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RESPONSE OF PEARL MILLET TO DIFFERENT RATES OF NITROGEN AND FOLIAR MICRONUTRIENTS UNDER SANDY SOIL CONDITIONS

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ABSTRACT

Two field experiments were conducted at Ismailia Agricultural Research Station during two successive summer seasons of 2010 and 2011. The response of pearl millet cultivar (Shandaweel-1) grown under sandy soil conditions to different mineral N fertilization rates (60, 90 and 120 kg N fed^{-1}) and foliar application of chelated-EDTA micronutrients (Fe + Mn + Zn) at rates of 0.0, 0.2, 0.4 and 0.6 g l^{-1} (400 l fed^{-1}) on growth characters, productivity, and some nutrient contents, were appraised. Such response was followed up through three cuts; at 45, 85, and 125 days from complete emergence of the seedlings. The obtained results reveal that plant height, number of tillers per plant and productivity of pearl millet; fresh forage and dry matter yields of the three cuts at the both seasons, were enhanced by increasing the application rate of N fertilization. Foliar application of micronutrients markedly augmented such parameters. The best results were obtained when applying 120 kg N fed^{-1} accompanied with micronutrient foliar application of either 0.4 or 0. 6 g l^{-1}. Carbohydrate, protein and crude fiber contents (%) of the dry matter of pearl millet plants were remarkably raised due to increasing rates of both; N fertilization and foliar micronutrients. Moreover, the uptake of N, P, K (kg fed^{-1}) and uptake of Fe, Mn and Zn (g fed^{-1}) by millet plants were elevated. Focusing on the necessity of growing pearl millet as a prosperous summer forage crop in Egypt was speculated.

Keywords: Pearl millet, Nitrogen, Macronutrients, Micronutrients, Foliar application.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.), is commonly grown in the arid and semi-arid regions of Africa and India as a staple food for millions of people. It is most likely used as a forage crop and its grains are considered as one of the major sources of animal feed in the world. In Egypt, pearl millet together with sorghum has received extra attention to be used as forage crops in summer; they occupy about 15,000 fed. It is particularly adapted to nutrient- poor soil and low rainfall conditions (Ali, 2010). Pearl millet has an excellent growing character, quick re-growth after harvesting and high nutritive value (Helmy, 2003). Based on dry matter contents, pearl millet forage has an average of 8 - 12 % protein, 37 - 45 % carbohydrates, 30 - 51 % crude fiber, and its grain contains 12.1 % protein, 68 % carbohydrates, and 5.7 % crude fiber (Hema, 2008). In Egypt, increasing green forage production during summer is an important target to cover the acute shortage in animal feed and this could be achieved through cultivating high yielding forage crop varieties and improving cultural practices such as macro- and micro-nutrient fertilization (Osman *et al.,* 2000).

Nitrogen is a key essential nutrient for crop plants. Forage grasses require high rates of N-fertilization to produce profitable yield especially when grown on sandy soils of poor fertility. In this regard, Mousa (1991) found that forage yield of pearl millet was increased when the rate of mineral nitrogen application increased from zero to 90 kg N fed^{-1}. Moreover, Ali (2010) indicated that application of 150 kg N fed^{-1} to pearl millet increased the grain yield, plant height, 1000-grain weight and grain protein content as well as the nitrogen use efficiency.

Micronutrients play a substantial role in enhancing plant growth and productivity of crops (Abo El-Fotoh *et al*., 2006 on wheat and rice, and Siam *et al.*, 2012 on maize). Ismail (2002) stated that supplying these micronutrients to plants as foliar application, could be more useful than soil application because the quick absorption by leaves. Moreover, loss of them through fixation or leaching could be avoided. Negm and Zahran (2001) reported that increased growth and yields of different crops were frequently obtained by foliar spraying of micronutrients even when there were no deficiency symptoms. However, El-Fouly (1983) indicated that micronutrients can only give good yield increase when the crop needs of the major elements are satisfied. Nijjar (1985) and Siam *et al.*, (2012) stated that the importance of spraying micronutrients, like; Fe, Zn and Mn can be accounted by their essential role in respiration, their metabolic activation of the enzymes, photosynthesis, chloroplast formation, chlorophyll synthesis and natural hormone biosynthesis as well as through improvement of nutritive status of plants. Kassab *et al.,* (2004) found that foliar application of a mixture solution of Fe, Mn, Zn and Mg significantly increased wheat yield components including grain and straw yields as well as carbohydrate yield fed^{-1}. Gupta *et al.,* (2008) indicated that micronutrients are required in micro quantities but their lack can cause serious crop production and crops vary considerably in their response to various micronutrients. Yong *et al.,* (2008) reported that micronutrients application; 0.90 kg ha^{-1} ($\simeq$375 g fed^{-1}) Zn, 0.015 kg ha^{-1} ($\simeq$ 6.3 g fed^{-1}) Se and 0.90 kg ha^{-1} ($\simeq$ 375 g fed^{-1}) Fe, significantly increased Zn, Se and Fe contents of rice by 36.7, 194.1 and 37.1 %, respectively, compared with the control without affecting grain yield, protein and ash contents of rice products. Mahmoud *et al.,* (2010) found that the foliar application of micronutrient fertilizer contains EDTA- (Fe+Mn+Zn+Cu) with a rate of 2.0 g l^{-1} led to the highest N, P, K, Mg, Fe, Mn, Zn and Cu uptakes by wheat plant.

The objective of this work was to study the effect of soil application of different levels of mineral N fertilizer and foliar spraying at different rates of micronutrients, on pearl millet (Shandaweel-1CV) productivity, in terms of quantitative and qualitative forage yield.

MATERIALS AND METHODS

Two field experiments were conducted at Ismailia Agricultural Research Station farm of the ARC, Egypt (30° ′33 N, 32° ′12 E), during two successive summer seasons of 2010 and 2011. The experiment was carried out in a split plot design in complete randomized blocks arrangement with three replicates. Main plots were assigned to three N levels namely; 60, 90 and 120 kg N fed^{-1}, while subplots were devoted to four rates of foliar spraying of chelated (Fe + Mn +Zn), in EDTA form namely; 0.0, 0.2, 0.4 and 0.6 g l^{-1}. Nitrogen fertilizer was applied as urea (46 % N), and added in three equal doses; at 10 days after planting and the other two doses were applied after the first and the second cuts; after 45 and 85 day. Foliar application treatments were applied three times; the first spraying was 20 days later than the first dose of N-fertilization, while the other two sprayings were applied 15 days after the first and the second cuts, and sprayed at a rate of 400 L fed^{-1}. Basal doses of calcium super phosphate at a rate of 30 kg P_2O_5 fed^{-1} and potassium sulphate at a rate of 36 kg K_2O fed^{-1} were applied before sowing. Seeds of pearl millet (Shandaweel-1CV) were sown by hand drilled on 15th of May, 2010 and on 20th of May, 2011, at a rate of 20 kg fed^{-1}. The experimental subplot area was 6 m^2. Each subplot consisted of 10 rows with a length of 3 m and 20 cm apart. A sprinkler irrigation system with a flowing rate of 30 m^3 hour^{-1}fed^{-1} was applied every 4 days.

Sampling: During each growing season, three representative cuts were taken; after 45, 85 and 125 days from complete emergence of the seedlings. Growth parameters namely; plant height (cm), No. of tillers plant^{-1}, fresh forage yield (Mg fed^{-1}) and dry matter yield (Mg fed^{-1}) were recorded for millet plants from each sub plot. The yield was calculated by harvesting the central three rows and then converted to Mg fed^{-1}. Then the plants were dried at 70 C^o for 72 h and weighed. The dried plants were ground and digested by a mixture of H_2SO_4 and $HClO_4$ acids to determine mineral nutrients. Nitrogen was estimated in the digested solutions of plants by mico-kjeldah according to AOAC (1990). N-values were multiplied by 5.75 to obtain the crude protein content. Phosphorus was detected spectro-photometrically using molybdate-stannus chloride method and potassium by a flame photometer according to Chapman and Pratt (1982). Fe, Mn and Zn were detected by the atomic absorption of GBC 932. Detergent fiber analysis was performed on dried sample for each cut to determine neutral detergent fiber (%) according to the method of AOAC (1990). Total carbohydrates were determined in the dried millet plants, using the method described by Dubois *et al.*, (1956).

Statistical Analysis: All data were analyzed with analysis of variance procedures using MSTATC statistical software package, version 2 (MSTATC, 1983). Differences between means values of the treatments were compared by LSD at 5% level of significance according to Steel and Torrie (1984).

Soil analysis: Some physical and chemical characteristics of the experimental soil, before sowing, were determined according to Piper (1950), Black (1980) and Page *et al*., (1982). The obtained data are presented in Table (1).

Table (1): Some physical and chemical characteristics of the soil of experimental field before planting.

Course Sand (%)	Fine sand(%)	Silt (%)	Clay (%)	Textural class	Organic matter(%)	$CaCO_3$ (%)
33.59	55.64	2.91	7.89	Sandy	0.56	1.23

Anions (meq l^{-1})				Cations (meq l^{-1})				EC dSm^{-1}	pH (1:2.5)
SO_4^{--}	Cl^-	HCO_3^-	CO_3^-	K^+	Na^+	Mg^{++}	Ca^{++}		
7.60	6.96	1.34	nil	0.68	8.08	2.33	4.81	1.59	7.90

Available macronutrients (mg kg^{-1})			Available micronutrients (mg kg^{-1})		
N	P	K	Fe	Mn	Zn
34.67	4.14	150	1.46	1.32	0.65

RESULTS AND DISCUSSION

Growth characters

Data in Table (2) show that the plant height (cm) and No. of tillers Plant^{-1} were substantionally elevated by increasing the rates of both; mineral N fertilization from 60 up to 120 kg fed^{-1} and foliar (Fe, Mn and Zn) from 0.0 to 0.6 g l^{-1}, compared with the lowest N rate (60 kg N fed^{-1}without micronutrient addition). This holds true at the both seasons. Application of the highest rate of mineral N exhibited the most pronounced effect on the plant height and tiller No. at the both seasons, when compared with its lowest rate. However, among the N rates, throughout the two seasons, differences between the two successive rates; 60 and 90 or 90 and 120 kg N fed^{-1} were sometimes not prominent. Concerning the effect of micronutrients, the obtained results indicate that all the applied rates of foliar (Fe, Mn and Zn) fertilization significantly enhanced both plant height and tiller number of millet plants, compared with control (60 kg N fed^{-1} without micronutrient addition). Apart from 0.4 and 0.6 g l^{-1} applied rates, remarkable differences among the other micronutrients rates, on both parameters, in most cuts during the two seasons could be noticed. The obtained results are in a good accordance with those of Abd El-Samad *et al.,* (2011). The current results show that the highest values of plant height and No. of tillers plant^{-1} were 152.5 cm and 16.9 in the first season, and 148.9 cm and 15.9 in the second one; assigned as pearl millet plants were treated with 120 kg N fed^{-1} accompanied with a foliar rate of 0.6 g l^{-1} (Fe+ Mn + Zn), at the both seasons. The enhanced effects of nitrogen are in conformity with Hussien *et al.,* (1984). In this regard, Piri and Tavassoli (2012) found that the highest and the biggest stem diameter of pearl millet plants were achieved from application of 300 kg ha^{-1} N ($\simeq$125 kg N fed^{-1}). Marschner (1986) indicated that N-fertilization promotes tillering in cereal crops as it enhances the meristematic activity of plant formation and maintenance of new tillering.

Yield productivity

Data presented in Table (3) show that fresh forage and dry matter yield of pearl millet (Mg fed^{-1}) exhibited the same responses of the previous characters owing to application of different rates of N and foliar micronutrients

(Fe+Mn+Zn), at the both seasons. It is worthy to mention that the higher yield of fresh forage and dry matter resulted from both application of 90 and 120 kg N fed^{-1}, in most taken cuts during the two seasons, indicates the imperative importance of applying mineral N at high rates for millet crop, especially when it is grown under sandy poor soil conditions. Such management could render more than two cuts with marked fresh forage and dry matter yields. Regarding the influence of foliar micronutrients, the obtained results show that foliar application of (Fe+Mn+Zn) at all rates significantly heightened both fresh and dry yields of pearl millet. The noticeable response resulted from micronutrients application could be justified as the sandy soil suffered from scarcity of these nutrients; (Table1). Elevating the rate of applied micronutrients mostly by far accentuating the fresh forage and dry yield. Nevertheless, such finding was inconsistent in some yield cuts, recorded between 0.4 and 0.6 g l^{-1} application.

Table (2): Effect of different rates of N fertilization and foliar application of (Fe +Mn +Zn) on plant height and number of tillers per plant of pearl millet.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates (g.l^{-1}) [B]	Plant height (cm)						No. of tillers plant^{-1}					
		2010			2011			2010			2011		
		Cut1	Cut2	Cut3	Cut1	Cut2	Cut3	Cut1	Cut2	Cut3	Cut1	Cut2	Cut3
60	0.0	102.3	106.5	94.4	90.2	101.0	90.7	9.35	10.22	9.14	8.77	9.10	8.14
	0.2	132.2	132.3	120.3	129.9	133.5	131.3	10.98	13.21	11.88	9.31	10.12	8.90
	0.4	133.5	136.9	124.7	135.1	138.5	137.4	12.36	14.10	12.46	9.98	10.85	9.44
	0.6	142.0	144.3	124.8	141.4	145.4	140.9	13.76	15.71	14.50	10.52	11.02	9.86
N_1 mean		127.5	130.0	116.0	124.1	129.6	125.0	11.61	13.31	12.00	9.65	10.27	9.09
90	0.0	116.1	119.6	112.4	95.9	105.4	95.0	9.88	10.41	9.37	9.51	9.96	9.22
	0.2	133.8	137.9	122.5	130.2	134.7	131.5	11.96	13.95	12.04	10.10	10.98	10.14
	0.4	138.3	142.8	130.8	134.7	141.6	140.9	12.40	14.85	13.14	10.18	11.83	10.22
	0.6	144.3	151.6	135.6	140.1	144.9	143.3	13.88	16.21	14.22	11.42	12.30	10.44
N_2 mean		133.1	140.0	125.9	125.2	131.8	127.6	12.03	13.85	12.10	10.30	11.27	10.01
120	0.0	124.3	132.0	120.3	104.6	113.5	100.2	10,13	10.58	10.04	9.98	10.05	9,89
	0.2	138.5	141.0	126.8	135.9	140.6	134.8	12.53	13.60	12.37	11.94	12.46	10.89
	0.4	145.9	146.9	132.1	140.6	147.9	138.8	12.75	15.49	13.89	14.16	15.33	11.46
	0.6	148.4	152.5	136.4	145.7	148.9	143.9	14.56	16.88	15.72	13.28	15.94	13.44
N_3 mean		139.3	145.1	129.2	131.7	137.7	129.4	12.49	14.14	13.01	12.34	13.45	11.42
Foliation mean	0.0	114.2	124.7	109.3	96.9	106.8	95.3	9.79	10.40	9.52	9.42	9.70	9.08
	0.2	134.8	137.1	123.9	132.0	136.2	132.5	11.82	13.59	12.10	10.45	11.19	9.98
	0.4	139.2	142.2	129.7	136.8	142.7	139.0	12.50	14.81	13.16	11.44	12.67	10.37
	0.6	144.9	149. 5	132.2	142.4	146.4	142.7	14.07	16.27	14.81	11.74	13.09	11.25
LSD at0.05	A	6.06	8.78	8.70	6.07	3.7	2.30	0.39	0.52	0.34	1.13	1.18	1.78
	B	8.10	10.40	7.35	3.37	7.1	5.29	0.43	0.29	0.29	1.04	1.43	0.85
	AxB	ns	ns	ns	ns	ns	ns	ns	0.50	0.49	ns	ns	ns

Table (3): Effect of different rates of N fertilization and foliar application of (Fe+ Mn+ Zn) on fresh forage and dry matter yield of pearl millet.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates (g.l^{-1}) [B]	Fresh forage yield (Mg fed^{-1})								Dry matter yield (Mg fed^{-1})							
		2010				2011				2010				2011			
		Cut1	Cut2	Cut3	Total cuts	Cut1	Cut2	Cut3	Total cuts	Cut1	Cut2	Cut3	Total cuts	Cut1	Cut2	Cut3	Total cuts
60	**0.0**	4.50	5.28	4.65	14.43	3.39	4.15	3.58	11.12	0.72	0.81	0.72	2.26	0.65	0.76	0.70	2.11
	0.2	5.47	6.67	6.44	18.58	4.54	4.87	4.40	13.81	0.95	1.14	1.01	3.16	0.88	0.90	0.87	2.65
	0.4	6.74	7.10	6.88	20.72	4.99	5.30	4.99	15.28	1.18	1.23	1.16	3.57	0.98	1.00	1.00	2.98
	0.6	7.29	7.27	6.92	21.48	5.25	5.47	5.07	15.79	1.30	1.27	1.20	3.76	1.04	1.04	1.03	3.11
N_1 mean		6.00	6.58	6.22	18.80	4.54	4.95	4.51	14.00	1.04	1.11	1.04	3.19	0.89	0.93	0.90	2.71
90	**0.0**	5.35	6.55	5.90	17.80	4.22	4.59	4.08	12.89	0.90	0.92	0.78	2.60	0.83	0.89	0.83	2.55
	0.2	5.92	7.26	6.55	19.73	4.61	4.95	4.76	14.32	1.11	1.29	1.11	3.52	0.91	0.96	0.98	2.85
	0.4	6.94	7.79	7.02	21.75	5.10	5.42	5.09	15.61	1.24	1.39	1.26	3.89	1.04	1.06	1.04	3.14
	0.6	7.92	8.50	7.94	24.06	5.48	5.69	5.35	16.52	1.42	1.52	1.42	4.36	1.13	1.15	1.12	3.40
N_2 mean		6.46	7.53	6.85	20.84	4.85	5.16	4.82	14.83	1.17	1.28	1.15	3.59	0.98	1.02	0.99	2.99
120	**0.0**	5.74	7.03	6.87	19.64	4.99	5.17	4.58	14.74	1.01	1.02	0.96	2.98	1.03	1.01	0.94	2.97
	0.2	6.84	7.63	7.10	21.57	5.05	5.24	4.98	15.27	1.31	1.41	1.32	4.03	1.04	1.03	1.02	3.09
	0.4	7.93	8.40	8.00	24.35	5.23	5.53	5.15	15.91	1.55	1.56	1.49	4.59	1.09	1.09	1.08	3.25
	0.6	8.20	8.74	8.40	25.34	5.69	5.88	5.74	17.31	1.62	1.65	1.59	4.86	1.24	1.17	1.22	3.63
N_3 mean		7.18	7.95	7.47	22.74	5.24	5.46	5.11	15.80	1.37	1.41	1.33	4.12	1.10	1.07	1.07	3.24
Foliation mean	**0.0**	5.02	6.29	5.61	17.29	4.20	4.64	4.08	12.92	0.88	0.91	0.82	2.61	0.83	0.89	0.82	2.54
	0.2	6.08	7.19	6.70	19.96	4.76	5.02	4.71	14.47	1.12	1.28	1.17	3.57	0.94	0.96	0.96	2.86
	0.4	7.20	7.76	7.30	22.34	5.11	5.42	5.08	15.61	1.32	1.39	1.30	4.02	1.04	1.05	1.04	3.12
	0.6	7.80	8.17	7.75	23.63	5.48	5.68	5.39	16.54	1.45	1.48	1.40	4.33	1.13	1.11	1.12	3.37
LSD at0.05	**A**	0.87	0.44	0.84	1.20	0.44	0.21	0.31	0.50	0.17	0.09	0.21	0.24	0.09	0.07	0.06	0.08
	B	0.50	0.75	0.98	1.05	0.51	0.20	0.36	0.75	0.09	0.15	0.17	0.30	0.10	0.07	0.07	0.15
	A×B	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Total yield productivity of the three cuts

Increasing the rates of both N fertilization and foliar micronutrients markedly enhanced the total yield of fresh forage and dry matter, of the three cuts, of pearl millet compared with control, at the both seasons. The highest total yield for fresh forage and dry matter was 25.34 Mg fed^{-1} with percentage of increase of 75.6 % and 4.86 Mg fed^{-1} with percentage of increase of 115% for dry matter; in the 1st season. However, they were 17.31 Mg fed^{-1}with percentage of increase of 55.67 % for forage yield and 3.63 Mg fed^{-1} with percentage of increase of 72.03 % for dry yield in the 2nd one. These results were obtained by applying N fertilization at 120 kg N fed^{-1} with foliar spraying at a rate of 0.6 g l^{-1}; compared with control of 60 kg N fed^{-1} without micronutrient addition. It should be mentioned that the total forage and dry yields in the first season were better than those of the second one. This difference might be ascribed to diverse climatic conditions. The desirable effects of applying high N fertilization rates are in complete accordance with findings of Tavassoli *et al.,* (2010 b); Piri and Tavassoli (2012) and Siam *et al.,* (2012). The stimulative effect of foliar application with Fe, Mn and Zn on the studied growth characters is similar to that reported by Kassab *et al*., (2004), Sairam and Aruna Tyagi (2004) and Ali (2010) who mentioned that foliar spraying with micronutrients, especially, Fe, Mn and Zn increased the yield of crops and mineral contents of many plant types. Siam *et al.*, (2006) illustrated that the role of micronutrients in enhancing growth and yields of plants could be due to their share in the enzymatic system catalyzing numerous metabolic reaction as well as improvement of the nutritive status of treated plants.

In the current investigation, the favorable applications effects of N and micronutrients on pearl millet plants could be categorized as follows: 120 > 90 > 60 kg N fed^{-1} for N and 0.6 $\geq$ 0.4 > 0.2 g l^{-1}, for micronutrients. The interaction effects due to N application and foliar micronutrients were not significant for the plant studied characters These findings are similar to those reported by Abd El- Samad *et al.,* (2011); using onion.

Carbohydrates, fiber and protein (%)

Data presented in Table (4) show that carbohydrates and fiber contents of pearl millet plants significantly elevated by increasing the rates of mineral N fertilizer, alone or in combination with the different rates of foliar spraying of micronutrients, in both seasons. In general; increasing the applied dose of N significantly accentuated carbohydrate contents recorded for the cuts of pearl millet grown in the two seasons.

Concerning micronutrient effect, the results indicate that the foliar spraying with chelated Fe, Mn and Zn markedly elevated the content of both carbohydrate and fiber in millet plants at all applied rates, in both seasons. The highest values of carbohydrate content was 43.75 % with percentage increase of 11.5 %, compared with control (60 kg N fed^{-1} without micronutrients), in the 1^{st} season and 42.56 % with percentage increase of 13.2 %, in the 2^{nd} season. These values were recorded for the plants treated with 120 kg N fed^{-1} accompanied with 0.6 g l^{-1} micronutrients, in the second cut. As for fiber content, the highest value was 33.72 % with percentage increase of 7.77 % as the plants were treated with 120 kg N fed^{-1} in the 1^{st} season; with 0.6 g l^{-1} applied micronutrients. These results are in agreement with those of Nijjar (1985) and El-Sayed *et al.*, (2012). The later found that the spraying with micronutrients significantly increased the concentration of total carbohydrates (%) in pea plants, compared with control in both seasons.

The obtained results show that the interaction effect due to the applied N and micronutrients was exhibited, in case carbohydrate content, at the both seasons while, it was existed only in the first season for fiber content. In this concern, Osman *et al.*, (2000) indicated that the interaction between different rates of macro and micronutrients fertilization had a significant effect on fiber at the three cuts of millet. The favorable effects of N fertilization on carbohydrates content may be related to its contribution in protein synthesis and incorporation in carboxylation processes (Schmitt and Edwards, 1981). The importance of micronutrients for carbohydrates is owing to its incorporation in development and function of chloroplast, chlorophyll biosynthesis as well as to their involvement in the redox system of chloroplast (Miller *et al*., 1982 and Mortvedt *et al*., 1991).

Table (4): Effect of different rates of N fertilization and foliar application of (Fe+Mn+Zn) on carbohydrates (%) and Fiber (%) of dry matter of pearl millet.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates (g.l^{-1}) [B]	Carbohydrate (%)						Fiber (%)					
		2010			2011			2010			2011		
		Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3
60	0.0	37.81	39.25	38.72	36.25	37.59	36.79	30.85	31.29	30.66	30.22	30.85	30.37
	0.2	39.78	40.15	39.66	39.52	40.07	39.42	31.59	32.84	31.99	30.19	31.76	31.41
	0.4	39.80	41.33	40.71	39.71	40.44	39.78	31.68	32.93	32.04	31.22	31.81	31.55
	0.6	41.25	41.75	40.88	40.66	41.28	40.39	31.88	33.10	32.26	31.66	31.98	31.80
N_1mean		39.66	40.62	39.99	39.03	39.85	39.10	31.50	32.54	31.74	30.82	31.60	31.28
90	0.0	37.65	39.36	38.91	36.74	38.91	37.00	30.89	31.54	30.72	30.36	30.97	30.56
	0.2	42.09	41.89	40.16	40.12	41.03	40.02	32.16	33.29	32.56	31.30	32.78	32.29
	0.4	42.53	42.17	41.09	40.58	41.77	40.36	32.44	33.41	32.67	31.44	32.83	32.41
	0.6	42.15	42.90	41.74	41.55	41.89	40.73	32.58	33.59	32.88	31.60	32.94	32.50
N_2 mean		41.11	41.58	40.47	39.75	40.90	39.53	32.02	32.96	32.21	31.18	32.38	31.94
120	0.0	37.98	39.41	38.92	37.14	38.98	37.10	31.05	31.88	30.91	30.79	30.89	30.64
	0.2	42.09	42.62	41.86	41.79	42.10	41.59	32.55	33.59	32.80	32.10	32.29	31.59
	0.4	42.53	43.69	41.95	41.95	42.23	41.70	32.67	33.50	32.76	32.17	32.40	31.67
	0.6	42.82	43.75	42.01	42.08	42.56	41.86	32.89	33.72	32.94	32.33	32.51	31.82
N_3 mean		41.36	42.37	41.18	40.74	41.47	40.56	32.29	33.17	32.35	32.01	32.02	31.43
Foliation mean	0.0	37.81	38.34	38.85	36.71	38.49	36.96	30.93	31.57	30.76	30.68	30.90	30.52
	0.2	40.69	41.55	40.56	40.48	41.07	40.34	32.10	33.24	32.45	31.19	32.28	31.76
	0.4	41.42	42.40	41.25	40.75	41.48	40.61	32.26	33.28	32.49	31.61	32.35	31.88
	0.6	41.83	42.80	41.54	41.43	41.91	40.99	32.45	33.47	32.69	31.86	32.48	32.04
LSD at0.05	A	ns	1.0	0.55	0.04	0.06	0.05	0.04	0.04	0.04	0.37	0.04	0.04
	B	0.64	0.33	0. 41	0.04	0.06	0.05	0.03	0.03	0.03	0.34	0.04	0.04
	AxB	1.11	0.57	0.71	0.10	0.10	0.09	0.05	0.05	0.05	ns	ns	ns

In Table (5), protein content (%) in pearl millet plants were significantly enhanced, in all the taken cuts, with the all applied treatments; N fertilization or micronutrients. Application of the highest rates of both of them resulted in the highest protein content in millet plants. The highest values were 14.66 %, in the first season with percentage of increase 34.9 % and 14.72 % in the second season with percentage of increase 32.61 %, obtained in the second cut. It is interesting to notice that, the significant differences among N-rates or micronutrients rates were existed in case of protein contents for all cuts of both seasons. These results coincide with those of Hao *et al.*, (2007), who reported that N fertilizer promoted accumulation of protein in rice plants. Zeidan *et al.*, (2010) indicated that foliar application of micronutrients; Fe, Zn and Mn, significantly increased protein % of wheat plants.

Table (5): Effect of different rates of N fertilization and foliar application of (Fe+Mn+Zn) on N uptake (kg fed^{-1}) and protein (%) of pearl millet plants.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates ($g.l^{-1}$) [B]	N (kg fed^{-1})						Protein (%)					
		2010			2011			2010			2011		
		Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3
60	0.0	13.53	18.31	15.96	14.57	17.67	15.74	10.00	10.87	10.35	10.24	11.10	10.47
	0.2	21.38	26.56	23.01	20.06	21.24	20.10	12.94	13.40	13.17	13.11	13.57	13.28
	0.4	28.08	29.40	27.26	23.88	24.60	24.00	13.69	13.74	13.51	13.92	14.15	13.80
	0.6	31.71	31.39	28.56	25.38	26.22	25.03	14.03	14.20	13.69	14.03	14.32	13.97
N_1 mean		23.68	26.42	23.70	20.97	22.43	21.23	12.66	13.05	12.68	12.82	3.28	12.88
90	0.0	18.93	20.66	17.27	18.11	19.53	18.44	10.18	11.04	10.52	10.47	11.33	10.70
	0.2	25.71	30.44	25.75	21.11	22.94	23.13	13.11	13.57	13.34	13.34	13.74	13.57
	0.4	29.76	34.06	30.00	25.17	26.18	25.06	13.80	14.09	13.69	13.92	14.20	13.86
	0.6	34.79	38.00	34.36	27.91	29.10	27.33	14.09	14.38	13.92	14.20	14.55	14.03
N_2 mean		27.30	30.79	26.85	23.08	24.44	23.49	12.79	13.27	12.87	12.98	13.46	13.04
120	0.0	21.08	21.79	20.86	21.96	22.10	20.73	10.35	11.16	10.73	10.58	11.44	10.87
	0.2	30.24	33.42	30.89	24.34	25.03	24.07	13.28	13.65	13.46	13.46	13.97	13.57
	0.4	37.97	38.69	36.21	27.03	27.80	27.11	14.09	14.26	13.97	14.26	14.66	14.43
	0.6	40.17	42.08	39.43	31.37	29.95	30.80	14.38	14.66	14.26	14.55	14.72	14.94
N_3mean		32.37	34.00	31.76	26.17	26.22	25.68	13.02	13.43	13.11	13.21	13.70	13.34
Foliation mean	0.0	17.85	20.25	18.03	18.21	19.77	18.30	10.18	11.02	10.54	10.43	11.29	10.68
	0.2	25.78	30.14	26.55	21.84	23.07	22.43	13.11	13.54	13.32	13.30	13.76	13.47
	0.4	31.94	34.05	31.04	25.36	26.19	25.40	13.86	14.03	13.72	14.03	14.34	14.03
	0.6	35.56	37.16	34.12	28.22	28.42	27.72	14.16	14.41	13.95	14.26	14.53	14.16
LSD at0.05	A	0.82	0.91	0.86	0.75	0.42	0.75	0.05	0.11	0.04	0.09	0.10	0.05
	B	1.06	0.82	0.84	0.72	0.80	0.74	0.08	0.05	0.07	0.08	0.04	0.09
	AxB	1.83	1.43	1.46	1.25	.39	1.29	ns	0.09	0.12	0.13	0.08	0.15

Macronutrients uptake (kg fed^{-1})

Data presented in Tables (5 and 6) demonstrate that the uptake of N, P and K by millet plants eminently raised by application of the higher rates of N and/or micronutrients. Prominent differences were found among the rates of both N and micronutrients in case of N and P uptake. Nonetheless, they were only present between the lowest and the highest rates, in most cuts for K content. The favorite effects of the studied fertilization on N, P and k are in conformity with the results obtained by Ziaeian and Malakouti (2001). They reported that Fe treatment significantly enhanced K content in wheat. Moreover; they found that increasing P and K contents of wheat were due to increasing N application. They attributed such finding to the effect of N on root proliferation. Khalil (2005) reported that P is necessary for assimilation of protein, fats and nucleic acids and needed for normal transformation of carbohydrates in plant. Moreover, Siam *et al.*, (2012) reported that application of N fertilizer and foliar micronutrients encouraged P-uptake and attributed this encouragement to its involvement in assimilation processes of organic and inorganic P compound like; phosphoprotein and phospholipids. Hassan *et al.*, (2005) on sweet potato and El-Sayed *et al.*, (2012) on pea, indicated that spraying of plants with micronutrients significantly increased N, P and K concentrations in different plant parts.

Table (6): Effect of different rates of N fertilization and foliar application of (Fe+Mn+Zn) on the uptake of P and K (kg fed^{-1}) by pearl millet plants.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates (g.l^{-1}) [B]	P (kg fed^{-1})						K (kg fed^{-1})					
		2010			2011			2010			2011		
		Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3
60	**0.0**	1.66	2.19	1.87	1.63	2.20	2.10	16.13	17.53	16.34	14.43	17.10	15.61
	0.2	2.47	3.53	2.83	2.55	3.06	2.78	21.57	25.34	23.13	19.88	20.52	19.66
	0.4	3.71	4.31	3.60	3.14	3.70	3.40	26.90	28.16	27.26	22.25	23.30	23.00
	0.6	4.16	4.70	3.96	3.64	4.06	3.71	30.29	29.49	28.44	24.13	24.54	24.10
N_1 mean		3.00	3.68	3.07	2.74	3.26	2.99	23.72	25.12	23.79	20.17	21.37	20.59
90	**0.0**	2.25	2.67	2.11	2.24	2.85	2.57	20.34	20.63	17.94	18.68	20.56	18.84
	0.2	3.11	4.39	3.55	2.91	3.46	3.23	25.53	29.45	25.86	20.84	22.27	22.54
	0.4	4.22	5.28	4.41	3.85	4.45	3.95	28.64	32.23	29.61	23.92	25.12	24.34
	0.6	5.11	6.38	5.40	4.29	5.29	4.48	33.37	35.79	33.80	26.33	27.49	26.43
N_2 mean		3.67	4.68	3.87	3.35	4.01	3.56	26.97	29.52	26.80	22.44	23.86	23.04
120	**0.0**	2.83	3.37	2.88	2.99	3.54	3.10	23.13	23.29	22.46	23.38	23.74	21.71
	0.2	3.93	5.08	4.49	3.43	4.12	3.88	30..65	32.43	31.15	24.13	24.31	23.87
	0.4	5.58	6.55	5.66	4.36	5.01	4.64	36.74	37.07	35.76	25.92	26.16	25.60
	0.6	6.48	7.26	7.00	5.21	5.50	5.61	38.72	39.77	38.64	29.39	28.67	29.28
N_3mean		4.71	5.57	5.01	3.99	4.54	4.31	32.31	33.14	32.00	25.71	25.72	25.12
Foliation mean	**0.0**	2.25	2.74	2.29	2.28	2.86	2.59	19.87	20.48	18.91	18.83	20.47	18.72
	0.2	3.17	4.38	3.62	2.96	3.55	3.29	25.92	29.07	26.71	21.62	22.37	22.02
	0.4	4.50	6.11	4.56	3.78	4.39	3.99	30.76	32.49	30.87	24.03	24.86	24.31
	0.6	5.25	6.07	5.45	4.38	4.95	4.60	34.13	35.17	33.62	26.62	26.90	26.60
LSD At 0.05	**A**	0.43	0.60	0.57	0.49	0.60	0.24	3.90	3.90	4.22	3.78	1.77	3.23
	B	0.61	0.41	0.35	0.21	0.42	0.49	2.70	2.70	2.67	2.98	0.90	3.01
	AxB	1.10	0.71	0.60	0.36	0.72	0.85	ns	ns	ns	ns	ns	ns

The interaction effect between different rates of N fertilization and micronutrients at the both seasons was significantly affected on increasing the uptake of P and N by millet plants in all cuts, while it had a minor effect on K uptake. It could be concluded that application of mineral N fertilizer together with foliar application of micronutrients remarkably elevated N, P, and K total content of pearl millet compared with control.

Micronutrients uptake (g fed^{-1})

Data in Tables (7 and 8) indicate that the uptake of Fe, Mn and Zn by pearl millet plants markedly increased as their rates of applications increased; under each applied rate of N. Such trend was prevailing at the different cuts. It is interesting to note that the total contents of the studied micronutrients recorded higher values as the applied nitrogen was heightened. This phenomenon could be ascribed to the role of N in accumulating the dry matter yield of millet (Table 3). Another explanation by Siam *et al.*, (2006) who said that when ammonium N is absorbed by plants they release proton causing the growth medium to be more acidic and nutrients availability is increased.

Table (7): Effect of different rates of N fertilization and foliar application of (Fe+Mn+Zn) on the uptake of Fe and Mn (g fed^{-1}) by pearl millet plants.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates (g.l^{-1}) [B]	Fe (g fed^{-1})						Mn (g fed^{-1})					
		2010			2011			2010			2011		
		Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3
60	**0.0**	60.0	68.3	59.3	53.9	64.0	56.9	28.2	27..7	28.9	25.4	31.4	27.9
	0.2	85.9	108.8	95.3	79.4	85.0	81.4	40.9	51.7	45.0	36.5	40.0	37.2
	0.4	112.6	120.1	111.1	92.0	96.9	94.6	51.3	57.9	52.0	41.7	46.7	43.9
	0.6	124.9	123.7	115.1	99.1	100.4	97.7	57.4	61.2	54.3	46.3	49.5	45.3
N_1 mean		95.9	105.2	95.2	81.1	86.6	83.4	44.5	49.7	45.1	37.5	41.9	38.6
90	**0.0**	84.74	87.9	73.4	77.6	84.4	77.6	36.2	39.3	31.5	33.3	36.8	33.4
	0.2	104.1	127.3	106.2	83.1	91.8	92.5	48.3	59.7	50.3	38.8	43.6	43.2
	0.4	118.4	137.4	122.3	99.0	101.9	98.5	55.2	66.2	57.2	45.3	48.9	46.2
	0.6	137.0	150.5	137.8	108.1	111.9	106.8	64.0	74.8	64.7	50.8	54.3	49.9
N_2 mean		111.1	125.8	109.7	91.9	97.5	93.9	50.2	59.9	50.9	42.1	45.9	43.2
120	**0.0**	95.4	98.2	90.6	96.4	95.8	87.9	40.8	43.7	38.8	41.4	41.8	37.9
	0.2	123.5	139.7	127.2	97.01	99.4	97.3	58.4	72.0	61.7	45.5	49.3	46.2
	0.4	149.1	154.8	145.4	104.7	105.5	103.2	69.9	80.1	69.8	48.1	52.2	49.0
	0.6	157.7	164.1	155.4	119.4	113.4	116.6	73.3	85.1	74.6	55.6	56.4	56.2
N_3 mean		131.4	139.2	129.7	104.4	103.5	101.3	60.6	70.2	61.1	47.7	49.9	47.3
Foliation mean	**0.0**	80.0	84.8	74.4	75.9	81.4	74.1	35.1	36.9	33.1	33.4	36.7	33.1
	0.2	104.5	125.3	109.6	86.5	92.1	90.4	49.2	61.1	53.3	40.3	44.3	42.2
	0.4	126.7	137.4	126.3	98.6	101.4	98.8	58.8	68.1	59.5	45.0	49.3	46.4
	0.6	139.7	146.1	136.7	108.9	108.6	107.0	64.9	73.7	64.5	50.9	53.4	50.4
LSD at 0.05	**A**	10.70	10.20	9.90	5.65	9.50	7.04	6.78	6.77	7.01	3.58	6.24	6.89
	B	8.86	8.60	8.55	11.75	8.67	6.08	5.63	6.18	5.89	2.85	5.81	5.95
	AxB	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Foliar spraying of (Fe+Mn+Zn) at all rates affected significantly the uptake of such micronutrients by pearl millet plants. These results are in agreement with Yassen *et al.*, (2010), who reported that spraying plants with (Fe+ Mn + Zn) gave the highest Fe, Zn and Mn uptake by straw.

Data generally show no marked differences between spraying 0.4 and 0.6 g l^{-1} (Fe+Mn+Zn), on both Mn and Zn uptake. It should be mentioned that prominent differences were detected among all foliar rates on Fe content. The interaction between N fertilization rates and foliar micronutrients (Fe+ Mn +Zn) exerted slight effects on the detected micronutrients of millet plants, at the both seasons. Abd El-Samad *et al.*, (2011) reported that foliar application of micronutrients was successfully used for improving the mineral status of plants.

Table (8): Effect of different rates of N fertilization and foliar application of (Fe+Mn+Zn) on the uptake of Zn (g fed^{-1}) by pearl millet plants.

N rates (Kg fed^{-1}) [A]	EDTA Fe+Mn+Zn Rates (g.l^{-1}) [B]	Zn (g fed^{-1})					
		2010			2011		
		Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3
60	0.0	13.2	16.0	13.3	11.8	14.6	12.9
	0.2	24.1	32.1	24.9	20.8	24.1	20.4
	0.4	30.1	34.9	28.7	23.4	26.9	23.6
	0.6	33.9	37.1	30.1	25.3	28.3	24.9
N_1 mean		25.4	30.0	24.3	20.3	23.5	20.5
90	0.0	16.6	18.2	14.5	15.1	17.2	15.4
	0.2	29.4	38.0	28.5	22.0	25.8	23.6
	0.4	33.0	41.3	32.6	25.4	28.8	25.3
	0.6	38.1	45.3	36.8	27.8	31.4	27.3
N_2 mean		29.3	35.7	28.1	22.6	25.8	22.9
120	0.0	18.7	20.3	18.0	18.8	19.6	17.5
	0.2	35.6	42.5	35.1	26.4	27.9	26.0
	0.4	42.4	47.6	39.7	27.7	29.7	27.7
	0.6	44.6	50.6	42.5	31.8	32.0	31.4
N_3 mean		35.3	40.3	33.8	26.2	27.3	25.7
Foliation mean	0.0	16.2	18.2	15.3	15.2	17.1	15.3
	0.2	29.7	37.6	29.5	23.1	25.9	23.3
	0.4	35.2	41.2	33.7	25.5	28.5	25.5
	0.6	38.9	44.3	36.5	28.3	30.6	27.9
LSD at0.05	A	2.78	3.11	4.00	1.89	1.77	3.13
	B	3.05	2.93	3.00	1.23	1.89	3.13
	AxB	ns	ns	ns	ns	ns	ns

CONCLUSION

In the light of the obtained results, pearl millet as a forage yield could be planted in the sandy newly reclaimed soil in summer season provided that pertinent fertilization management would be practiced. It could be inferred that the application of nitrogen fertilization as urea at a rate of 120 kg N fed^{-1} with foliar application of a mixture solution of chelated Fe, Mn and Zn at rates; 0.4 or 0.6 g l^{-1} could give the best growth and produce the highest fresh forage and dry matter yields of pearl millet; having ample contents of macro and micronutrients. The results revealed the needs for applying a relatively high rate of N fertilizer to pearl millet to meet the high requirement of N to produce profitable total yield of three cuts.

In Egypt, this crop could play a substantial role in feeding the farm animals in summer as the lack of green forage at that time is crucial. Moreover, planting this crop in the newly reclaimed soils and storing it to be consumed as stable food in winter might reduce, somehow, the cultivated area of clover. Consequently, one may predict that the cultivated area of wheat in Egypt would be elevated at the expense of that allocated for clover.

Such strategy is needed to alleviate the tremendous amount of annually imported wheat.

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استجابة نبات الدخن اللؤلؤي للمعدلات المختلفة من النيتروجين والرش الورقي بالعناصر الصغرى تحت ظروف التربة الرملية

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أجريت تجربتان حقليتان بمحطة بحوث الإسماعيلية خلال موسمي الصيف المتعاقبين 2010، 2011 وذلك لدراسة تأثير اضافة ثلاث معدلات من التسميد النيتروجيني المعدني وهى 60، 90 و 120 كجم ن/فدان و أيضا الاضافة الورقية بمحلول يحتوي على خليط من العناصر الصغرى (حديد+منجنيز+زنك) المخلوبة بمركب EDTA بمعدلات هي 0.0 ، 0.2 ، 0.4 ، 0.6 جم/ لتر بمعدل 400 لتر/فدان على صفات النمو، والإنتاجية و بعض العناصر الغذائية الممتصة لمحصول نبات الدخن اللؤلؤي (صنف شندويل1)/ فدان، النامي تحت ظروف التربة الرملية.

وقد أخذت ثلاث حشات ممثلة كعينات خلال موسم النمو وهى بعد 45 يوم ، و 85 يوم وبعد 125يوم من الانبات الكامل للبادرات. وقد أظهرت النتائج المتحصل عليها أن طول النبات و عدد التفريعات لكل نبات و انتاجية نبات الدخن اللؤلؤي الممثلة في العلف الطازج و محصول المادة الجافة له قد زادت بزيادة معدلات التسمد النيتروجيني و أن اضافة الرش الورقي بالعناصر الصغرى بجميع معدلاته زاد كل هذه الصفات بزيادة معنوية.و كانت أفضل النتائج المتحصل عليها عند اضافة معدل التسميد النيتروجيني 120 كجم/فدان المصاحب لاضافة الرش الورقي لخليط العناصر الصغرى (حديد+منجنيز+زنك) بمعدل 0.4 أو 0.6 جم/ لتر. وقد زاد محتوى كل من الكربوهيدرات و البروتين والالياف الخام فى المادة الجافة لنبات الدخن عند زيادة كل من معدلات التسميد النيتروجيني أو العناصرالصغرى المضافة بالرش الورقي . وبالإضافة الى ذلك حدثت زيادة معنوية في الممتص بواسطة المادة الجافة لنبات الدخن لكل من النيتروجين، و الفوسفور، والبوتاسيوم (كجم/فدان) ، والممتص من الحديد، والمنجنيز، والزنك(جم/فدان). وتم إلقاء الضوء على أهمية استزراع محصول الدخن اللؤلؤي كعلف واعد يستزرع في الصيف في مصر.

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