yield components and this in turn might account much for high accumulation of metabolities in forage yield.

The content of available Cu (DTPA-extractable) in the soil, being 2.2 μg Cu g^{-1} is most certainly more than adequate and enough, even for boosted plant growth and increased forage production caused by the application of high NP macronutrient.

REFERENCES

Abdel-Gawad, K.I. (1993): Water stress and nitrogen fertilization of forage sorghum. Bull. Fac. Agric., Cairo Univ., 44(3):587-598.

Ali, R.M. and Sarhan, A.A. (1992): Effect of nitrogen fertilization and intercropping millet with Sudan grass on efficiency of light utilization and forage yield. Proc. 5th Conf. Agron., Zagazig. 1:428-440.

Ashoub, M.A.; Hussein, M.M. and El-Zeiny, H.A. (1987): Maize (*Zea mays*, L.) productivity as influenced by nitrogen and phosphorus fertilization under calcareous soil conditions in Egypt. Ann. Agric. Sci., Fac. Agric., Ain Shams Univ., Egypt. 32(1):215-227.

Bakheit, Bahy. R. (1990): Performance, phenotypic and genotypic stability for green fodder and leafiness in sorghum under different nitrogen fertilization levels. Assiut J. of Agric. Sci., 21(1):65-77.

Barsoum, M.M. and Abdel-Gawad, M.A. (1989): Effect of foliar and soil application of some micronutrients on growth and yield of sordan plants under calcareous soil of Maryut. Ann. Agric. Sc., Moshtohor, Egypt. 27(4):2071-2080.

El-Keredy, M.S.; Zahran, M.A.; Sorour, F.A. and Ramadan, G.A. (1986): studies on sorghum cultivars as affected by seeding rate and nitrogen fertilization. 2- Yield and yield components. proc. 2nd Conf. Agron., Alex., Egypt. (1):801-813.

El-Khawaga, A.A.H. and Geweifel, H.G.M. (1991): Effect of seeding rate and nitrogen fertilization on forage sorghum. I. Growth analysis. Zagazig J. Agric. Res. Egypt. 18(6):1805-1816.

Epstein, E. (1972): Mineral nutrition of Plants. Principles and respectives. John Wiley and Sons Inc. New York.

Follett, R.H.; Soltanpour, P.N.; Westfall, D.G. and Self, J.R. (1991): Guide to fertilizer recommendation. Colorado State Univ. Coop. Exten. XCM-37.

Geweifel, H.G.M. and El-Khawaga, A.A.H. (1991): Effect of seeding rate and nitrogen fertilization on forage sorghum. II- Forage yield and quality. Zagazig J. Agric. Res., Egypt., 18(6):1817-1829.

Ghobrial, K.M.; Harfoush, M.A. and Nor El-Din, M.A. (1984): Effect of different levels of NPK and cutting at different plant heights on green and dry yield in hybrid millet. Proc. EMCIP symb. No. 84(2):142-146. A.R.C., Egypt.

Khadr, M.S.; Nasr, M.A.; El-Sehemy, S.A.; Younis, A.A. and Mikhiel, G.S. (1988): Effect of some mineral micronutrient compounds on the forage yield of some hybrids and varieties of sorghum at a calcareous soil. Proc. 3rd Conf. Agron., Kafr El-Sheikh, Egypt, 1:264-274.

Khalil, K.W., Barsoum, M.S. and Hatem, H.H. (1991): Response of sordan to foliar and soil applications of Fe and Mn under conditions of the newly reclaimed highly calcareous soils. Egypt. J. Appl. Sci., 6(7):17-27.

Leslie, L.F. (1981): The influence of sorghum Sudan grass roots on nutrients leaching. Agron. J. 73:537-545.

Marschner, H. (1986): Mineral nutrition of higher plants. Academic Press INC. (London) Ltd. 279-287.

Nasr, M.A.; Gabra, M.A. and Ghobrial, K.M. (1984): Effect of phosphorus fertilization on fodder yield in some hybrids and varieties of sorghum. Proc. EMCIP Symb. No. 84(2):110-116. A.R.C., Egypt.

Ohki, K. (1984): Zinc nutrition related to critical deficiency and toxicity level for sorghum. Agron. J. (2):253-256.

Oji, C.K. and Ugherughe, P.O. (1993): Effect of nitrogen fertilization and cutting height on forage yield and quality of Maiwa pearl millet. Tropical Agriculture 69(1):11-14, 1992 (c.f. Soil and Fertilizers, 56(1):909).

Olsen, S.R.; Cole, C.V.; Watanabe, F.S. and Dean, L.A. (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Circular No. 939.

Sharaan, A.N. and Abdel-Gawad, K.I. (1986): Forage yield and its components of some sorghum cultivars in relation to different NPK fertilization levels. Ann. Agric. Sc., Moshtohor, Egypt. 24(3):1215-1226.

Snedecor, G.W. and Cochran, W.G. (1967): "Statistical Methods" 6th Ed. Iowa State Univ. Press, Ames, Iowa, U.S.A.

Wahdan, H.M. (1989): The effect of micronutrients application on productivity and quality of forage sorghum grown in Fayoum Governorate. 2nd Symp. on Micronutrients within a complete fertilization. Cairo Univ. Fayoum Branch. Fayoum 25-27 March pp. 27-36 (in Arabic).

التغذية المتوازنة والتفاعل بين الحديد، المنجنيز، الزنك أو النحاس والنيتروجين والفوسفور على سورجم العلف

على أحمد عبدالسلام* – فاضل طلبه زينهم محمد الشيخ**

* قسم الأراضى والكيمياء الزراعية، ** قسم المحاصيل – كلية الزراعة بمشتهر – جامعة الزقازيق (فرع بنها) – مصر.

أقيمت تجربتان حقليتان بمحطة البحوث والتجارب بكلية الزراعة بمشتهر خلال موسمى ١٩٩٢، ١٩٩٣م لدراسة تأثير أربع معاملات سمادية من النيتروجين والفوسفور (بدون، ٣٠ كجم ن + ٣,٥ كجم فو، ٦٠ كجم ن + ٧ كجم فو، ٩٠ كجم ن + ١٠,٥ كجم فو/فدان) وخمس معاملات من العناصر الصغرى [بدون (ماء)، ٧٢ جم حديد، ٦٠ جم منجنيز، ٤٨ جم زنك، ١٨ جم نحاس/فدان] على انتاج سورجم العلف. والعناصر الصغرى كانت فى صورة مخلبية ورشت بحجم ماء مقداره ٦٠٠ لتر/فدان بعد ٤ أسابيع من الزراعة، ٣ أسابيع من الحشة الأولى.

أما النتائج فكانت كالأتى:-

١- أدت أضافة ٩٠ كجم ن + ١٠,٥ فو/فدان الى زيادة فى طول النبات والوزن الغض والجاف والكلى لمختلف أجزاء النبات وعدد السيقان/متر مربع والمحصول الغض والجاف للفدان فى الحشة الأولى والثانية. وقد انعكس ذلك على المحصول الكلى من العلف الغض والجاف فزاد بنسبة ٦٦، ٦٧٪ على التوالى.

٢- زادت معظم صفات النمو ومكونات المحصول ومحصول العلف الغض والجاف للسورجم معنويا فى كلا الحشتين عند رش الحديد أو المنجنيز أو الزنك وبوجه عام أعطى رش الزنك أفضل النتائج مقارنة برش الحديد أو المنجنيز. ولم تظهر فروق معنوية بين الحديد، المنجنيز على معظم الصفات المدروسة – ولم تظهر أستجابة لرش النحاس.

٣-من الناحية التطبيقية نوصى برش الزنك تحت أى مستوى من مستويات التسميد النيتروجينى والفوسفاتى. أما رش الحديد أو المنجنيز فانها مطلوبة فقط عند أضافة النيتروجين والفوسفور بمعدلات عالية. وفى كل الحالات يؤخذ فى الأعتبار محتوى التربة الفعلى من العناصر الغذائية الميسرة.