Arab Gulf J. Scient. Res. **13**(2), pp. 309-321 (1995)

Effect of Intensive Fertilization Practice on Some Calcareous Soils in Saudi Arabia

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ABSTRACT. A soil fertility survey was conducted over two years in two major agricultural regions in Saudi Arabia. Four centre pivot fields representing Hail and Tabuk sites were chosen. Effect of intensive application of chemical fertilizers used for wheat production on soil chemical properties was studied. Soil test levels of P, K, Fe, Zn, Mn and Cu were determined.

The results show that there is considerable P accumulation in the surface layers of all fields under investigation; whereas the K content of the soils is decreasing. Mn build up in the surface layers of all the fields has also been observed.

Wheat production in Saudi Arabia increased from just over 3000 tons in 1974 to about 3.5 million tons in 1990 (ASYB 1990). Self-sufficiency in wheat was achieved in 1984 (Cheeseworth 1986). Government's subsidies and free distribution of agricultural lands as well as the introduction of mechanization, modern irrigation systems (mainly centre pivot), highyielding crop varieties, certified seeds, pesticides and the application of large amounts of fertilizers are the main factors contributing to the large increase in crop production. In the late 1970s the main fertilization programme used in many parts of the country for wheat production was the application of three doses of urea at a total rate ranging from 400 to 500 kg ha^{-1} and triple super phosphate at a total rate ranging from 400 to 500 kg ha^{-1} . Addition of either K or trace elements was not practiced. However, since the mid 1980s the most common fertilization programme practiced for wheat production in many parts of the country is as follows:

1. Potassium sulphate applied as fertilizer material before planting at a rate of 100 to 150 kg ha^{-1}.

2. Diammonium phosphate to large extent or monoammonium phosphate at a rate of 400 to 500 kg ha^{-1} applied as fertilizer material during sowing at a distance from the seed using special seeder.

3. Urea applied through the irrigation water during the growing season (8-14 doses) at a total rate of 400 to 500 kg urea ha^{-1}.

4. Trace elements applied during the growing season in chelated form at a rate, of 3 to 5, 3 to 5, 2 to 3 and 2 to 3 kg ha^{-1} for Fe, Zn, Mn and Cu, respectively.

This soil fertility survey was conducted to observe the effect of intensive application of chemical fertilizers on topsoils chemical properties of two major agricultural regions in Saudi Arabia.

Materials and Methods

Four centre pivot fields representing a very small portion of wheat production sites in Ha'il and Tabuk regions located in the northern part of Saudi Arabia were chosen to monitor the effect of intensive application of fertilizers on soils. The choice of the locations was based on several important factors. It was seen that quality of irrigation water was good so that the negative effect of saline water on the ability of plants to absorb nutrients is obviated; secondly, the fields had been under cultivation and been intensively fertilized for over five years (Table 1) under professional management; and thirdly, reliable farm records in terms of inputs and outputs were available.

Soil sampling

All the studied fields were under centre pivot irrigation system and planted with wheat with an average area of about 40 hectares per field. Each field was divided into four sections (Fig. 1) and a total of twenty soil smaples from two different layers (0-15 cm depth and 15-30 cm depth) were collected from each section. The soil samples of each layer were then thoroughly mixed and a composite soil sample at each depth was analyzed for P, K, Fe, Zn, Mn, and Cu. The soil sampling was done in August after harvesting in 1991 and 1992.

Table 1. Amount of Fertilizer Materials (kg ha^{-1}) Added to the Study Fields Over Five Years

C. P.	Fertilizer		Year				
			1988	1989	1990	1991	1992
TA1	Urea		500	500	450	450	450
	DAP[1]	a	400	400	500	500	350
		b	150	150	-	-	150
	PS[2]		-	-	-	-	150
TE[3]	Fe		-	3	5	5	5
	Zn		-	0	2	2	2
	Cu		-	0	2	2	2
	Mn		-	3	5	5	5
TA2+	Urea		450	450	450	450	450
	DAP	a	400	400	500	500	350
		b	150	150	-	-	150
	PS		-	-	-	-	-
TE	Fe		-	3	5	5	5
	Zn		-	2	-	-	-
	Cu		-	2	-	-	-
	Mn		-	3	5	5	5
HA1*	Urea		550	550	550	500	500
	DAP	a	500	500	450	450	300
		b	-	-	-	-	150
	PS		-	100	100	150	150
TE	Fe		-	5	5	5	5
	Zn		-	3	3	3	3
	Cu		-	3	3	3	3
	Mn		-	2	2	2	2
HA2	Urea		-	450	450	500	500
	DAP	a	-	400	400	400	350
		b	-	-	-	-	150
	PS		-	-	-	-	-
TE	Fe		-	-	5	5	5
	Zn		-	-	2	2	2
	Cu		-	-	1	1	2
	Mn		-	-	1	1	2

1. Diammonium phosphate.
   a. First application added at two different times (50% broadcasted before planting and mixed with topsoil - 50% placed at a distance from the seed during sowing).
   b. Second application side dressed 35 days after germination.
2. Potassium sulphate broadcasted before planting and mixed with topsoil.
3. Trace elements added in chelated form as EDDHA for Fe and EDTA for Zn, Cu and Mn.
   + Straw burned in 1991.
   * Straw burned for the last three years.

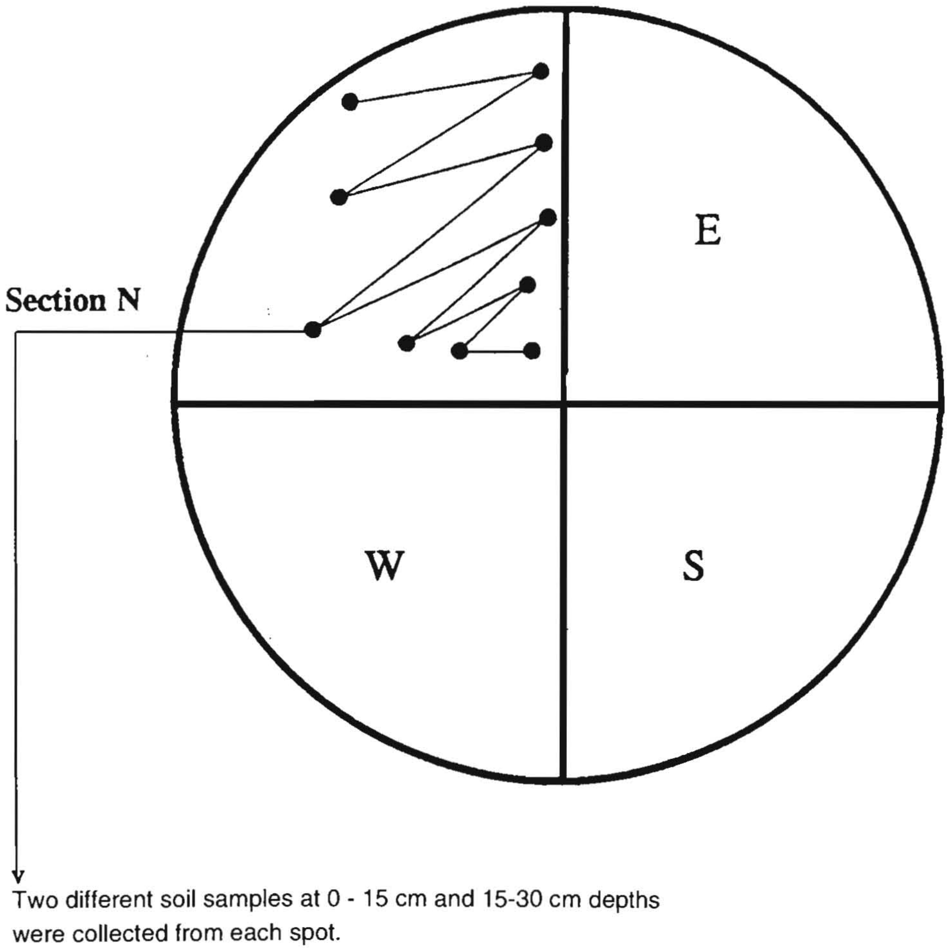

Fig. 1. Shows the methodology of samples collection.

Laboratory analyses

The soil samples were air dried and passed through a 2 - mm sieve. Phosphorus was determined by the modified $NaHCO_3$ extraction method using ascorbic acid as a reducing agent (Watanabe and Olsen 1965). Potassium, Fe, Zn, Mn and Cu were determined by the extraction method of macro and micro nutrients in alkaline soils (Soltanpour and Schwab 1977). Determinations of pH were made as described in U. S. D. A. Salinity laboratory Handbook 60 (Richards 1954).

Results and Discussion

Available phosphorus:

Available P in Saudi calcareous virgin soils is generally very low (Bashour *et al.* 1983). Table 2 shows that available P in the virgin soils of Tabuk and Ha'il sites is far below the critical level of 10 ppm given by Kamprath and Waston (1980). This is in agreement with the analysis of available P in uncultivated Saudi soils (unpublished results) carried out by the staff of soil section of the National Agriculture and Water Research Centre (NAWRC), Riyadh, Saudi Arabia. Table 2, however, shows considerable accumulation of available P especially in the top soil (0-15 cm depth) in all sections of all studied fields as a result of intensive fertilization. The data in Table 2 show that the accumulation of P in the second year of the study at surface depths in most fields is significantly higher than that of the first year. This could be attributed to the fact that most of the free calcium in these fields is saturated with P, whereby the accumulation of available P is sharply increased. Campbell (1965) pointed out that most of the applied P over a period of several years can be recovered.

The accumulation of available P above agronomic requirements could be inducing Fe and Zn deficiency in many agricultural areas all over the country. It must be emphasized that lack of knowledge about the negative aspect of intensive fertilization among most of farm managers makes the problem more complicated and very costy to overcome.

Extractable K

The content of potassium in all studied fields is given in Table 3. Apart from the field HA1 in Ha'il region which has been fertilized with K for many years, and the field TA1 which was fertilized with K in the second year the amount of K in the soils is generally decreasing. The content of K in the virgin soils varies from one location to another depending on the amount and type of the clay. Excluding the field TA2, which is mainly fine textured, the general trend indicates that the native content of K in the studied soils is below the critical level of 150 ppm (local interpretations). Bashour *et al.* (1983) concluded that the content of potassium in seven out of twelve samples collected from all over the country is below the critical level of 175 ppm given by Doll and Lucas (1973).

Table 2. Analysis of Available P (ppm) in Tabuk and Ha'il Sites in 1991 and 1992

C. pivot		Depth	Sections					Virgin Soil
			N	S	W	E	$\bar{X}$	
Tabuk								
TA1	1991	0 - 15	17.0	14.4	25.2	19.2	19.0 al*	2.0
		15 - 30	5.8	6.0	13.4	8.2	8.4 a2	1.0
	1992	0 - 15	27.6	28.6	33.0	12.4	25.4 al	
		15 - 30	11.6	11.4	14.8	7.6	11.4 a2	
TA2	1991	0 - 15	15.8	13.8	14.2	17.2	15.3	3.6
		15 - 30	3.6	4.6	4.6	3.2	4.0	3.0
	1992	0 - 15	25.6	26.4	28.0	26.0	26.0	
		15 - 30	7.4	8.4	8.0	9.0	8.2	
Ha'il								
HA1	1991	0 - 15	13.0	18.0	17.0	19.0	16.8	3.5
		15 - 30	8.1	7.2	7.4	7.0	7.4 a3	3.4
	1992	0 - 15	24.4	26.0	26.0	27.4	26.0	
		15 - 30	9.0	8.2	11.0	9.6	9.5 a3	
HA2	1991	0 - 15	12.0	14.0	10.4	9.4	11.5	2.5
		15 - 30	4.0	1.8	Tr	0.5	2.1 a4	1.4
	1992	0 - 15	19.0	24.4	16.6	39.0	24.8	
		15 - 30	3.6	7.8	2.4	3.2	4.3 a4	

* The corresponding year-wise ($\bar{x}$) values, marked by the same alphanumeric symbol, are not significantly different at 5% level of probability.

Table 3. Analysis of Extractable K (ppm) in Tabuk and Ha'il Sites in 1991 and 1992

C. pivot		Depth	Sections					Virgin Soil
			N	S	W	E	$\bar{X}$	
Tabuk								
TA1	1991	0 - 15	106	84	58	76	81 *	131
		15 -30	106	110	77	95	97 a1	90
	1992 (K was added)	0 - 15	106	100	106	126	109	
		15 - 30	116	112	92	154	119 a1	
TA2	1991	0 - 15	228	163	227	152	193 a2	284
		15 - 30	284	187	330	144	236 a3	572
	1992	0 - 15	214	120	180	220	184 a2	
		15 - 30	360	166	234	230	247 a3	
Ha'il								
HA1	1991	0 - 15	162	176	158	166	166	72
		15 - 30	160	146	166	162	159	72
	1992	0 - 15	230	194	176	226	207	
		15 - 30	106	94	90	104	99	
HA2	1991	0 - 15	100	102	122	120	111 a4	162
		15 - 30	106	90	118	114	107	88
	1992	0 - 15	138	72	64	78	88 a4	
		15 - 30	54	42	36	52	46	

* The corresponding year-wise ($\bar{x}$) values, marked by the same alphanumeric symbol, are not significantly different at 5% level of probability.

It is believed by many agricultural workers and farm managers in the Kingdom that the potassium content of most irrigation water and most soils is rather high. Therefore, the general recommendation is that K should not be added for wheat production. This is not true. In fact, the decision to apply or not to apply this nutrient should be based on the results of annual analyses of both the irrigation water and the soil, to guard against any deficiency of K.

Available trace elements

The available trace elements contents are given in Table 4 and Table 5 for Tabuk and Ha'il sites respectively. The general trends indicate that the level of Zn and Cu is adequate in all fields under investigation. However, the level of Cu in field HA1 (Table 5) in Ha'il is much higher than its level in other fields. This could be attributed to the large amount of fertilizers added to this field as well as the burning of straw for several years. It is also clear in the same field (HA1) that the level of Fe at both depths is much higher than that observed in the other fields. The results also show that the level of Fe in Tabuk sites (Table 4) in the second year of the study is significantly higher at the surface depths compared to its level in the first year.

The accumulation of Mn in the surface layers of all fields is considered to be the most pronounced effect of fertilization practice especially in Tabuk sites (Table 4). In Ha'il sites (Table 5) the same trend can be noticed in both fields where, although, the accumulation in the first year was less compared to that in Tabuk. However, it increased significantly in the second year in the field HA2.

The results of soil pH (Table 4 and Table 5) show a slight drop in pH values during the study period in all fields as a result of acidification effect of high amounts of nitrogen fertilization. This could have largely contributed to Mn and Fe accumulation in all fields under investigations.

Lindsay and Norwell (1978) pointed out that, in calcareous soils, the critical levels, expressed in ppm, of Fe, Zn, Mn and Cu are 4.5, 0.8, 1.0 and 0.2, respectively. The analysis of virgin soils show that the soil of Tabuk and Ha'il sites are deficient in Fe, Zn and Mn; whereas, the level of Cu is adequate. Stewart-Jones and Kelso (1977) and Bashour *et al.* (1983) indicated that several soil samples taken from different parts of the country were mainly deficient in Fe and Zn.

Table 4. Analysis of Available Trace Elements (ppm) in Tabuk Sites in 1991 and 1992*

C. pivot	Depth	Fe	Zn	Cu	Mn	pH
TA1 1991	0 - 15	5.16 +	1.42 a1+	0.82 a1+	10.6 a1+	8.06
	15 - 30	5.27 a1	0.88 a2	0.57 a2	4.81 a2	7.79
1992	0 - 15	10.8	1.5 a1	0.87 a1	15.7 a1	7.95
	15 - 30	5.3 a1	0.64 a2	0.5 a2	3.7 a2	7.70
Virgin	0 - 15	3.36	0.42	0.20	0.24	8.29
soil	15 - 30	2.12	0.18	0.12	0.16	8.06
TA2 1991	0 - 15	4.22	0.71 a3	0.61	7.96 a3	8.15
	15 - 30	3.25 a2	0.29	0.40 a3	1.10	8.22
1992	0 - 15	6.90	0.75 a3	0.70	10.7 a3	8.02
	15 - 30	5.00 a2	0.39	0.44 a3	2.40	8.08
Virgin	0 - 15	2.74	0.18	0.26	0.52	8.38
soil	15 - 30	3.24	0.22	0.34	0.72	8.58

* Figures in this table represent the average content ($\bar{x}$) of each element of the study fields.

\+ For each element, the corresponding year-wise (mean) values, marked by the same alphanumeric symbol, are not significantly different at 5% level of probability.

Table 5. Analysis of Available trace elements (ppm) in Ha'il Sites in 1991 and 1992*

C. pivot	Depth	Fe	Zn	Cu	Mn	pH
HA1 1991	0 - 15	10.4 a1^{+}	1.1 a1^{+}	1.8 a1^{+}	4.5 a1^{+}	7.87
	15 - 30	9.9 a2	0.6 a2	1.1 a2	1.9 a2	7.97
1992	0 - 15	16. a1	1.1 a1	1.6 a1	8.9 a1	7.75
	15 - 30	12.5 a2	0.5 a2	0.9 a2	2.2 a2	7.87
Virgin	0 - 15	2.3	0.1	0.4	0.7	8.15
soil	15 - 30	3.0	0.2	0.4	0.8	7.92
HA2 1991	0 - 15	6.80 a3	0.7 a3	0.8 a3	4.9	7.94
	15 - 30	10.00 a4	0.5 a4	0.8 a4	2.9 a3	7.94
1992	0 - 15	5.6 a3	0.9 a3	0.9 a3	11.6	7.81
	15 - 30	9.0 a4	0.5 a4	0.7 a4	1.8 a3	7.89
Virgin	0 - 15	3.4	0.2	0.6	1.1	8.19
soil	15 - 30	2.1	0.2	0.5	0.9	7.99

* Figures in this table represent the average content ($\bar{x}$) of each element of the study fields.

\+ For each element, the corresponding year-wise (mean) values, marked by the same alphanumeric symbol, are not significantly different at 5% level of probability.

Conclusions

The low native productivity of calcareous soils is the main reason for the large application of fertilizers for crop production all over the country. This study showed that the continuous intensive application of all kinds of fertilizers could result in accumulation of P and Mn and to small extent Fe with a potential for substantial reduction in yields. On the other hand, the little or no addition of K would also adversely effect the productivity of all crops in few years time of cultivation as a result of the decrease in the content of soil potassium.

The acidification effect of excessive amounts of nitrogen fertilization on soil pH value could be a major factor contributing to the accumulation of available form of P, Mn and Fe. This should be thoroughly studied and investigated under local calcareous soils conditions.

The current practice of applying excessive amounts of fertilizers for crop production must be drastically improved and balanced. This will surely help to stem the production cost and bring about higher yield by eliminating the serious interactions between different elements.

Acknowledgements

The author is very thankful to Dr. M. A. Ali for reviewing the manuscript and to Dr. A. S. Al-Khalifa for doing the statistical analysis. Thanks are also given to Dr. A. I. Adam for his valuable suggestions and help in collecting soil samples.

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(Received 29/01/1994;
in revised form 25/01/1995)

تأثير التسميد المكثف على الترب الجيرية في المملكة العربية السعودية

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إدارة استثمار الأراضي – وزارة الزراعة والمياه – الرياض – المملكة العربية السعودية

تم القيام بعملية مسح لخصوبة التربة في منطقتين زراعيتين رئيسيتين في المملكة لمدة سنتين متواليتين . حيث تم دراسة تأثير اضافة كميات كبيرة من الأسمدة المستخدمة لزراعة محصول القمح على الترب المحلية ، وذلك بتقدير الصور الميسرة للنبات من العناصر الغذائية الآتية :

الفوسفور ، البوتاسيوم ، الحديد ، الزنك ، المنجنيز ، النحاس .

اشارت النتائج إلى تراكم عنصر الفوسفور وبشكل كبير في الطبقات السطحية لجميع الترب الخاضعة للدراسة . كذلك اشارت النتائج إلى النقص المتواصل لمحتوى عنصر البوتاسيوم من الترب المدروسة . أيضاً دلت النتائج إلى تراكم عنصر المنجنيز في الطبقات السطحية من الترب المدروسة .