International Journal of Water Resources and Arid Environments 11(1): 13-17, 2022
ISSN 2079-7079

Efficiency of Phosphorus in Cultivation of Cotton and Winter Wheat in Uzbekistan

A.J. Bairov, N. Yu. Abdurakhmonov, Sh.A. Juraev and X.T. Nuriddinova

Research Institute of Soil Science and Agrochemistry,
100173 st. Kamarniso, 3, Tashkent, Uzbekistan

Abstract: The problem of phosphorus is relevant in agriculture in Uzbekistan due to the low use of P (18-20%) from mineral fertilizers and the low availability of mobile P. In Uzbekistan, the efficiency of P is calculated by the traditional "difference" method, which does not take into account the use of residual P in the soil by plants. The "balance" method proposed by Syers *et al*. [1] also takes into account the residual P of fertilizers. The hypothesis of the experiment assumed that the application of the "balance" method would allow an objective assessment of the efficiency of P on cotton and winter wheat cultivated in Uzbekistan. Experiments with cotton and winter wheat were carried out on irrigated typical serozem soils according to the cotton-cotton-winter wheat alternation scheme adopted in Uzbekistan. On cotton, against the background of $N_{200}K_{100}$, P was applied at rates: 0, 100, 120 and 140 kg/ha; on winter wheat against the background of $N_{180}K_{60}$, P rates were 0, 90, 110 and 130 kg/ha. The results showed that the efficiency P according to the "difference" method was 18-19.6% and according to the "balance" method 54.2-70.8%, depending on the rate of application of P. Higher efficiency indicators P according to the "balance" method is the result of accounting for the residual P of mineral fertilizers. The yield of cotton at a rate of P 100, 120 and 140 kg/ha, on average over 2 years, was 31.3; 33.1 and 34.1 centner/ha, respectively. The yield of winter wheat at the rate of P 90, 110 and 130 kg/ha was 51.0; 53.0 and 53.5 centner/ha, respectively. Taking into account the efficiency of P and the yield of crops, the optimal norm of P is 120 kg/ha for cotton variety C-6524 and 110 kg/ha for winter wheat variety Zamin-1.

Key words: Cotton · Winter wheat · Phosphorus efficiency · Difference method · Balance method · Yield

INTRODUCTION

World food production is now highly dependent on the use of P, which accounts for 50–60% of all P supplies [2]. P is a key component of molecules such as nucleic acids, phospholipids and ATP [3] and is the most important nutrient (after nitrogen) limiting agricultural production in most regions of the world [4]. In modern agricultural production, the P needed by plants comes mainly from the soil, but the efficiency of P from mineral fertilizers in the soil is usually only 10–25% [5]. Of the mechanisms that drive P limitation, we suggest that depletion, soil barriers and low-P parent material often cause ultimate limitation because they control the ecosystem mass balance of P. Similarly, demand-independent losses and constraints to N fixation can control the ecosystem-level mass balance of N and cause it to be an ultimate limiting nutrient [6]. P is the main factor limiting plant productivity in many regions of the world [7]. Fertilizer P increases yield, but at the same time pollutes the environment due to the low efficiency of absorption by plants [8]. P deficiency is more critical in highly withered soils as well as in calcareous and alkaline soils [9]. In the agriculture of Uzbekistan, the efficiency of using P by crops from mineral fertilizers, calculated by the "differences" method, is 15-20%. Johnston and Poulton [8] proposed a new method for calculating the efficiency P [10], later developed by Syers *et al*. [1] and called the "balance" method [11]. The "balance" method takes into account not only the fertilizer applied in the year of application P, but also the residual phosphorus introduced in previous years. Rowe *et al*. [12] showed that residual P of mineral fertilizers can provide plants for 10 years or more without applying P fertilizers [1]. The efficient assimilation of P by plants is necessary to prolong the effective use of the world's phosphate reserves, reduce the cost of agricultural production and increase the cost of plant products [13]. Therefore,

Corresponding Author: A.J. Bairov, Research Institute of Soil Science and Agrochemistry,
100173 St. Kamarniso, 3, Tashkent, Uzbekistan.

increasing the efficiency of P assimilation can be a powerful potential strategy for increasing the efficiency of P in modern crops in intensive farming systems [14]. Residual N in prairie soils is preserved in forms available to plants; wheat crops can restore almost 100% of the applied fertilizer n if there is sufficient time [12]. According to Jagmandeep Dhillon *et al*. [6], the efficiency of global assimilation of P by cereals in the world sown areas was 77 and 16%, respectively, when determined by the “balance” method and the “difference” method [15]. There are other opinions on the assessment of the balance method. As noted by Chien SH *et al*. [14], the difference method is superior to the balance method in terms of the calculated percentage recovery of the applied fertilizer P. The balance method is suitable for determining the percentage of P in the soil in order to assess whether fertilization contributes to the accumulation, depletion or maintenance of P reserves in the soil [16].

In Uzbekistan, irrigated agriculture is carried out on an area of 4.3 million hectares, where mineral fertilizers, including phosphorus, are used. Evaluation of the efficiency P of the applied mineral fertilizers, taking into account the residual P, is of great importance for increasing the efficiency of crop production in Uzbekistan. The aim of the study was a comparative study of the effectiveness of phosphorus of mineral fertilizers on cotton and winter wheat by the "difference" method and the "balance" method.

MATERIALS AND METHODS

The studies were carried out on irrigated typical serozem soils of the Tashkent region with alternating cotton varieties C-6524 and winter wheat Zamin-1 according to the "cotton-cotton-winter wheat" scheme. The soil is medium loamy, non-saline (Table 1).

In the soil, the content of organic matter and nitrogen is low. The total content of P is high, the content of mobile P is 25.1 mg/kg and in accordance with the gradation adopted in Uzbekistan, it belongs to the group with low supply (21-30 mg/kg) (Table 2).

In the first and second years, cotton was cultivated, at the end of 2 years (October), after the harvest of raw cotton, winter wheat was sown, in the third year, the experiment on winter wheat was continued. On cotton against the background of $N_{200}K_{100}$, P was applied at rates of 0, 100, 120 and 140 kg/ha. On winter wheat against the background of $N_{180}K_{60}$, P was applied at rates of 0, 90, 110 and 130 kg/ha. The experiment was carried out in 3 randomized blocks. During the experiment, the agrotechnical measures recommended for this zone were applied. Mineral fertilizers were applied in the form of urea, ammophos and potassium salt (KCl). On cotton, 70% of the annual P norm was applied for autumn plowing, 30% - during the flowering period, on winter wheat - 70% before sowing and 30% at the beginning of the booting phase. The amount of nitrogen in ammophos was taken into account when determining the annual nitrogen norm.

Soil Analysis: The obtained soil samples were dried in air and sieved through sieves with cells of 0.25 mm and 1 mm. Soil texture was determined by mechanical analysis of soil particles (sand, silt and clay) by hydrometer method by dispersion with sodium hexametaphosphate. The content of organic matter was determined by the oxidation of organic matter with K-dichromate in sulfuric acid, total N by the Kjeldahl method, total P by the Ginsburg method (soil combustion in concentrated H_2SO_4 + 50% $HClO_4$ (10:1) with Fe^{3+} precipitation according to Warren and Pugh. Mobile P was determined in accordance with Machigan in 1% NH_4HCO_3 by the method of Murphy and Riley, exchange K also in 1% NH_4HCO_3 on a flame photometer.

Table 1: Texture of the soil used in the experiment

Depth (sm)	Sand 0.05 - 1.0	Silt 0.001 - 0.05	Clay <0.001	Phisical clay <0.01
0-30	15.8	72.7	11.5	41.4
31-50	12.5	76.0	11.5	41.5
51-80	12.5	76.0	11.5	41.5
81-100	12.6	77.3	10.1	42.1
101-120	11.8	79.0	9.2	41.9

Table 2: Properties of the soil used in the experiment

Depth (sm)	Organic matter (%)	Total N (%)	N-NO_3, (mg kg^{-1})	Total P_2O_5 (%)	Total K_2O (%)	Available P_2O_5 (mg kg^{-1})	Exchangeable K_2O (mg kg^{-1})
0-30	0.882	0.0784	15.5	0.214	1.85	25.1	211
31-50	0.680	0.0560	12.3	0.186	1.65	12.0	184
51-80	0.502	0.0470	10.0	0.152	1.50	7.9	156
81-100	0.446	0.0336	8.2	0.121	1.32	5.3	137
101-120	0.405	0.0308	7.4	0.118	1.29	5.3	137

Plant Analysis: The plant material was dried at 70°C for 24 h in an oven and crushed. Total N, P and K were determined by the Ginsburg method (soil combustion in conc. H_2SO_4 + 50% $HClO_4$ (10:1) when heated.

Calculation Methods: The efficiency of P was determined by the following choices in conventional differences and balance methods.

The Difference Method:

$$\text{P recovery (\%)} \frac{\text{P uptake by crop (fertilized soil) - P uptake by crop (unfertilized soil)}}{\text{P dose applied}} \text{x100}$$

The Balance Method:

$$\text{P recovery (\%)} = \frac{\text{P uptake by crop}}{\text{P dose applied}} \text{x100}$$

Total P uptake = P uptake by root + P uptake by shoot

RESULTS AND DISCUSSION

Changes in the Content of Mobile Phosphorus in Soil: Studies have shown that only during the flowering period of cotton, when P was introduced into top dressing, the content of mobile P in the soil reached the highest values (35–40 mg/kg) at a P norm of 140 kg/ha. In other periods of cotton development, its content fluctuated within the range of 25-30 mg/kg, depending on the rate of cotton and at the end of the growing season it decreased to 15-20 mg/kg. The same dynamics of mobile P was observed in the soil and during the cultivation of winter wheat.

Efficiency of Phosphorus in Cotton: The application rates of P significantly influenced the total removal of P by plants. On average, over 2 years with an increase in the dose of P, the total removal of it by plants increased. The consumption of P for the formation of 1 ton of raw cotton crop, on average for the variants, amounted to 22.2 kg. At the same time, the efficiency of P calculated by the "differences" method, on average for 2 years, was 18.5 - 19.8% and significant fluctuations were not observed between the norms of P. And when calculated by the "balance" method, it was 3-3.5 times higher compared to the "differences" method, which is consistent with the data of Syers *et al*. [1]. An increase in the P norm was accompanied by a decrease in the P efficiency calculated by the "balance" method, which indicates a decrease in the assimilation of residual P by plants with an increase in the P norm.

The increase in the yield of raw cotton at the rates of P 100, 120 and 140 kg/ha was 4.7; 6.5 and 7.5 centner/ha, respectively. The cotton yield increased to a norm of

Table 3: Efficacy of P in cotton (average 2 years)

		P use efficiency %		
Fertilizer rate (kg/ha)	Total P uptake (kg/ha)	The difference method	The balance method	Yield cen./ha
$N_{200}P_0K_{100}$	49.9	-	-	26.6
$N_{200}P_{100}K_{100}$	69.2	19.3	69.2	31.3
$N_{200}P_{120}K_{100}$	73.6	19.8	61.3	33.1
$N_{200}P_{140}K_{100}$	75.8	18.5	54.1	34.1
L.s.d.: Least significant difference value (P = 0.05)				1.71

Table 4: Efficacy of P in winter wheat

		P use efficiency %		
Fertilizer rate (kg/ha)	Total P uptake (kg/ha)	The difference method	The balance method	Yield cen./ha
$N_{180}P_0K_{60}$	48.7	-	-	45.0
$N_{180}P_{90}$ K_{60}	67.0	18.3	74.4	51.0
$N_{180}P_{110}$ K_{60}	68.6	16.5	62.4	53.0
$N_{180}P_{130}$ K_{60}	70.4	15.5	54.2	53.5
L.s.d.: Least significant difference value (P = 0.05)				1, 85

Table 5: Efficiency P at 3-year crop rotation

Phosphorus given in 3 years, kg/ha	Total P uptake (kg/ha)	P use efficiency %	
		The difference method	The balance method
0	148.4	-	-
290	205.4	19.6	70.8
350	215.8	19.3	61.7
410	222.1	18.0	54.2

P 120 kg/ha and at a norm of 140 kg/ha did not have significant differences from the norm of 120 kg/ha (Table 3). Thus, in the conditions of irrigated typical serozem soils with low mobile P, the optimal rate of P on cotton of the C-6524 variety is 120 kg/ha.

P Efficiency on Winter Wheat: The total removal of P by winter wheat also increased with an increase in the norm of P. The consumption of P for the formation of 1 ton of grain yield was 13.1 kg. The efficiency P according to the “balance” method was 3.5-4 times higher than that calculated by the “differences” method. The highest yields of winter wheat were obtained at rates of P 110 and 130 kg/ha. The yield levels for these variants were almost the same. The yield increase from the introduction of P at the rates of P 90, 110 and 130 kg/ha was 6.0; 8.0 and 8.5 centner/ha (Table 4). Thus, the optimal P norm for winter wheat is 110 kg/ha.

Efficiency P at 3-year Crop Rotation: When alternating crops according to the "cotton-cotton-winter wheat" scheme, the efficiency P for 3 years calculated by the "differences" method was 18.0-19.6% and according to the "balance" method it was 3-3.6 times higher, which confirms the conclusions of Syers *at al*. [1] and Dhillon *at al*. [16] on the significant use of residual P by plants of previously applied mineral fertilizers.

CONCLUSION

With the introduction of the recommended rate of R. of 140 kg/ha for cotton and 110 kg/ha for winter wheat, the content of mobile P in the soil was below the optimal level (40-45 mg/kg). And the efficiency of P calculated by the "balance" method was 54-71%, which is 3-3.6 times higher than the results of the "differences" method. However, the question remains, what will be the efficiency of P when the optimal level of mobile P is reached in the soil. In the future, the establishment of P efficiency by the "balance" method when the optimal level of mobile P is reached may help to effectively plan the use of phosphorus fertilizers in agriculture in Uzbekistan.

REFERENCES

1. Syers, J.K., A.E. Johnston and D. Curtin, 2008. Efficiency of Soil and Fertilizer Phosphorus Use-Reconciling Changing Concepts of Soil Phosphorus Behaviour With Agronomic Information. FAO Fertilizer and Plant Nutrition Bulletin 18. Rome. Electronic Publishing Policy and Support Branch Communication Division FAO. Retrieved from http://www.fao.org/3/a1595e/a1595e00.htm
2. Xiurong, W.J. and H.L. Shenb, 2010. Acquisition or utilization, which is more critical for enhancing phosphorus efficiency in modern crops? Plant Science, 179(4): 302-306. https://doi.org/10.1016/j.plantsci.2010.06.007
3. Holford, I.C.R., 1997. Soil phosphorus: its measurement and its uptake by plants Australian Journal of Soil Research, 35(2): 227-240. https://doi.org/10.1071/S96047
4. Hinsinger, P., 2001. Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: a review. Plant and Soi, 237:173-195.https://doi.org/10.1023/A:1013351617532
5. Ying, Z., L. Yuelei and Y. Fan, 2021. Critical review on soil phosphorus migration and transformation under freezing-thawing cycles and typical regulatory measurements. Science of Total Enviromen, 751. https://doi.org/10.1016/j.scitotenv.2020.141614
6. Jagmandeep, D., T. Guilherme, D. Ethan, F. Bruno and William R. Raun, 2017. World Phosphorus Use Efficiency in Cereal Crops Soil fertility & Crop nutrition. Agron. J., 109: 1670-1677. https://doi:10.2134/agronj2016.08.0483
7. Vitousek, P.M., S. Porder, B.Z. Houlton and O.A. Chadwick, 2010. Terrestrial phosphorus limitation: mechanisms, implications and nitrogen–phosphorus interactions. https://doi.org/10.1890/08-0127.1
8. Johnston, A.E. and P.R. Poulton, 1977. Rothamsted Experimental Station Report for 1976, Part 2., pp: 53-85
9. Batten, G.D., 1992. A review of phosphorus efficiency in wheat. Plant Soil, 146: 163-168. https://doi.org/10.1007/BF00012009

10. Shenoy, V.V. and G.M. Kalagudi, 2005. Enhancing plant phosphorus use efficiency for sustainable cropping. Biotechnol Adv. https://doi.org/10.1016/j.biotechadv.2005.01.004
11. Selles, F., C.A. Campbell, R.P. Zentner, D. Curtin, D.C. James and P. Basnyat, 2011. Phosphorus use efficiency and long-term trends in soil available phosphorus in wheat production systems with and without nitrogen fertilizer. Can. J. Soil Sci., 91: 39-52. https://doi.org/10.4141/cjss10049
12. Rowe, H., P.J.A. Withers, P. Baas, *et al.*, 2016. Integrating legacy soil phosphorus into sustainable nutrient management strategies for future food, bioenergy and water security. Nutr. Cycl. Agroecosyst, 104: 393-412. https://doi.org/10.1007/s10705-015-9726-1
13. Smil, V., 2000. Phosphorus in the environment: natural flows and human interferences. Annu. Rev. Energy Environ, 23(7-8): 501-13. https://doi.org/10.1146/annurev.energy.25.1.53
14. Chien, S.H., F.J. Sikora, R.J. Gilkes, *et al.*, 2012. Comparing of the difference and balance methods to calculate percent recovery of fertilizer phosphorus applied to soils: a critical discussion. Nutr. Cycl. Agroecosyst, 92(1-8). https://doi.org/10.1007/s10705-11-9467-8
15. Prem, S.B.I., O.D. Christian and P. Renu, 2020. Exploring phosphorus fertilizers and fertilization strategies for improved human and environmental health. Biology and Fertility of Soils, 56: 299-317 https://doi.org/10.1007/s00374-019-01430-2
16. Daniel, P.S., J.R. Robert and S.M. Ayling, 1998. Phosphorus Uptake by Plants: From Soil to Cell. Plant Physiology, 116(2): 447-453. https://doi.org/10.1104/pp.116.2.447.