Soil & Environ. 25(2): 128-134, 2006

Residual effect of phosphorus applied to wheat on sorghum fodder in a loam soil

Obaid-ur-Rehman[1*], A.M. Ranjha[2], M. Jamil[3] and Jalil Akhtar[3]
[1] Soil and Water Testing Laboratory, Attock
[2] University of Agriculture, Faisalabad
[3] Soil Salinity Research Institute, Pindi Bhattian

Abstract

A field experiment was conducted on a loam soil (Sultanpur Soil Series) to observe the residual effect of phosphorus (P_2O_5) on sorghum fodder applied to wheat in a wheat-sorghum fodder rotation. The treatments applied to wheat were computed from modified Freundlich model which ranged from 8.04-54.48 mg kg^{-1} P (36.82 - 249.52 kg P_2O_5 ha^{-1}) along with control with and without N and K_2O. Maximum fresh fodder yield of 30.58 Mg ha^{-1} and oven dried yield (7.13 Mg ha^{-1}) was obtained at residual Olsen-extractable P value of 20.75 mg kg^{-1}. Fodder contained maximum P concentration of 0.19% with total P uptake of 13.55 kg ha^{-1}. Olsen–extractable P built up to level of 20.75 mg kg^{-1} after wheat harvest was declined to 10.05 mg kg^{-1} after harvest of sorghum fodder. Similarly, maximum phosphorus recovery of 18.50% was obtained with sorghum fodder at residual P value of 20.75 mg kg^{-1} soil after wheat.

Key words: Sorghum fodder, fresh yield, oven dried yield, P concentration, P uptake, residual P, P recovery.

Introduction

Phosphorus is relatively immobile in the soil and so remains near the site of fertilizer placement. It is generally admitted that the recovery of applied phosphatic fertilizer by plants is very low as compared with other nutrients, only 10-20% of applied fertilizer is available to the current crop (Cooke, 1982) and the rest is fixed in the soil by adsorption or precipitation (residual P) and available to subsequent crops by desorption and dissolution reactions (Wild, 1988). An over all assessment is based on one direct plus one residual measurement in cereal based system, the direct response generally makes up to 60% and the residual is 40% of the total rotational yield response. If P is added to rabi crop, the proportion is 63% direct and 37% residual and if vice versa, then 57% direct and 43% residual (Tandon, 1992).

The area under fodder crops in Pakistan is 2.359 million hectares having production of 54.40 million tons with an average yield of 23.1 Mg ha^{-1} (Anonymous, 2006). This yield is low to provide even half of the maintenance ration to existing livestock population, so a fodder revolution is required as “Prosperous are the nations who have green pastures and copious fodder for their animals” (Bhatti and Khan, 1996). Sorghum (*Sorghum bicolor* L.) is the best modern and high yielding fodder grass especially for hay and silage (Dogget, 1988; Skerman and Riveros, 1999). It is cultivated on 0.566 million hectare with total production of 7.384 million tons in the Punjab province of Pakistan (Anonymous, 2005). Sorghum is an exhaustive crop and it depletes soil fertility at faster rates if proper care is not taken. On an average, phosphorus dose @ 40-60 kg P_2O_5 ha^{-1} is found to be good. Its luxurious vegetative growth (0.5–4.0 m height, 7–8 nodes and internodes, 7-24 leaves) favours its production as fodder, which is used in various forms like soiling (fodder) crop, silage crop and hay making depending upon its availability and surplus. For fodder purposes, it is cut after 60 days with green fodder yield of 30-35 t ha^{-1} (Singh, 1998). Iqbal *et al*. (2004) discussed the importance of phosphorus in the diet of animals and found that many diseases were caused by the deficiency of phosphorus like Pica, Austiomalysia, etc. and recommended that animals required a fodders containing 0.35-0.40% P and if the weight of the animal was 100, 200, 300 and 400 kg, they correspondingly needed 8.1, 13.2, 14.0 and 14.4 g P daily. Naeem *et al*. (2003) checked 11 varieties of sorghum for fodder yields under irrigated conditions and found that “Hegari” variety ranked first in green fodder yield (62.7 t ha^{-1}). Das *et al*. (1996) observed that response of sorghum to P was strongly influenced by soil P status as well as applied P level and was similar at all the three physiological stages of crop growth samples viz.

* E-mail: drobaidtmn@yahoo.com.

boot leaf initiation, 50% flowering and maturity. The fertilizer P requirement for optimum dry matter production decreased with increase in P status of soils. The study also indicated decrease in P concentration in plant tissue with the advancement of maturity. Kanwar (1986) concluded that response of cereal crops to P such as sorghum, varied across the soil types and followed the order Alfisol > Entisol > Vertisol. Bishnoi *et al*. (1983) reported significant response of applied P to sorghum on 10 sites at cultivators' field and found that increase in yield due to applied P decreased at higher levels of applied P and found economic dose of P as 25 kg ha^{-1} P_2O_5. Pathak *et al*. (2001) worked out optimum dose of P for sorghum alone and sorghum + cowpea in semi arid conditions as 12 kg ha^{-1} P_2O_5 in low P soils (< 10 kg Olsen P ha^{-1}), 80 kg ha^{-1} P_2O_5 in medium (10-20 kg ha^{-1}) and 40 kg ha^{-1} P_2O_5 in high P soils (>20 kg P_2O_5 ha^{-1}) for economic yield and nutrients removal (NPK & S) and critical limit of available P extracted by Olsen method was 12 kg ha^{-1}. The residual soil P is helpful in deciding the fertilizer dose to the succeeding crops grown in semi arid and sub humid conditions. Bauder *et al*. (1997) suggested two strategies (i) to apply P fertilizer at rates sufficient to increase or evaluate the bicarbonate-extractable soil test P concentration to ≈ 30 µg P g^{-1} soil and then supply P annually at a rate comparable to crop removal (ii) to attempt to maximize the crop response to each increment of P applied by applying relatively higher rates of P to soils with low soil P concentrations and relatively lower rates of P to soils with high soil P concentrations.

The present study was conducted with the objective to evaluate the effect of residual P applied to wheat on the yield, P uptake and P recovery by forage sorghum because it is an important feed for dairy and beef cattle.

Materials and methods

The study was conducted at Soil Salinity Research Institute, Pindi Bhattian during 2003 to observe the residual effect of phosphatic fertilizer on sorghum fodder applied to wheat. The layout was permanent with 14 treatments arranged in randomized complete block design (RCBD) with three replications having plot size of 6 m x 4 m. The phosphorus levels for wheat were computed as under.

Treatment	P in soil solution (mg L^{-1})	P (mg kg^{-1} soil) to be added	P_2O_5 (kg ha^{-1}) to be added
1	Native (0 NK)	0	0
2	Native (+ NK)	0	0
3	0.01	8.04	36.82
4	0.02	11.29	51.71
5	0.03	13.76	63.02
6	0.04	15.84	72.54
7	0.05	17.67	80.93
8	0.10	24.80	113.58
9	0.15	30.24	138.50
10	0.20	34.80	159.38
11	0.25	38.81	177.75
12	0.30	42.43	194.33
13	0.40	48.84	223.69
14	0.50	54.48	249.52

After wheat harvest, sorghum (*Sorghum bicolor* L. Moench) cv. Hegari was raised to reap the benefits as animal fodder at seed rate of 75 kg ha^{-1} with recommended dose of N (62.5 kg ha^{-1}). No phosphatic fertilizer was added to the sorghum crop that was grown only on the carryover effect of the P added to wheat. All the agronomic and recommended cultural practices were followed for normal growth of the crops. Plant sampling (20-25 above ground portion of plants) at booting stage was done to observe the P concentration (Jones *et al*., 1991). Fodder was harvested after 55 days of growth and fresh fodder yield was recorded.

Plant samples were collected and oven dried at 70°C for analysis to measure oven dried weight of fodder and then ground, passed through 0.5 mm sieve, and analyzed. One gram oven dried plant material was digested in 20 mL concentrated HNO_3 and 10 mL of 72 % $HC1O_4$. The digest was transferred to 100 mL volumetric flask and volume was made (U. S. Salinity Lab. Staff, 1954). Five mL of the digested aliquot was taken in 50 mL volumetric flask, 5 mL of ammonium vanadate (0.25 %) and ammonium molybdate (5 %) were added, volume was made and allowed to stand for 15-30 minutes. Reading was recorded on spectrophotometer. Then from the standard curve, phosphorus concentration (%) in plant was calculated. Phosphorus uptake was calculated by the formula:

P uptake (kg ha^{-1}) = P concentration (%) x yield (Mg ha^{-1}) x 10

Phosphorus recovery (%) was calculated by the formula,

$$\frac{\text{P uptake from fertilized plot} - \text{P uptake from control (NK) plot}}{\text{P added}} \times 100$$

Analysis of variance (ANOVA) technique was used and Duncan's multiple range test (DMR) was applied to see the significance of difference among treatment means by the procedures as described by Steel and Torrie (1980).

Results and discussion

Original soil analysis at the start of the experiment before wheat showed that soil was loam in texture, alkaline and free from salinity/sodicity, poor in organic matter and in available P but adequate in extractable potassium as described in table 1.

Table 1. Original soil analysis at the start of experiment

Determinant	Units	Values
Sand	%	45
Silt	"	33
Clay	"	22
Textural class	-	Loam
Sub group	-	Typic Camborthid
Series		Sultanpur
pHs	-	8.16
ECe	dSm^{-1}	0.87
TSS	meL^{-1}	8.7
Ca^{2+}+ Mg^{2+}	"	4.28
Na^{+}	"	3.62
SAR	(m mol L^{-1})$^{0.5}$	1.30
CO_3^{2-}	meL^{-1}	-
HCO_3^{-}	"	1.4
Cl^{-}	"	2.4
SO_4^{2-}	"	4.9
$CaCO_3$	%	6.48
Organic matter	"	0.62
Olsen P	mg kg^{-1}	4.95
Extractable K	"	126

Fresh fodder yield of sorghum (Mg ha^{-1})

Data regarding sorghum fresh fodder yield depicted in table 2 showed a progressive increase in fodder yield of sorghum raised on the residual phosphorus applied to previous wheat crop. Maximum fresh fodder yield (30.58 Mg ha^{-1}) was obtained in treatment 14 where residual P was 20.75 mg kg^{-1} soil. The minimum yield (17.54 Mg ha^{-1}) was obtained in control plots (without NPK). Although the yield increased due to the residual effect of phosphorus but not to that extent where the P fertilizer is applied directly. This means that the residual effect is not equal and always less as compared to the direct application of P fertilizer. These results are in line with Das *et al*. (1996) and Naeem *et al*. (2002).

Oven dry fodder yield of sorghum (Mg ha^{-1})

Oven dry fodder yield was determined by multiplying the factor of moisture percentage of each plot (76-77 %) with fresh fodder yield and is given in table 2. The data showed that the oven dry fodder was 7.13 Mg ha^{-1} in T14 (residual P 20.75 mg kg^{-1}). The reason might be that the water, which was taken up during the vegetative growth, was dried to minimum at 70° C and the silage yield dropped. But still the silage production of sorghum was quite high in this medium textured soil. However, in the control plots, the oven dried yield was quite low and it was only 4.09 Mg ha^{-1}. The results are in line with those of Shaukat *et al.* (1992) who studied yield response of maize to residual soil phosphorus and found that the application of 120 kg P ha^{-1} to wheat crop left sufficient residual P for the following maize crop to increase its dry matter yield over control with no extra fertilizer. Sahrawat *et al*. (1995) also obtained similar results by comparing fresh P applied and residual P for sorghum and concluded that phosphorus applied in the previous year was 58 % as effective as fresh P but P applied two years earlier was only 18 % as effective as fresh P.

Phosphorus concentration (%) in sorghum fodder

Data regarding P concentration in sorghum fodder has been given in table 3. The results revealed that P concentration was maximum (0.19 %) in T14 (residual P 20.75 mg kg^{-1}). Minimum P concentration (0.07 %) was observed in control plots. Duivenbooden *et al.* (1996) reported P concentration in sorghum straw ranging from 0.03-0.14 % and sorghum grain between 0.21-0.40 percent.

Phosphorus uptake (kg ha^{-1}) by sorghum

The results about P uptake by sorghum are given in table 3. The data showed that maximum uptake (13.55 kg ha^{-1}) was found in T14 where the residual P was 20.75 mg P kg^{-1} soil. Minimum P uptake (2.86 kg ha^{-1}) was found in the control plots without NPK. Reddy and Surekha (1998) reported increase in P uptake with increase in residual

Table 2. Residual Olsen-extractable P status of soil and sorghum fodder yield

Treatments	P added to wheat	Residual P after wheat	Fresh fodder Yield	Oven dry fodder yield
	mg kg^{-1}		Mg ha^{-1}	
T1	0	4.70M	17.54J	4.09J
T2	0	4.65M	18.62I	4.34I
T3	8.04	5.30L	18.92I	4.41I
T4	11.29	6.00K	20.13H	4.69H
T5	13.76	6.45J	20.79H	4.84H
T6	15.84	6.95I	22.13G	5.16G
T7	17.67	7.60H	22.88FG	5.33FG
T8	24.80	9.10G	23.75EF	5.54EF
T9	30.24	11.15F	24.58E	5.73E
T10	34.80	13.05E	25.83D	6.02D
T11	38.81	15.53D	27.17C	6.33C
T12	42.43	16.85C	27.46C	6.40C
T13	48.84	18.20B	28.50B	6.64B
T14	54.48	20.75A	30.58A	7.13A
LSD	-	0.3140	0.9085	0.2123

Means sharing the same letters are statistically at par at 5% level of probability.

Table 3. Phosphorus concentration and uptake by sorghum, Olsen-extractable P in soil and P recovery

Treatments	Phosphorus concentration	Phosphorus uptake	Olsen–P after sorghum	Phosphorus recovery
	%	kg ha^{-1}	mg kg^{-1}	%
T1	0.07J	2.86M	4.35KL	0
T2	0.08IJ	3.47L	4.25L	0
T3	0.08HIJ	3.53L	4.50K	0.75
T4	0.09HI	4.22K	5.15J	6.64
T5	0.09GH	4.36J	5.60I	6.61
T6	0.10FG	5.16I	6.00H	10.67
T7	0.11F	5.86H	6.58G	13.53
T8	0.11F	6.09G	7.25F	10.56
T9	0.13E	7.45F	7.45F	13.16
T10	0.13DE	7.83E	7.85E	12.53
T11	0.14CD	8.86D	8.50D	13.89
T12	0.15C	9.60C	9.10C	14.45
T13	0.17B	11.29B	9.75B	16.01
T14	0.19A	13.55A	10.05A	18.50
LSD	0.013	0.0919	0.2313	-

Means sharing the same letters are statistically at par at 5% level of probability.Phosphorus recovery (%) by the sorghum phosphorus. The results are also in line with those of Sahrawat (2000) who reported the criteria for assessment of the residual value of fertilizer phosphorus on P uptake by sorghum.

Data regarding Olsen-extractable P at wheat harvest is depicted in table 2. The results revealed that there was an increase in the Olsen-extractable P with increase in the P fertilizer application and maximum value of 20.75 mg kg^{-1} was found in T14, which was developed by adding 54.48 mg P kg^{-1} soil. However, there was a little bit reduction in native Olsen-extractable P where no NK was applied and further decrease was observed in native Olsen-extractable P where NK was applied. Tandon (1987) summarized the results of 18 experiments and concluded that when half of the optimum rates of P were used, available P declined or showed little change at 60 % sites and when applied optimum rates of P, a significant improvement in available P status was found.

As the sorghum fodder is highly exhaustive crop with respect to phosphorus, so maximum P recovery of 18.50 % was observed where 54.48 mg P kg^{-1} (249.52 kg P_2O_5 ha^{-1}) was added to the previous wheat crop (Table 3). Phosphorus recovery was erratic at lower rates of residual P (i.e. 11.15 mg P kg^{-1}) while at higher rates; this P recovery was consistent and correspondingly increased. The reason might be that phosphorus uptake by the crop was not satisfied at lower rates from the residual P while the higher rates were sufficient to meet the internal P requirement of the crop. Cooke (1982) and Tandon (1992) obtained similar results.

Available phosphorus status of soils after wheat harvest

Crops seldom absorb more and often less than 20 % of fertilize P during the first cropping season after application (Tandon, 1987). Phosphate fertilizers can have long lasting residual effects on succeeding crops and due to accumulated residues, the level of soil P gradually rises contributing more to phosphorus pool available to growing plants (Harapiak and Beaton, 1986). As the sorghum fodder was raised on the residual phosphorus applied to previous wheat crop, so a marked reduction in Olsen-extractable P was observed (Table 3) and the values dropped to almost half after sorghum harvest. But still there was sufficient available P for raising another crop after sorghum.

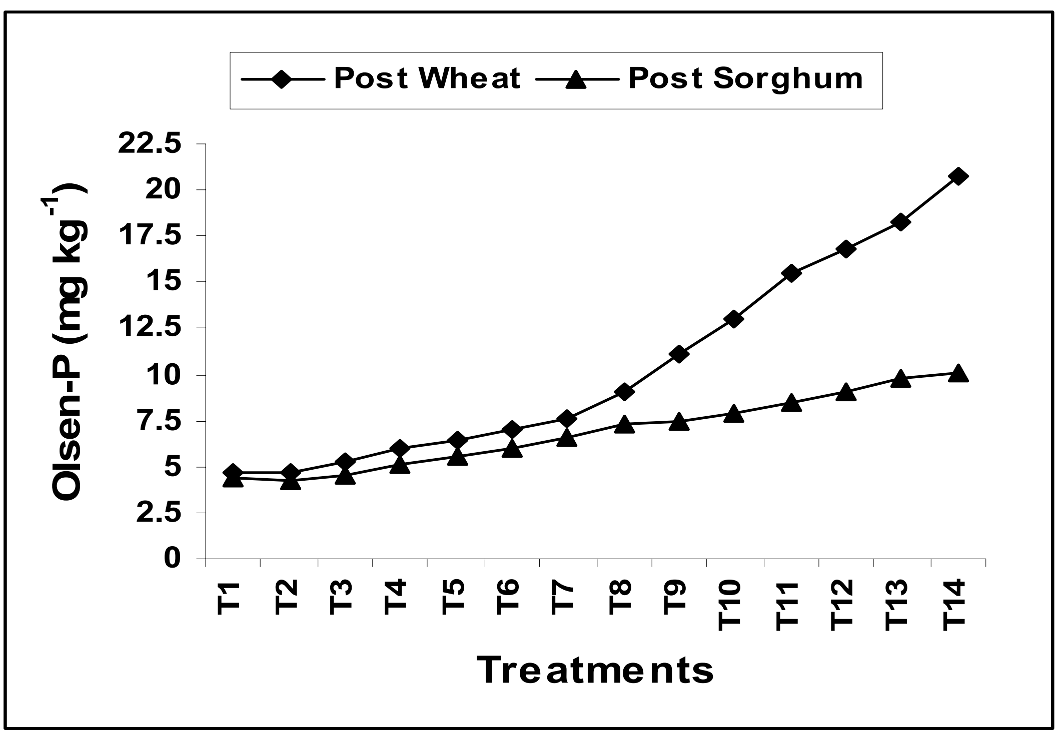

Figure 1. Available phosphorus status of soils after wheat and sorghum fodder harvest

The available P after sorghum fodder was 10.05 mg kg^{-1} in T14 (residual P 20.75 mg kg^{-1} after wheat). Native Olsen P further dropped to 4.35 mg kg^{-1} where no NK was applied and 4.25 mg kg^{-1} where NK was applied. So imbalance application of fertilizers caused a great reduction in native P pool. A comparison of Olsen-extractable P status of soil before and after harvesting the sorghum fodder is given in figure 1.

Conclusions

It can be concluded from this study that residual effect of phosphorus on sorghum fodder was quite significant in improving the fresh and dry matter yield. Phosphorus concentration of the fodder on the higher side of treatments was appreciable for the animal diet. Phosphorus uptake was less than 14 kg ha^{-1} and P recovery was almost 18 %. Olsen-extractable P in soil was still adequate for raising further crops.

References

Anonymous. 2005. Punjab Development Statistics. 2005. Bureau of Statistics, Government of the Punjab, Lahore. p. 96.

Anonymous. 2006. Agricultural Statistics of Pakistan. 2004-05. MINFAL, Pakistan.

Bauder, J.W., S. Mahmood, B.E. Schaff, D.J. Sieler, J.S. Jacobsen and E.O. Skogley. 1997. Effect of phosphorus soil tests level on sorghum–sudan grass response to phosphorus fertilizer. *Agronomy Journal* 89: 9-16.

Bhatti, M.B. and M.S. Khan. 1996. Fodder production in Pakistan. PARC, Pakistan.

Bishnoi, S.R. and S.P.S.B. Singh. 1983. Apply phosphorus to sorghum. *Progressive Farming* 19: 11.

Cooke, G.W. 1982. Fertilizing For Maximum Yield. Granada, London.

Das, S.K., K.L. Sharma, B.R. Singh, B.R.C. Parasada Rao, K. Srinivas and M.N. Reddy. 1996. Availability of desorbed phosphorus and internal phosphorus requirement by sorghum in an Alfisol. *Journal of Indian Society of Soil Science* 44(3): 427-433.

Dogget, H. 1988. Sorghum. 2nd Edition. Longman, London.

Duivenbooden, N. Van, C.T. deWit and H. vanKeulen. 1996. Nitrogen, Phosphorus and Potassium relation in five major cereals reviewed in respect to fertilizer recommendations using simulation modeling. *Fertilizer Research* 44:37-49.

Harapiak, J.T. and J.D. Beaton. 1986. Review of Phosphorus fertilizer, considerations for maximum yields in the Great Plain. *Journal of Fertilizer Issues* 3(3): 113-123.

Iqbal, M.A., G. Muhammad and M.Q. Bilal. 2004. Significance of phosphorus in animal diet. *Zarai Digest* 39(3): 77-78.

Jones, Jr. J.B., W. Benjamin and H.A. Mills. 1991. Plant Analysis Handbook. Micro- Macro Publishing, Inc., USA.

Kanwar, J.S. 1986. Crop production techniques and fertilizer management areas: ICRISAT experiences. In: Proc. "Crop production techniques and fertilizer management in rainfed agriculture in southern Asia". Jan. 22-25, 1986. New Delhi, India.

Naeem, M., M.S. M. Chohan, A.H. Khan and S. Salahuddin. 2002. Evaluation of different varieties of sorghum for green fodder yield potential. *Asian Journal of Plant Sciences* 1(2): 142-143.

Naeem, M., M.S.M. Chohan, A.H. Khan, R.A. Kainth and S. Salahuddin. 2003. Comparison of different sorghum varieties for green fodder yield potential. *Journal of Agriculture Research* 41(3-4): 223-228.

Pathak, P.S., S.B. Tripathi and R.B. Yadav. 2001. Phosphorus management in fodder crops. p. 161-168. In: Phosphorus in Indian Agriculture: Issues and Options. National Workshop Oct. 4, 2001, Haryana, India.

Reddy, M.N. and K. Surekha. 1998. Direct and residual effects of applied phosphorus on yield and nutrient uptake in chickpea-upland rice system. *Oryza* 35(1): 47-52.

Sahrawat, K.L. 2000. Criteria for assessment of the residual value of fertilizer phosphorus. *Journal of Indian Society of Soil Science* 48: 113-118.

Sahrawat, K.L., T.J. Rego, J.R. Burford, M.H. Rahman, J.K. Rao and A. Adam. 1995. Response of sorghum to fertilizer phosphorus and its residual value in Vertisol. *Fertilizer Research* 41: 41-47.

Shaukat, A., Farmanaullah, M. Afzal, J.K. Khattak, A.U. Bhatti, M. Shah and S. Ali. 1992. Two years study on the yield response of maize to residual soil Phosphorus. *Sarhad Journal of Agriculture* 8(4): 495-502.

Singh, S.S. 1998. Jowar. p. 120-130. In: Crop improvement under irrigated and rainfed management. 3rd ed. Kalyani Publishers, New Delhi, India.

Skerman, P.J. and F. Riveros. 1999. Tropical grasses. FAO. Plant Production and Protection Series No. 23, FAO, Rome.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. 2nd Ed. Mc Graw-Hill Book Corp. Inc., NY, USA.

Tandon, H.L.S. 1987. Phosphorus Research and Agricultural Production in India. Fertilizer Development and Consultant Organization, New Delhi, India.

Tandon, H.L.S. 1992. Phosphorus Research in India. p. 93-129. In: Proc. of Symp. on "Role of Phosphorus in Crop Production." July 15-17, 1990. NFDC, Islamabad, Pakistan.

U.S. Salinity Lab. Staff. 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No. 60, Washington, DC, USA.

Wild, A. 1988. Plant Nutrients in Soil: Phosphate. p. 696-742. In: Russell's Soils Conditions and Plant Growth. A. Wild (Ed.). Longman Scientific & Technical, UK.