LIMING EFFECT ON P AVAILABILITY FROM MAARDU PHOSPHATE ROCK

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Abstract

Thirty years ago phosphate rock from the Maardu deposit was intensively used for soil fertilization in Lithuania. However, the application of finely ground product caused an undesirable dusty operation. Afterwards, a superphosphate production plant was built in Kedainiai and the use of phosphate rock was completely abandoned.

Field experiments with fodder beets and barley were carried out to evaluate the P availability of granulated superphosphate and Maardu phosphate rock. The comparison was made at three acidity levels: a) unlimed acid soil with a high content of Al (pH_{kcl} 4.3-4.4, hydrolytic acidity was 41-44 meq/kg soil), b) soil limed with 0.5n rate $CaCO_3$ powder limestone based on hydrolytic acidity, and c) soil limed with 1.0n rate $CaCO_3$.

Two field experiments were carried out with fodder beets. In 1997 the yield increased significantly due to liming. However, no significant yield increases were found due to the application of phosphorus fertilizers. Differences between the effect of superphosphate and phosphate rock were also not observed. This might have been caused by a severe drought during the vegetative growth of plants. In the following year, 1998, a soil with similar acidity was chosen, however it contained even lower amounts of available phosphorus in the arable soil (about 50 mg/kg soil A-L method). In the unlimed soil the yield was low, the effect of superphosphate was better than that of phosphate rock. A good fodder beet yield of 32 to 35 t/ha was obtained and the effect of phosphate rock was better than that of superphosphate at 0.5n $CaCO_3$ rate. When liming with at the high rate (1.0n $CaCO_3$ rate according to hydrolytic acidity) the action of phosphate rock declined, and a better yield was obtained with superphosphate.

Barley was grown after fodder beets in the 1997 experimental field and the residual effect of superphosphate and phosphate rock was investigated. Weather conditions were favorable for barley growth. Therefore a normal yield (4.1 to 4.8 t/ha) was obtained on limed soil. Although yield differences due to different phosphorus fertilizers were small, a significant yield increase through phosphate rock application was obtained in the soil limed with a 0.5n $CaCO_3$ rate, as compared with superphosphate. The P fertilizer studied did not have any effect on fodder beet and barley yield quality changes. The changes in the yield of the by-product of the investigated plants (barley straw and fodder beet tops) were analogous to those of the primary yield.

1. INTRODUCTION

Lithuania climate is determined by its geographical location in the Northwest of the Eurasian continent and by its closeness to the Baltic Sea. Lithuania has a more severe climate than Western Europe because it is located in the transition zone from the Atlantic marine climate to the continental one. The average annual temperature is approximately 6°C. The average temperature in January is -4.8°C, and that of July is 17.2°C. The annual precipitation ranges from 700 mm in the very west to 559 mm in the east and the average precipitation rate is 626 mm. Most of the rain falls in summer, which often hampers farming operations, such as haymaking and harvesting of field crops. The eastern half experiences colder winter temperatures and the western coastal areas experience higher precipitation levels. Lithuania is crossed by an average of 120-140 cyclones annually, which cause frequent meteorological changes. Due to the influence of cyclones, the summer temperatures are slightly lower, but winter temperatures higher than the average at middle latitudes. Lithuania is a relatively low-lying country, the highest point being 290 meters above sea level.

Land resources of Lithuania cover 65.2 million ha and are distributed as follows: 54% farming land (3.5 million ha), 70.5% arable land (2.5 million ha), 27.5% grassland, 2.0% shrubs, sands and slopes, 27.6% forest (61.0% coniferous and 39.0% deciduous), 18.4% cities, towns, villages, lakes, rivers, roads, etc.

The territory of Lithuania is divided into three zones; namely, the West, the Middle and the East. They reflect some common features of climate peculiarities, organic matter accumulation and mineralization rate. Moreover, the territory of Lithuania is divided into 15 soil-agronomic regions. These regions are defined according to both soil and agronomic characteristics in order to include consideration of the productive capacity of the soils. In Lithuania, 6 principal genetic types of soils can be distinguished: podzol, podzol-bog, sod-calcareous, sod-gley, bog and alluvial soils. Soddy-podzolic soils prevail (45.3%). Soil properties depend not only on the texture of topsoil, but also on subsoil. Seven groups of soil texture are distinguished: sand, loamy-sand, sandy-loam and loam, clay-loam and clay, muck sod, shallow peat and peat. Loamy-sand and different loams make up almost 60% of all soils.

Crops sold in internal or foreign markets are 53.4% of total crops with 46.6% of these crops being fodder crops. Crops for sale in agricultural companies are 49.8% and 55% in other farms. Agricultural companies cultivate 40% of the national grain crop, 45% of sugar beet but only 1.5% of potatoes, 11% of fruit and berries, and 3.1% of vegetables. Average Lithuania yields are well below those achieved in other Baltic/Scandinavian countries with similar climates. The best level of cereal production quoted for Lithuania is 3,1 t/ha during the former Soviet Union.

Political, social and economic changes as well as decreasing fertilizer application rates might have caused the decrease of the yield. Fertilizer application rates have decreased dramatically since 1992. Nitrogen fertilizers are mainly used as the most effective fertilizer in Lithuania. The amount of phosphorus and potassium fertilizer application has even decreased more severely than nitrogen. According to the experimental data of 1985-1993, one fifth of Lithuanian soils had a very low content of available phosphorus. About 42% of the soils were low in phosphorus, 22% medium in available phosphorus and only 16% of soils were relatively high in available phosphorus.

However, during the recent years the decline in the use of mineral fertilizers is likely to result in an increase of the soil area with low status of available phosphorus and potassium. Therefore, it is very important to find cost-effective sources of fertilizers. Rock phosphate could be a potential source in acid soils. In order to maintain the current soil acidity level it would be necessary to lime 174 thousand hectares of soil annually. However, this is hardly possible to achieve. Therefore the acid soil area will inevitably increase.

Thirty years ago, phosphate rock accounted for 40% in the total range of phosphoric fertilizers. This was determined by its simpler and cheaper production. Later, due to its application only on acid soils and the dust operation in its application, the use of phosphate rock was gradually abandoned. At present, superphosphate has completely replaced phosphate rock.

Experiments were carried out with large rates of phosphate rock to choose the best type and to determine its efficiency conditions. Posphate rock from the Maardu deposit showed a better action in soils with low acidity without mobile aluminum. In soils with a higher acidity and a small content of mobile aluminum, Jegorovsk phosphate rock was more effective. Other researchers [6, 12] also noted a high efficiency of Jegorovsk phosphate rock.

The most comprehensive studies on phosphate rock in Lithuania were carried out by K. Plesevicius [2, 4, 5]. It was determined that phosphate rock acts in the soil when hydrolytic acidity is above 25 meq/kg soil. Combination of phosphate rock with farmyard manure, granular superphosphate and its use for grassland fertilization was also investigated. Experiments were conducted where lime and phosphate rock application was combined and lime and phosphate rock were placed as separate layers. Other researchers confirmed these findings [17]. Studies were conducted on composting materials (with peat and manure) and their incorporation in the soil, and fertilization with increased phosphate rock rates for several years (3-6 years) [16]. This practice resulted from the better effect of phopshjate rock in the second or third year after incorporation in the soil [9, 18].

Finely ground phosphate rock is a very dusty material and to improve its application conditions it is recommended to granulate it or to make mixtures with other hygroscopic fertilizers such as potassium chloride [8]. The efficiency of broadcast application of phosphate rock is also increased by combining it with 50 kg/ha superphosphate applied in rows [10].

Due to economic difficulties, liming rates have been markedly reduced which, in turn, has resulted in increased soil acidification. Therefore, a new interest in phosphate rock is emerging. Moreover, its production requires less energy costs. Production of 1 t of superphosphate requires 38-40 GJoules, while that of phosphate rock requires only 7-8 GJoules [15]. Besides, there are more than 160,000 ha of karstic soils in Northern Lithuania. According to environmental regulations, it is forbidden to apply chemical and commercial fertilizers. Therefore, phosphate rock is an extremely important source of phosphoric fertilizers in this particular region.

Field experiments with fodder beets and barley were carried out to evaluate the P availability of granulated superphosphate and Maardu phosphate rock. The comparison was made at three acidity levels: a) unlimed acid soil with a high content of Al (pH_{kcl} 4.3-4.4, hydrolytic acidity was 41-44 meq/kg soil), b) soil limed with 0.5 rate $CaCO_3$ powder limestone based on hydrolytic acidity, and c) soil limed with 1.0 rate $CaCO_3$.

2. MATERIALS AND METHODS

In 1998, experiments were carried out at the LIA's Vezaiciai Branch on soddy-podzolic, medium podzolized loam. The soil was acid with the following properties: pH_{Kcl} of 4.3-4.4, hydrolytic acidity of 42-44 meq/kg, exchange acidity of 5.0-5.1 meq/kg, total absorbed bases of 33-35 meq/kg soil, available aluminum of 45-48 mg/kg soil [7].

In the experiments, standard granular superphosphate and phosphate rock from Maardu deposit in Estonia were used. Phosphate rock was of sedimentary origin enriched by the flotation method up to 20-2% of phosphorus active ingredient.

The experiment design included the following treatments:

1. Control
2. NK
3. NK+P_{Sp}
4. NK+P_{PR}
5. NK+0.5n $CaCO_3$
6. NK+0.5n$CaCO_3$ +P_{Sp}
7. NK+0.5n $CaCO_3$+P_{PR}
8. NK+1.0n $CaCO_3$
9. NK+1.0n $CaCO_3$ +P_{Sp}
10. NK+1.0n $CaCO_3$+P_{PR}

where N refers to nitrogen application, K refers to potassium application, P_{sp} refers to the application of P as superphosphate, P_{pr} refers to the application of P as phosphate rock. 1.0n is the recommended rate of $CaCO_3$ necessary for neutralization of soil acidity to the optimum level for crops or crop rotation. The 0.5n $CaCO_3$ rate is half the recommended rate [3].

A crop rotation of fodder beets (cv. Ekendorfo geltonieji) and spring barley (cv.Ula) was sown at the end of April or beginning of May depending on the climatic conditions. Spring barley was harvested in August and fodder beet in early October. The plot area was 68 m^2. The harvested area was 45 m^2. Plots were replicated four times.

Fertilizer rates for spring barley were 45 kg/ha N, 30 kg/ha P, and 45 kg/ha K. For fodder beet the rates were 90 kg/ha N, 60 kg/ha P, and 90 kg/ha K. Before fertilizer and lime application, soil samples from the arable layer (25cm) was taken for the determination of total nitrogen, humus, exchangeable phosphorus, potassium, aluminum, hydrolytic and exchangeable acidity, cation exchange capacity and pH.

Total nitrogen was determined using the Kjeldahl procedure. Available phosphorus and potassium was determined by the Egner-Riem-Domingo (A-L) method. Humic materials were determined by the Turin procedure. Hydrolytic acidity was determined by the Kappen method. Exchangeable acidity and exchangeable aluminium was extracted by potassium chloride by the Sokolov method. Cation exchange capacity was determined by the Hilkovic method and pH in extract of potassium chloride was determined with a pH glass electrode [7, 14].

At harvesting spring barley in autumn, soil samples were taken to assess the changes in soil pH level, hydrolytic and exchangeable acidity, cation exchange capacity, exchangeable phosphorus, potassium and aluminium.

Plant samples were collected for the determination of total nitrogen, phosphorus and potassium. Ashes and plant biometrics analyses were collected as well. Total nitrogen was determined using the Kjeldahl procedure. Phosphorus was determined after ashing using a molybdovanadate colorimetric method. Potassium was determined after ashing using flame photometry. Raw ash content was determined by weighing the sample before and after ashing at 525°C [13].

2.1. Weather conditions

Meteorological conditions of the 1998 experimental period were favorable for the growth and development of spring barley and fodder beets. In May, rather warm weather prevailed. There was a sufficient amount of moisture in the soil arable layer. The crust, which had formed on the soil surface after heavy rain, made it difficult for the seeds to emerge. Conditions for spring barley establishment and growth were favorable during the whole month.

In the first half of June, the weather was very warm. While in the second half the weather was cool. At the end of month the weather became warmer again. During the second ten-day period, moisture reserve was replenished and was close to average. Spring barley and fodder beets grew well and beet leaves covered the inter rows.

In July, cool and rainy weather was prevalent which was not favorable for the formation of high-quality spring barley grain. Conditions for grain maturation improved only during the third ten-day period, when the weather became warmer. During the whole month the reserve of productive moisture was markedly higher than many year's average. Conditions for beet growing were good as well.

In August, the conditions for spring barley ripening were normal as warm and relatively dry weather was prevailing. Cool and rainy weather in the second five-day period slowed down grain ripening process. In many fields, spring barley was in wax ripeness. The reserve of productive moisture during the whole month exceeded average levels. Although the conditions during the larger part of the month were favorable for beet growth, the weather conditions became worse during the last ten-day period.

In September, relatively warm and dry weather prevailed. Conditions for fodder beet growth were most often good, especially during the second to third five-day period. Reserve of productive moisture in fodder beet fields was close to average.

3. RESULTS AND DISCUSSION

3.1. Effect of phosphate rock and superphosphate on fodder beet yield

The comparison of superphosphate and phosphate rock effectiveness was made at three soil acidity levels: background 1 — not limed, acid soil, with a high content of aluminum (pH_{Kcl} 4.3-4.4, hydrolytic acidity: 41-44 meq/kg soil, mobile aluminum: 44-49 mg/kg soil); background 2 — the soil was limed with 0.5 rate $CaCO_3$ powder limestone, the content of mobile aluminum was reduced and pH_{Kcl} was 5.7-5.8; background 3 — the soil was limed with 1.0 rate of $CaCO_3$ and the soil acidity was reduced even more with pH_{Kcl} 6.0-6.1 (Table I). There was a sufficient amount of mobile potassium in the soil for plant growth, whereas phosphorus was very low. Thus a good plant growth response from the application of superphosphate and phosphate rock was expected.

Fodder beets showed a very poor performance in the control (unlimed and unfertilized soil) because of its sensitivity to soil acidity (Table II). With NK fertilization, the action of superphosphate was significantly higher than that of phosphate rock. This result may have been due to high mobile aluminum content in soil causing small and gradual release of mobile forms of P from phosphate rock to bind into aluminophosphates that are not readily taken up by plants. The mobile forms of P from superphosphate are released rapidly and taken up by the plants.

Soil acidity declined with liming at the 0.5n $CaCO_3$ rate. The harmful effect of aluminum on plant growth was eliminated and the yield of fodder beets increased. Both phosphatic fertilizers gave a significant yield increase, as the soil acidity was sufficient for P dissolution from phosphate rock into mobile forms.

When liming with the 1.0n rate $CaCO_3$, fodder beet yield in the soil treated with phosphate rock was lower and its efficiency lagged behind superphosphate. The P availability from phosphate rock was reduced by lower soil acidity present at the 1.0n $CaCO_3$ rate.

3.2. Effect of phosphate rock and superphosphate on the chemical indicators of fodder beet

Chemical indicators of fodder beet roots and leaves did not change significantly under the effect of liming and fertilizing with superphosphate and phosphate rock (Table III). Liming and mineral fertilizers had a tendency to increase nitrogen, phosphorus and potassium content in the roots of fodder beets. Ash content varied little. Ash content in leaves increased slightly. Nitrogen content in leaves also increased. Content of phosphorus varied little, and the content of potassium had a tendency to decline.

3.3. Soil chemical indices in spring barley experiment

In the same place where the efficiency of superphosphate and phosphate rock on fodder beets was evaluated in 1997 with fodder beet, the residual effect of these P fertilizers was measured in 1998 with spring barley. The soil was analyzed in spring before planting and it had three acidity levels (Table IV). The first level included unlimed acid soil with pH of 4.4-4.5, hydrolytic acidity of 37.2-41.2 meq/kg soil, mobile aluminum of 32.5-40.2 mg/kg, P_2O_5 of 89.8-121.5, K_2O of 214-256 mg/kg soil. In the second acidity level, the soil was limed with 0.5 rate of $CaCO_3$, which resulted in pH of 5.0-5.1, hydrolytic acidity of 17.9-18.4 meq/kg soil, and very little mobile aluminum from 0.8-2.2 mg/kg soil. The P_2O_5 and K_2O contents were analogous to that of the unlimed soil. For the third acidity level the soil was limed with 1.0 rate of $CaCO_3$ resulting in pH of 5.6-5.7, hydrolytic acidity of 15.9-19.1 meq/kg soil. Mobile aluminum, P_2O_5 and K_2O content were analogous to the second acidity level.

3.4. Effect of phosphate rock and superphosphate on barley yield

In the soil where 0.5n rate of $CaCO_3$ was applied to fodder beets a year ago, a significant barley grain yield increase was obtained in the plots treated with phosphate rock compared to superphosphate (Table V). At the high liming (1.0 $CaCO_3$) rate, the soil acidity declined even more and the grain yield of spring barley fertilized with phosphate rock was 0.21 t/ha lower than the barley yield fertilized with superphosphate.

3.5. Effect of phosphate rock and superphosphate on the chemical indicators of spring barley grain yield

Liming and mineral fertilization increased ash content in barley grain (Table VI). The highest ash content was found in the treatment limed with one lime rate. No significant differences in the ash content in barley grain were found between the treatment fertilized with superphosphate and phosphate rock.

A more distinct tendency of nitrogen, phosphorus and potassium content in barley grain was not identified. In addition, no regularities were observed when analyzing variations of ash, nitrogen and phosphorus content in barley straw. The content of potassium in barley straw had a tendency to increase in the treatments that had received lime and mineral fertilizers.

TABLE I. THE EFFECT OF SUPERPHOSPHATE AND PHOSPHATE ROCK ON THE SOIL CHEMICAL PROPERTIES IN FODDER THE BEET TRIAL

Treatment	pH_{KCl}	Total N	Hydrolytic acidity	Exchange acidity	Total absorbed bases	Available		
						Al	P_2O_5	K_2O
		%	meq/soil kg			mg/soil kg		
1. Control	4.38	0.13	43.17	5.18	34.6	49.5	58.3	221.0
2. NK	4.31	0.14	42.08	4.98	36.2	44.8	62.5	208.9
3. $NK+P_{Sp}$	4.40	0.13	44.01	5.11	37.6	46.6	71.4	198.6
4. $NK+P_{PR}$	4.39	0.13	41.83	5.17	33.9	45.6	61.5	210.6
5. NK+0.5n $CaCO_3$	5.76	0.14	21.18	1.27	51.8	1.2	66.5	230.8
6. NK+0.5n $CaCO_3$ $+P_{Sp}$	5.80	0.14	18.61	1.14	53.6	0.8	74.5	217.5
7.NK+0.5n $CaCO_3+P_{PR}$	5.71	0.14	17.18	1.11	55.0	1.5	68.2	209.8
8. NK+1.0n $CaCO_3$	6.10	0.13	11.63	0.47	86.7	0.6	64.8	211.7
9. NK+1.0n $CaCO_3$ $+P_{Sp}$	5.95	0.14	10.18	0.51	91.2	1.0	61.7	209.9
10. NK+1.0n $CaCO_3+P_{PR}$	6.05	0.14	9.83	0.49	88.5	0.7	62.4	213.4
$LSD_{0.05}$	0.59	0.02	8.03	1.89	8.16	14.31	18.30	46.71

TABLE II. THE INFLUENCE OF SUPERPHOSPHATE AND PHOSPHATE ROCK ON FODDER BEET YIELD

Treatment	Yield, t/ha			
	Natural moisture		Dry matter	
		Tops	Roots	Tops
1. Control [Without NPK and liming]	1.01	0.89	0.13	0.12
2. NK	3.04	3.39	0.43	0.44
3. NK+P_{Sp}	6.19	6.90	0.87	0.83
4. NK+P_{PR}	4.88	5.48	0.63	0.66
5. NK+0.5n $CaCO_3$	32.08	12.56	4.49	1.38
6. NK+0.5n $CaCO_3$ +P_{Sp}	34.70	15.71	4.86	1.73
7.NK+0.5n $CaCO_3$+P_{PR}	35.95	16.19	5.75	1.78
8. NK+1.0n $CaCO_3$	33.45	13.81	5.35	1.80
9. NK+1.0n $CaCO_3$ +P_{Sp}	36.55	15.65	5.48	1.88
10. NK+1.0n $CaCO_3$+P_{PR}	34.52	13.87	5.52	1.80
$LSD_{0.05}$	1.30	1.23	0.19	0.14

TABLE III. THE EFFECT OF SUPERPHOSPHATE AND PHOSPHATE ROCK ON FODDER BEET YIELD QUALITY

	Roots				Tops			
Treatment	Ash	N	P	K	Ash	N	P	K
		%				%		
1. Control	7.94	1.38	0.19	2.44	26.1	1.62	0.31	6.80
2. NK	7.81	1.47	0.21	2.52	26.2	2.32	0.28	6.42
3. NK+P_{Sp}	7.62	1.52	0.22	2.65	26.4	1.80	0.27	5.95
4. NK+P_{PR}	7.43	1.44	0.23	2.03	26.2	1.83	0.29	5.41
5. NK+0.5n $CaCO_3$	7.89	1.58	0.18	2.86	25.8	1.84	0.24	6.28
6. NK+0.5n $CaCO_3$ +P_{Sp}	7.65	1.48	0.20	2.47	26.3	1.70	0.29	6.43
7.NK+0.5n $CaCO_3$+P_{PR}	7.48	1.52	0.19	2.61	26.4	1.82	0.27	6.78
8. NK+1.0n $CaCO_3$	7.52	1.47	0.20	2.87	25.4	1.74	0.30	6.58
9. NK+1.0n $CaCO_3$ +P_{Sp}	7.65	1.46	0.21	3.05	26.3	1.92	0.27	6.16
10. NK+1.0n $CaCO_3$+P_{PR}	7.44	1.50	0.22	2.82	26.2	1.94	0.28	5.97
$LSD_{0.05}$	1.04	0.11	0.07	0.62	3.47	0.10	0.07	0.18

TABLE IV. THE EFFECT OF SUPERPHOSPHATE AND PHOSPHATE ROCK ON THE SOIL CHEMICAL PROPERTIES IN THE FIELD TRIAL WITH BARLEY

Treatment	pH_{KCl}	Total N%	Hydrolytic Acidity	Exchange Acidity	Total absorbed bases	Available		
						Al	P_2O_5	K_2O
			meq/soil kg			mg/soil kg		
1. Control	4.42	0.12	41.16	4.26	38.2	32.5	89.8	214.2
2. NK	4.46	0.12	38.12	4.72	36.1	33.0	94.5	243.5
3. NK+P_{Sp}	4.43	0.13	37.26	5.01	40.1	40.2	118.4	256.1
4. NK+P_{PR}	4.48	0.13	38.01	4.89	38.2	37.3	121.5	235.4
5. NK+0.5n $CaCO_3$	5.10	0.13	18.53	0.63	62.8	1.2	109.5	261.2
6. NK+0.5n $CaCO_3$ +P_{Sp}	5.08	0.13	19.42	0.78	60.7	2.2	110.6	231.5
7.NK+0.5n $CaCO_3$+P_{PR}	5.01	0.13	17.94	0.67	59.8	0.8	114.7	235.0
8. NK+1.0n $CaCO_3$	5.71	0.14	19.13	0.32	84.5	1.4	103.7	239.5
9. NK+1.0n $CaCO_3$ +P_{Sp}	5.65	0.14	16.17	0.31	86.8	0.9	120.5	241.2
10. NK+1.0n $CaCO_3$+P_{PR}	5.68	0.13	15.94	0.27	92.5	1.0	119.5	238.8
$LSD_{0.05}$	0.39	0.02	8.13	1.32	13.04	12.1	31.6	53.4

TABLE V. THE EFFECT OF SUPERPHOSPHATE AND PHOSPHATE ROCK ON BARLEY YIELD

Treatment	Yield, t/ha		1000 kernel weight, g
	Grain	Straw	
1. Control	1.67	2.45	37
2. NK	1.95	2.54	37
3. NK+P_{Sp}	2.15	2.41	39
4. NK+P_{PR}	2.30	2.39	39
5. NK+0.5n $CaCO_3$	3.99	4.25	39
6. NK+0.5n $CaCO_3$ +P_{Sp}	4.23	4.43	38
7.NK+0.5n $CaCO_3$+P_{PR}	4.51	4.60	39
8. NK+1.0n $CaCO_3$	4.36	4.72	40
9. NK+1.0n $CaCO_3$ +P_{Sp}	4.82	4.71	40
10. NK+1.0n $CaCO_3$+P_{PR}	4.61	4.46	40
$LSD_{0.05}$	0.16	0.42	1.9

TABLE VI. THE EFFECT OF SUPERPHOSPHATE AND PHOSPHATE ROCK ON BARLEY YIELD QUALITY.

Treatment	Grain				Straw			
	Ash	N	P	K	Ash	N	P	K
	%				%			
1. Control	1.98	1.36	0.24	0.53	6.38	0.94	0.18	1.69
2. NK	2.21	1.32	0.38	0.73	6.83	0.89	0.16	2.12
3. NK+P_{Sp}	2.39	1.60	0.36	0.60	6.71	0.90	0.20	1.97
4. NK+P_{PR}	2.25	1.50	0.39	0.57	6.92	0.93	0.17	2.05
5. NK+0.5n $CaCO_3$	2.14	1.23	0.30	0.56	6.23	0.90	0.21	1.96
6. NK+0.5n $CaCO_3$ +P_{Sp}	2.24	1.34	0.34	0.58	6.18	0.98	0.18	2.07
7.NK+0.5n $CaCO_3$+P_{PR}	2.27	1.47	0.36	0.57	6.43	0.96	0.17	1.98
8. NK+1.0n $CaCO_3$	2.31	1.40	0.32	0.53	6.22	0.89	0.20	2.14
9. NK+1.0n $CaCO_3$ +P_{Sp}	2.40	1.38	0.34	0.58	6.72	0.94	0.17	2.07
10. NK+1.0n $CaCO_3$+P_{PR}	2.39	1.47	0.36	0.57	6.63	0.96	0.19	1.99
LSD_{05}	0.09	0.22	0.08	0.18	0.53	0.21	0.09	0.47

4. CONCLUSIONS

In conclusion, our study showed:

1. Phosphate rock showed better effects and it was identical to the efficiency of granulated superphosphate in the slightly acid soil (soil limed at 0.5n $CaCO_3$).
2. When the soil acidity decreased more (soil limed at 1.0n $CaCO_3$) the efficiency of phosphate rock was also reduced.
3. In the very acid soil (unlimed), the efficiency of phosphate rock was low.
4. No significant effects on the chemical indicators of fodder beets and spring barley were found between plants fertilized with phosphate rock and superphosphate.

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