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Evaluation of Some Chemical Extraction Methods Used as Indices of Soil Nitrogen Availability in Polatlı State Farm Soils in Ankara Province*

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Abstract: In pursuit of evaluating the suitability of methods for determining the ability of soils to supply available nitrogen under different soil conditions, two biological aerobic and anaerobic incubation procedures and six chemical extraction methods were applied to 31 samples of soil collected from the Central Anatolian area. The selected area for the study represents the criteria of arid and semi-arid regions. Statistically significant correlation coefficients were found between the biological methods and the five chemical methods that were evaluated out of the six. Only the alkaline $KMnO_4$ method did not give a significant correlation cofficient. The results of the phosphate-borate buffer method gave the highest correlation with the results of the biological methods. Although the method of hot 2 M KCl had a good correlation with biological methods, the r values obtained by this method were lower than those that obtained by the phosphate-borate buffer method. When the six chemical extraction methods were compared with each other, it was seen that the highest correlations were established between the acid $KMnO_4$ method and each of the total hydrolyzable ammonium and total hydrolyzable nitrogen methods. However, the lowest relations were found between the results obtained by the alkaline $KMnO_4$ method and the other chemical extraction methods. It was concluded that phosphate–borate buffer and acid $KMnO_4$ methods were the most suitable for Central Anatolian soils and other similar soil types. The total hydrolyzable NH_4-N value gave a high correlation with the biological method.

Key Words: Potantially available nitrogen, aerobic and anaerobic incubation, chemical extraction, arid and semi-arid regions, mineralization.

Ankara-Polatlı Tarım İşletmesi Topraklarında Yarayışlı Azotun Belirlenmesinde Kullanılabilecek Uygun Kimyasal Ekstraksiyon Yöntemlerinin Saptanması

Özet: Farklı özelliklere sahip toprakların bitkiye yarayışlı azot sağlama yeteneklerinin belirlenmesinde kullanılacak uygun bir yöntemi tespit etmek üzere Orta Anadolu Bölgesinden alınmış olan 31 adet toprak örneğinde biyolojik aerobik ve biyolojik anaerobik olmak üzere iki inkübasyon yöntemi ile 6 değişik kimyasal ekstraksiyon yöntemi ile çalışılmıştır. Çalışma alanı kurak ve yarı kurak bölge özelliklerini taşımaktadır. Çalışılan kimyasal yöntemlerden 5 tanesi ile biyolojik yöntemler arasında istatistiki olarak önemli korelasyon katsayıları tespit edilmiştir. Yalnızca alkali $KMnO_4$ yöntemi istatistiksel önemli korelasyon vermemiştir. Biyolojik yöntemlerle en yüksek korelasyon katsayısını fosfat-borat tampon yöntemi vermiştir. Sıcak 2M KCl yöntemi de biyolojik yöntemler ile iyi korelasyon vermiş olmasına rağmen, bu yöntemle elde edilen r değerleri fosfat-borat tampon yöntemiyle elde edilenlerden daha küçük olmuştur. Altı kimyasal ekstraksiyon yöntemi birbirleriyle karşılaştırıldığında, en yüksek korelasyon katsayısının asit $KMnO_4$ yöntemi ile hem toplam hidrolize olabilir amonyum yöntemi hem de toplam hidrolize olabilir azot yöntemi arasında olduğu görülmüştür. Buna karşın, en düşük korelasyon katsayıları da alkali $KMnO_4$ yöntemi ile diğer kimyasal ekstraksiyon yöntemleri arasında elde edilmiştir. Bu sonuçlardan Orta Anadolu ve benzer koşullar için fosfat-borat tampon yöntemi ile asit $KMnO_4$ yönteminin en iyi yöntemler olduğu, toplam hidroliz olabilir amonyum değerinin de biyolojik yöntemlerle iyi korelasyon verdiği görülmektedir.

Anahtar Sözcükler: Potansiyel yarayışlı azot, aerobik ve anaerobik inkübasyon, kimyasal ekstraksiyon, kurak ve yarı kurak bölgeler, mineralizasyon.

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Introduction

Many efforts have been made to verify the suitability of chemical and biological methods that can estimate, with reasonable accuracy, the potentially available soil-N in different soil conditions (Bremner, 1965b; Kacar and Arat, 1973; Stanford and Smith, 1978; Gezgin and Karakaplan, 1994; Jalil et al., 1996). However, in arid and semi-arid regions there have been relatively few studies on this subject. The ability of soils in such areas to supply this macronutrient during the growing season of a plant is of paramount importance. In the soils of arid and semi-arid areas, such as in Central Anatolia, the generally low levels of native soil-N and the apparent high losses of applied N fertilizers make the prediction of soil N availability and N supplying power or response difficult.

On the other hand, the adverse effects of the excessive application of fertilizer N on crop quality and the environment have been well recognized. Recent biological methods involving the incubation of soils under conditions, that promote the mineralization of organic-N generally have proven to be promising indices of the N supplying power of soils.

Recently, many studies have proven that biological incubation techniques provide a fairly satisfactory index of the availability of soil-N, and they are considered to be the best laboratory method currently available for the assessment of potentially available soil-N (Korkmaz and Gülser, 1995; Keeney, 1982). However, these biological methods are not simple and rapid enough for use in soil testing laboratories, and subsequently, there is an urgent need for more simple, accurate and rapid chemical extraction techniques for measuring the potentially available soil-N. Although it seems impossible from the outset to find a unique chemical procedure that simulates the activities of microorganisms in the release of soil-N, chemical methods evaluating these forms of N by extraction are frequently used because of their simplicity, rapidity and low cost (Stanford, 1978; Gianello and Bremner, 1986; Smith and Li, 1993).

The objective of this study is to evaluate some of the most promising chemical extraction methods to estimate the capacity of arid and semi-arid soils of Central Anatolia to supply available soil-N for crop utilization. In addition, it sought to compare the extracted soil-N by chemical methods with the quantities of mineralizable soil-N obtained by biological aerobic and anaerobic incubation methods.

Materials and Methods

The soils used in the study were collected from 31 locations in the Polatlı State Farm area, located in Central Anatolia, and they fit the criteria of arid and semi-arid regions. The soils in that area are mainly used for the production of cereal crops.

The soil samples collected from 0 to 20 cm depth were taken from the central part of each location using a spade, and three subsamples were picked from each sampling and were combined to give one homogeneous sample. The selected plots for sampling had not received nitrogen fertilizers and the samples were taken just before planting.

Soil samples were shipped to the laboratory and air dried without delay. Bulk samples were passed through a sieve with 3-cm square openings, to remove stones, coarse root fragments and stubble, and prepared for the pot experiment. Subsamples were removed, passed through a 2-mm sieve and stored frozen at –5°C. The analysis reported in Table 1 shows some pertinent physical and chemical properties of the soils used in the study.

In the research, particle size analysis was performed according to Day's (1965) hydrometer method, soil pH by a pH-meter with glass electrode for 1:2,5 soil-water suspension, organic matter content by the modified Walkley-Black method (Nelson and Sommers, 1982), lime content by the calcimeter method (Nelson 1982), total nitrogen content by the micro-Kjeldahl method, and exchangeable ammonium and nitrate-nitrite by the steam distillation method (Bremner, 1965a).

Biological Methods of Assessing Potentially Available Soil-N

Aerobic Incubation Procedure

This procedure involved the determination of (NH_4+NO_3+NO_2)-N produced from the incubation of a mixture of 10 g sample of air dried soil and 30 g of water washed by 30- to 60-mesh quartz sand (Keeney and Bremner, 1967). The mixture was distributed evenly over the bottom of a 250-ml bottle containing 6 ml of distilled water to moisten the mixture and to bring the moisture content to the field capacity.

Then the bottles were tapped gently many times to level the surface of the mixture. The necks of the bottles were fitted with rubber stoppers having a central hole

Table 1. Some pertinent physical and chemical properties of soil samples used in the study.

Sample No.	Soil series	Clay %	Silt %	Sand %	PH 1:2.5	$CaCO_3$ %	SOM %	Total N%	NH_4-N ppm	NO_3-N ppm
S1	Kap 21*	36	41	23	7.72	25.7	1.93	0.21	4.74	4.08
S2	Kap 94	35	38	27	7.52	32.1	1.53	0.13	3.56	9.82
S3	Kap 93	30	39	31	7.48	44.8	2.04	0.18	11.12	5.84
S4	Beyazbayır 17	35	31	34	7.63	25.7	1.13	0.14	3.08	2.68
S5	Beyazbayır 18	39	37	24	7.62	24.3	1.37	0.13	12.52	7.44
S6	Beyazbayır 85	38	37	25	7.55	35.7	1.53	0.15	11.08	18.25
S7	Çıralı 85	29	37	34	7.56	36.4	2.78	0.24	16.97	5.49
S8	Çıralı 101	34	31	35	7.64	30.8	1.76	0.13	3.78	7.37
S9	Çıralı 17	35	38	27	7.58	32.1	2.06	0.16	8.71	10.18
S10	Bezik 89	36	37	27	7.54	22.8	2.10	0.18	11.82	14.17
S11	Bezik 90	33	36	31	7.52	27.2	2.06	0.17	6.52	4.65
S12	Bezik 96	38	37	25	7.58	18.5	1.44	0.17	5.62	5.24
S13	Çiftağıl 81	34	37	29	7.53	22.1	1.82	0.16	8.18	11.98
S14	Çiftağıl 95	22	38	40	7.44	2.3	1.86	0.16	6.52	6.45
S15	Çiftağıl 90	35	38	27	7.68	17.2	1.90	0.19	11.22	17.71
S16	Çiftağıl 82	36	37	27	7.52	35.7	2.41	0.25	9.54	15.97
S17	Kepir 42	40	43	17	7.58	21.4	2.69	0.2	3.45	20.63
S18	Kepir 34	39	42	19	7.55	14.3	1.16	0.14	5.93	19.56
S19	Kepir 33	41	40	19	7.39	10.7	1.64	0.15	8.65	61.20
S20	Kırbeli 36	46	41	13	7.57	13.5	1.35	0.14	10.85	7.30
S21	Kırbeli 35	47	40	13	7.38	8.2	2.14	0.18	8.25	8.50
S22	Kırbeli 33	44	37	19	7.46	9.9	2.35	0.17	4.95	32.40
S23	Polatlı 94	38	39	23	7.64	5.3	1.37	0.15	2.55	5.40
S24	Polatlı 93	36	37	27	7.54	17.1	1.06	0.15	5.95	16.50
S25	Polatlı 97	35	42	23	7.62	7.6	1.72	0.14	8.22	6.80
S26	Yaylabel 15	32	34	34	7.56	16.2	1.29	0.14	5.12	6.20
S27	Yaylabel 16	37	39	24	7.64	26.2	1.95	0.12	6.47	8.30
S28	Yaylabel 84	42	37	21	7.62	12.8	1.98	0.15	5.87	7.20
S29	Yüzükbaşı 80	29	37	34	7.65	26.4	1.35	0.15	3.52	2.90
S30	Yüzükbaşı 86	40	41	19	7.59	7.2	2.62	0.19	7.15	4.10
S31	Yüzükbaşı 92	39	38	23	7.61	5.9	1.12	0.14	3.05	10.70

*: Plot Number

(16-17 mm in diameter) sealed tightly with an aeration device. The bottles were then placed in a constant-temperature cabinet (incubator) at 30 ±1°C.

After 14 days, the bottles were taken out of the incubator, and their rubber stoppers were removed. A total of 100 ml of 2 M KCl was added to each bottle and the bottles were fitted with solid rubber stoppers and shaken for one hour in a mechanical shaker. Then the bottles with their resulting suspension were allowed to stand until the soil-sand mixture settled and the supernatant liquid was clear (about 30 min.). A 20 ml aliquot of the supernatant liquid was added to a 100-ml distillation flask by means of a dispenser.

The amounts of (NH_4+NO_3+NO_2)-N produced from the soil-sand mixture during the incubation period were determined from the ammonium-N liberated by the steam distillation of this aliquot with 0.2 g MgO and 0.2 g Devarda alloy for 3.3 minutes. The mineralizable-N was calculated as the difference between the amount of NH_4-N liberated after the incubation and the amount of NH_4-N liberated from the soil sand mixture before the incubation.

Anaerobic Incubation Procedure

The anaerobic incubation procedure (waterlogged) used in the study was previously described by Waring and Bremner (1964) and modified and developed by Keeney (1982) and is strongly recommended for the assessment of the mineralizable–N during an incubation period.

The method involves the incubation of a soil sample under waterlogged conditions in an enclosed test tube with as little head space as possible in the tube. Distilled water of about 12±1 ml was placed in a 16X150-mm test tube, then 5g of oven-dry equivalent soil was added to the tube. The test tubes were stoppered and placed in a constant temperature cabinet maintained at 40±1°C. At the end of 7 days, the tubes were removed from the cabinet and shaken briefly to mix the content. The soil water mixture of each tube was quantitatively transferred to a 150-ml distillation flask. About 12 to 15 ml of 4 M KCl were used to facilitate the transfer. About 0.2 to 0.3 g of MgO was added, and the amounts of NH_4-N liberated by steam distillation for 4 minutes were determined. The steam distillation apparatus used was as described in the previous method. The initial amounts of NH_4-N present in the soil before incubation were determined in the steam distillation apparatus by the procedure used for the analysis of the incubated mixture. The mineralizable–N was calculated from the difference between the results of these two analyses.

Chemical Extraction Methods

1. Hot 2 M KCl extraction method

The method used was as described by Gianello and Bremner (1986). A 3 g sample of 2 mm soil was placed in a 100-ml technicon digestion tube (25mm X 300mm), and 20ml of 2 M KCl was added to the soil. The tubes were fitted with rubber stoppers and placed in a technicon block digester maintained at 100°C. After 4 hours, the tubes were removed from the block digester and allowed to cool. Then 0.2 g of MgO was added and the digestion tubes were directly connected to the steam distillation apparatus to determine the extractable NH_4-N liberated from the soil. The ammonium-N initially present in the soil was determined by the same procedure described above but without heating the soil-KCl mixture in the block digester. The extracted NH_4-N by this method could be calculated by the difference between the NH_4-N produced by heating the soil sample with 2M KCl and the NH_4-N produced from the soil without heating.

2. Phosphate-Borate Buffer Method

This method was essentially the phosphate-borate buffer method described by Gianello and Bremner (1986). Some 4 g of air-dried soil was steam-distilled with 40 ml of pH 11.2 phosphate-borate buffer for 8 min in the steam distillation apparatus.

The ammonium-N initially present in the soil sample was determined by estimating the ammonia-N liberated by the steam distilling of 4 g of soil with 0.2 MgO and 20 ml of 2M KCl for 3.3 min. The ammonium-N produced from organic soil-N by heating the samples with pH 11.2 buffer was calculated as the difference between the result of these two analyses.

3. Total Hydrolyzable Ammonium-N

The procedure of hydrolyzing the soil under reflux with 6M HCl for 6 to 12 h is usually used in estimating total hydrolyzable-N, total hydrolyzable ammonium-N and some major known fractions of organic soil-N (Stevenson, 1982). Some 5 g of finely ground (< 100 mesh) soil sample was placed in a round-bottom flask fitted with a standard taper (24/40) ground-glass joint. Some 2 drops of octyle alcohol and 20 ml of 6N HCl were

added, and the flask was swirled thoroughly to mix the contents. Then the flask was placed in an electric heating mantle and connected to a Liebig condenser fitted with a 24/40 ground-glass joint, and the soil-acid mixture was heated under reflux for 6 h.

The hydrolysis mixture was then filtered, and the residue in the filter paper was washed with a 5 to 10 ml portion of distilled water. The pH of the filtrate was neutralized to pH 6.5±0.1 by the cautious addition of NaOH, using a pH-meter to follow the coarse of neutralization. Some 10 ml of the hydrolyte was placed in a 100-ml distillation flask, 0.07±0.01 g of MgO was added, and the flask was connected to the steam distillation apparatus. The NH_4-N in the distillate was determined by titration with standard 0.005 N H_2SO_4 from a digital micro-burette.

4. Total Hydrolyzable Nitrogen

The determination of total hydrolyzable nitrogen by hydrolyzing the soil under reflux with 6N HCl was carried out by the same procedure as described above. In addition to that, a portion of 5 ml of soil hydrolysate was placed in 50-ml distillation flask. A 0.5 g amount of K_2SO_4-catalyst mixture and 2 ml of concentrated H_2SO_4 were added to the distillation flask. Then the flask was cautiously heated on a micro-Kjeldahl digestion unit until the water was removed and frothing ceased. After digestion, the flask was allowed to cool.

The distillation flask was then connected to the steam distillation apparatus, about 10 ml of 10 M NaOH was added in the entry funnel and the alkali was run slowly in the distillation flask by raising the funnel plug. Steam distillation was commenced by closing the stopcock of the steam bypass tube, and the distillation was stopped by opening the stopcock when the distillate reached the 35-ml mark on the receiver flask.

The amount of NH_4-N in the distillate was then determined by titration with standard 0.005 N H_2SO_4 from a digital micro-burette.

5. Alkaline Permanganate Extraction Method

The procedure followed was the same as that described by Stanford (1978). A 1.0 g sample of air-dried soil was placed directly in a 100-ml distillation flask designed for use with the steam distillation apparatus. Next, 10 ml of 0.25 M NaOH containing 0.1g of $KMnO_4$ was added to the flask. The distillation flask was attached to the steam distillation apparatus and the ammonia-N liberated from the distillation of the mixture for 4 minutes was collected in a 50-ml Erlenmeyer flask containing 5 ml of H_3BO_3 acid-indicator solution. The amount of NH_4-N was then determined by titration with standard 0.005 N H_2SO_4 from a digital micro-burette. Another 1.0 g sample of soil was treated with 10 ml of 0.25 M NaOH in the absence of the $KMnO_4$, and the previous procedures were carried out. The NH_4-N produced by alkaline $KMnO_4$ oxidation was calculated as the difference between the results of the two analyses.

6. Acid Permanganate Extraction Method

The acid $KMnO_4$ extraction method assessing the oxidative release of potentially mineralizable soil nitrogen used in the study was essentially the same as that described by Stanford and Smith (1978).

A 1.0 g soil sample was placed in a 50-ml plastic centrifuge tube and treated with 25 ml of 1 N H_2SO_4. The tube was then stoppered and shaken for 1 h in a mechanical shaker. Then the tube was centrifuged to separate the supernatant liquid from the soil sample. The clear supernatant was discarded and the soil residue was treated with 25 ml of 0.05 N $KMnO_4$: 1.0 N H_2SO_4 solution. This extracting solution was prepared by dissolving 1.58 g of solid $KMnO_4$ in 1 l of 1 N H_2SO_4.

Results and Discussion

The results presented in Table 2 show the amounts of mineralized soil-N measured by the two biological incubation procedures and the amounts of extractable soil-N obtained by six different chemical extraction methods. The biological incubation procedures used in determining the potentially available soil-N in Central Anatolian soil were: (1) The aerobic incubation procedure (Keeney and Bremner, 1967) and (2) The anaerobic incubation procedure (Keeney 1982, modified from Waring and Bremner, 1964). However, the chemical extraction methods under evaluation for the sampled soil were: (1) Hot 2 M KCl solution (2) Phosphate-borate buffer solution, (3) Total hydrolyzable ammonium-N, (4) Total hydrolyzable nitrogen, (5) Alkaline $KMnO_4$ solution (6) Acid $KMnO_4$ solution.

The quantities of the mineralized nitrogen (Nmin) measured in aerobic incubation conditions, when all samples of soil tested were considered, ranged between

Table 2. Nitrogen values in mg kg-1 soil obtained by biological incubation methods and chemical extraction methods.

Sample No	Soil series	Aerobic mg(NH_4+NO_3+NO_2)-N kg^{-1} soil	Anaerobic mg NH_4-N kg^{-1} soil	Hot 2M KCl	Phosphate-borate buffer mg	Total Hyd. NH_4-N N	Total Hyd. N kg^{-1}	Alkaline $KMnO_4$	Acid $KMnO_4$
S1	Kap 21*	28.87	67.02	19.80	15.83	181.3	1335	189	74.9
S2	Kap 94	12.20	46.74	14.02	9.88	127.1	946	148	72.1
S3	Kap 93	20.85	78.13	16.31	10.62	198.2	1198	134	83.0
S4	Beyazbayır 17	15.53	67.02	13.51	12.42	138.9	828	109	65.8
S5	Beyazbayır 18	6.34	36.75	11.18	6.78	128.8	722	127	55.0
S6	Beyazbayır 85	9.34	42.52	15.61	10.17	203.7	966	124	72.8
S7	Çıralı 85	24.15	102.25	20.27	18.67	233.1	1545	187	123.2
S8	Çıralı 101	12.45	29.92	14.77	11.02	125.6	887	145	61.6
S9	Çıralı 17	15.34	35.93	9.55	12.42	202.5	966	125	87.2
S10	Bezik 89	19.89	52.72	13.28	12.24	176.1	1050	118	82.6
S11	Bezik 90	17.84	60.24	17.02	13.32	132.4	1033	171	73.2
S12	Bezik 96	12.99	28.37	15.24	11.21	120.5	896	142	51.8
S13	Çiftağıl 81	27.07	62.12	19.81	13.50	200.5	1019	137	74.2
S14	Çiftağıl 95	13.13	39.75	18.10	11.48	151.2	1002	100	69.0
S15	Çiftağıl 90	34.08	80.59	18.07	20.30	216.4	1218	161	85.4
S16	Çiftağıl 82	74.33	111.32	24.20	26.82	329.1	1500	187	111.7
S17	Kepir 42	36.96	101.94	18.64	21.86	226.5	1257	162	106.4
S18	Kepir 34	18.58	55.06	9.64	9.36	174.0	988	149	83.7
S19	Kepir 33	29.32	67.85	20.02	18.55	198.8	912	130	81.9
S20	Kırbeli 36	12.32	62.73	13.86	14.92	176.4	756	182	80.9
S21	Kırbeli 35	19.17	76.12	13.98	15.92	234.0	806	182	77.2
S22	Kırbeli 33	24.88	72.28	17.92	17.94	174.1	1145	168	77.4
S23	Polatlı 94	18.47	66.41	17.70	14.72	169.1	896	127	63.5
S24	Polatlı 93	16.91	45.49	12.35	11.97	206.5	1086	138	57.4
S25	Polatlı 97	19.74	53.46	14.45	15.62	173.6	1008	176	51.8
S26	Yaylabel 15	31.35	80.86	17.24	15.12	183.1	879	115	70.7
S27	Yaylabel 16	15.85	26.02	16.54	15.05	138.5	949	134	56.7
S28	Yaylabel 84	21.68	80.99	15.38	13.31	172.2	957	106	72.5
S29	Yüzükbaşı 80	18.64	69.20	17.01	15.03	186.2	929	137	68.3
S30	Yüzükbaşı 86	25.11	94.61	19.09	16.30	212.1	1226	176	94.2
S31	Yüzükbaşı 92	21.76	85.52	16.54	11.69	208.9	831	128	70.4
	Average	21.78	63.87	16.16	14.32	183.9	1024	146	76.0

6.34 and 74.33 and averaged 21.78 mg (NH_4+NO_3+NO_2)-N kg^{-1} soil. However, in the results of the anaerobic (waterlogged) incubation methods greater amounts of soil organic nitrogen were mineralized and results ranged between 26.02 and 111.32, giving a mean value of 63.87 mg NH_4-N kg^{-1} soil. These findings were in line with the results obtained by Gianello and Bremner (1986) in Brazilian soils.

The reasons for obtaining greater amounts of mineralized nitrogen in anaerobic conditions were discussed by Bremner (1965b) and Keeney (1982). Under anaerobic conditions, the losses of ammonia gas, which may occur in aerobic conditions, were avoided in the enclosed system of the anaerobic technique. Also, in the anaerobic procedure, there is no problem associated with water content adjustment throughout the incubation period. Higher temperatures (hence more rapid mineralization) can be used under anaerobic test conditions since optimum temperatures for nitrification are of no concern, and only NH_4-N released from the soil organic-N is measured.

A significant correlation coefficient was found between the results of the aerobic and anaerobic incubation procedures ($r = 0.716$ $p>0.001$) when assessing the potentially available soil-N in the 31 samples of Central Anatolian soils (Figure 1).

The correlation coefficients between the potentially available soil-N as measured by the six chemical extraction methods under evaluation and the mineralizable-N measured by the biological incubation procedures are presented in Table 3.

It is seen from the data presented in Table 3 that five of the chemical extraction methods highly correlated with both aerobic and anaerobic incubation methods. However, only the results obtained by the alkaline $KMnO_4$ method showed the lowest correlation.

The present study showed that the phosphate-borate buffer method correlated as well or better with the two biological procedures than did the other methods under evaluation. This may be attributed to the fact that such extraction methods did not surpass the phosphate-borate buffer method in their ability to simulate the microbial nitrogen mineralization in the soils of Central Anatolia. Also, the ability of such methods to solubilize the different soil nitrogen compounds susceptible to the mineralization process was less related to the mineralizable nitrogen.

The total hydrolyzable NH_4 method is considered to be one of the six chemical extractions methods under evaluation, and its results were included as a laboratory index of the potentially available soil-N in such soils. The results obtained from the method are presented in Table 3 and the correlation coefficients between the total hydrolyzable NH_4-N and the two biological aerobic and anaerobic incubation procedures were $r = 0.789$ $p>0.001$ and $r = 0.729$ $p>0.001$, respectively. As a result, it is concluded that the total hydrolyzable NH_4-N technique could be used with satisfactory confidence as a reliable laboratory index to refer to the potentially available nitrogen in Central Anatolian soils.

The results presented in Table 3 showed that of the six chemical extractions methods tested in Central

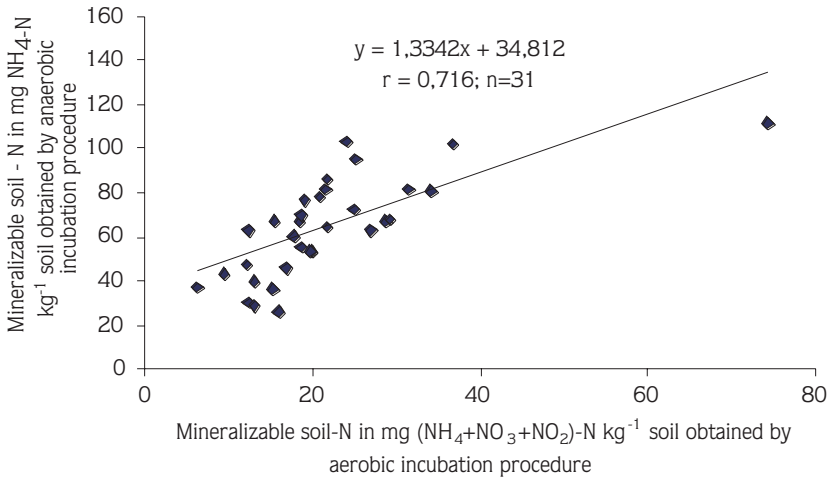

Figure 1. Relationship between the results of mineralizable soil-N obtained by aerobic and anaerobic incubation procedures.

Table 3. Correlation coefficients for the relationships between the biological incubation methods and the chemical extraction methods.

Biological methods	Chemical extraction methods					
	Hot 2M KCl	Phosphate-borate buffer	Total Hyd. NH_4-N	Total Hyd. N	Alkaline $KMnO_4$	Acid $KMnO_4$
Aerobic incubation	r = 0.689	r = 0.846	r = 0.782	r = 0.656	r = 0.387	r = 0.616
Anaerobic incubation	r = 0.611	r = 0.706	r = 0.729	r = 0.575	r = 0.409	r = 0.744

r values between 0.455 and 0.562 are significant at 0.01 level.
r values above 0.562 are significant at 0.001 level.

Anatolian soils, the alkaline permanganate method showed no significant correlation with the biological incubation methods. Although the alkaline permanganate method has been proposed for the assessment of potentially available nitrogen in different soils, many researchers have reported that this method does not provide satisfactory results (Stanford, 1978; Osborne and Storrier, 1976; Jenkinson 1968; Conforth and Walmsley, 1971). Our findings in Central Anatolian soils are in accordance with the above cited reference. However, Gianello and Bremner (1986) noted that the alkaline permanganate method had the poorest precision of 12 chemical methods used in assessing Brazilian soils.

The acid permanganate method evaluated in the study was the same as that described by Stanford and Smith (1978). The results obtained from the method were evaluated as a chemical index of the soil-N availability based on acid permanganate oxidation. The correlation coefficients between the results of the acid $KMnO_4$ method and the results of the aerobic and anaerobic incubation were r = 0.616 p>0.001 and r = 0.736 p>0.001, respectively.

Although the method requires two extractions with H_2SO_4 and with H_2SO_4 + $KMnO_4$, and double centrifugation, it is still relatively simple and rapid and applicable to a broad range of soil conditions. Moreover, the method has the capability to extract amounts of soil nitrogen similar in magnitude and most closely related to the anaerobic incubation procedure.

As for soil studied from the Central Anatolian area that has appreciable amounts of $CaCO_3$, in some cases up to 44.8%, this method could be employed with reasonable accuracy. Nevertheless, the method was strongly recommended in soils of arid and semi-arid conditions where there is an abundance of $CaCO_3$.

The results presented in Table 4 show the correlation coefficients between the six chemical extraction methods used for estimating the potentially available soil nitrogen of the Central Anatolian soils.

The highest correlation relationships were found between phosphate-borate buffer method and hot 2M KCl method (r=0.729) and total hydrolizable-N and acid $KMnO_4$ Methods (r=0.725). The lowest correlation relationships were found alkaline $KMnO_4$ and other chemical extraction methods. This findings support the results of our previous section. From the our experimental results it can be conluded that phosphate-borate buffer method, hot 2M KCl method and total hydrolizable nitrogen methods are suitable for the some conditional soils.

Table 4. Correlation coefficients for the relationships between the chemical extraction methods.

Chemical extraction methods	Phosphate-borate buffer	Total hydrolyzable NH_4-N	Total hydrolyzable N	Alkaline $KMnO_4$	Acid $KMnO_4$
Hot 2 M KCl	r = 0.729	r = 0.490	r = 0.614	r = 0.334	r = 0.453
Phosphate-borate buffer		r = 0.711	r = 0.631	r = 0.549	r = 0.625
Total hydrolysable NH_4			r = 0.604	r = 0.400	r = 0.717
Total hydrolyzable N				r = 0.523	r = 0.725
Alkaline $KMnO_4$					r = 0.443

r values between 0.455 and 0.562 are significant at 0.01 level.
r values above 0.562 are significant at 0.001 level.

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