www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(4): 1120-1123

www.thepharmajournal.com
Received: 21-02-2021
Accepted: 24-03-2021

Shilpa
Ph.D. Scholar, Division of Soil Science and Agricultural Chemistry, ICAR- Indian Agricultural Research Institute, New Delhi, India

BG Vasanthi
Senior Scientist, AICRP for Dryland Agriculture, University of Agricultural Sciences, GKVK, Bangalore, India

Corresponding Author:
Shilpa
Ph.D. Scholar, Division of Soil Science and Agricultural Chemistry, ICAR- Indian Agricultural Research Institute, New Delhi, India

Phosphorus use efficiency as affected by long-term manuring and fertilization under finger millet based cropping systems in acidic *Alfisols*

Shilpa and BG Vasanthi

Abstract
Nutrient use efficiency is a critically important concept in assessing the performance of crop production systems. Phosphorus is one of the most critical externally added source for any crop production system. Optimizing phosphorus use efficiency can increase grain yield while reducing its adverse effects on environment. Therefore, a study was carried out at research farm of All India Co-ordinated Project for Dryland Agriculture (AICRPDA) in University of Agricultural Sciences, Bangalore to predict the effects of long-term application of phosphatic fertilizers along with manures on phosphorus use efficiency of finger millet under different cropping system. Experiment was laid down in randomised completely block design (RCBD) with 10 treatments, replicated four times. Application of FYM 10 t ha^{-1} + 100 % RDF under finger millet-groundnut rotation (T_9) resulted in higher grain yield (28.67 q ha^{-1}) as well as phosphorus uptake by grains (6.78 kg ha^{-1}) of finger millet. However, phosphorus use efficiency, in terms of partial factor productivity (110.50 kg kg^{-1}), agronomic efficiency (94.10 kg kg^{-1}) and apparent recovery (18.85 %), was more with application of FYM 10 t ha^{-1} under finger millet-groundnut rotation (T_7) indicated the importance of organics in present day agriculture.

Keywords: Finger millet, long-term, phosphorus, phosphorus use efficiency

Introduction
Phosphorus (P) is the second most important macronutrient next to nitrogen limiting plant growth. It is essential to all forms of life and contributes towards increasing the native soil fertility and sustainability, especially under intensive cultivation. This nutrient plays a significant role in many cellular processes, including the maintenance of membrane structures, biomolecules synthesis, energy generation and as indispensable constituent of several plant structures such as phospholipids (Vance *et al.*, 2003) [15]. Phosphorus is considered as non-renewable resource owing to limited global rock phosphate reserves (Gilbert, 2009) [7] and its availability is generally low due to slower diffusion rate and higher fixation in soils that makes it a prominent factor limiting plant growth. More than 40 per cent of arable land globally is deficient in phosphorus (Vance *et al.*, 2003) [15].
There arises a need to monitor phosphorus dynamics in soils including its efficiency. Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly influenced by fertilizer as well as by soil - plant - water management. The aim of nutrient use is the improvement in the overall performance of cropping systems by providing economically optimum nourishment to the crop while lessening nutrient losses from the field. NUE addresses some but not all aspects of that performance.
Out of the total minor millets produced, finger millet is accountable for about 85% of production in India. In India, finger millet is grown over an area of 1.19 million hectares giving an output of 1.98 million tonnes with an average productivity of 1662 kg ha^{-1} (Anon., 2018) [1]. Out of this, Karnataka accounts for 56.21 and 59.52 per cent of area and production, respectively. In India, *Alfisols* cover an area of 79.7 million ha accounting for about 24 per cent of the total geographical area of 328.7 million ha. It is one of the most dominant soil orders in dryland regions of India, characterized by higher P fixation capacity
Lower efficiency of P fertilizer leads to application of large quantity of P fertilizer every year to keep higher yield. However, imbalanced use of fertilizer has resulted in declining of yield and fertility status in long-term cropping sequences (Frossard *et al.*, 2014) [6]. Therefore, prolonged use of fertilizer and manure should be monitored, the rate and type of fertilizer application redefined, to increase crop yield and sustainability of cropping systems (Srivastava

et al., 2015). Therefore, present study was concerned with investigation on the effect of long-term addition of manures and fertilizers on phosphorus use efficiency of finger millet under rainfed finger millet based cropping systems.

Material and methods

In India, first long-term field experiment began at Kanpur (1905); subsequently, these experiments were introduced at Pusa (1908) and Coimbatore (1909), respectively. The University of Agricultural Sciences (UAS), Bangalore initiated long-term integrated nutrient management experiment during 1978 taking finger millet the principal crop. Later, recognizing the importance of legume crops in enhancing soil fertility, groundnut was superimposed in the trial in the year 1992.

A research study was conducted at research farm of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Bangalore on this ongoing long-term experimental trial located in the Agro-climatic Zone-V, Eastern Dry Zone of Karnataka at 12°58' N latitude and 77°35' E longitude with an altitude of 929 m above mean sea level (MSL) during *kharif* season of 2019-20. The soils of Dryland Agriculture Project represent the typical lateritic area and belong to *Vijaypura* series, which is a dominant soil series of Bangalore plateau. These soils are classified as fine, kaolinitic, Isohyperthermic, *Typic Kandiustalf*, as per USDA classification. The soil of the experimental site is sandy clay loam in texture and the physico-chemical properties of the soils, at the initiation of the experiment, are presented in Table 1.

Table 1: Physico-chemical properties of LTFE soil prior to the experimentation in 1978

Physical properties	
Coarse sand (%)	42.00
Fine sand (%)	30.50
Silt (%)	6.20
Clay (%)	21.20
Textural class	Sandy clay loam
Maximum water holding capacity (%)	29.40
Pore space (%)	41.80
Volume expansion (%)	2.40
Bulk density (Mg m^{-3})	1.64
Chemical properties	
pH (1:2.5)	5.00
EC (dS m^{-1})	0.20
Organic carbon (%)	0.40
Available nitrogen (kg ha^{-1})	200.0
Available phosphorus (kg ha^{-1})	8.70
Available potassium (kg ha^{-1})	132.80
Exchangeable calcium (cmol (p^+) kg^{-1})	2.30
Exchangeable magnesium (cmol (p^+) kg^{-1})	0.75
Exchangeable potassium (cmol (p^+) kg^{-1})	0.30
Cation exchange capacity (cmol (p^+) kg^{-1})	7.10

Experimental design

The experiment was laid down in randomized complete block design (RCBD) with 10 treatments which were replicated four times. Test crop variety was GPU-28.

Treatment details

Different treatments imposed were T_1 - Control under finger millet monocropping; T_2 - FYM @ 10 t ha^{-1} under finger millet monocropping; T_3 - FYM @ 10 ha^{-1} + 50 % RDF under finger millet monocropping; T_4 - FYM @ 10 t ha^{-1} + 100 % RDF under finger millet monocropping; T_5 - 100 % RDF under finger millet monocropping; T_6 - Control under finger millet - groundnut rotation; T_7 - FYM @ 10 t ha^{-1} under finger millet - groundnut rotation; T_8 - FYM @ 10 t ha^{-1} + 50 % RDF under finger millet - groundnut rotation; T_9 - FYM @ 10 t ha^{-1} + 100 % RDF under finger millet - groundnut rotation; T_{10} - 100 % RDF under finger millet - groundnut rotation. FYM was applied @10 t ha^{-1} prior to experimentation in 2019 and RDF (N: P_2O_5: K_2O in 50:25:25) through Urea, DAP and Muriate of Potash (MOP).

Soil sample analysis

Soil samples were collected from 0-15 cm depth, dried in shade, sieved through 2 mm sieve and analyzed for available phosphorus (P_2O_5) using Bray's ascorbic acid-molybdate complex method (Bray and Kurtz, 1945) [3]. Bray's No. 1 (0.03 N NH_4F + 0.025 N HCl) reagent was used as an extractant for extracting available P (1:10).

Plant sample analysis

Grain yield of finger millet was quantified using standard procedure and expressed as kg ha^{-1}. Grain samples at harvest of finger millet, were dried, powdered and pre-digestion was carried out with 10 ml HNO_3 (62 %) for 24 hours. Later, pre-digested samples were treated with 10 ml diacid mixture (HNO_3 + $HClO_4$ in 10:4 ratio. Phosphorus in digested grain sample was estimated by vanodomolybdo- phosphoric yellow colour method (Piper, 1966) [10]. Phosphorus uptake was calculated using the following formula:

$$\text{Phosphorus uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%)}}{100} \times \text{Biomass (kg ha}^{-1})$$

Nutrient use efficiency of phosphorus in grains of finger millet, was quantified using concept of agronomic efficiency, apparent recovery and partial factor productivity (Dobermann, 2007) [5] which were calculated as:

i. Partial Factor Productivity: $\dfrac{\text{Total yield (kg ha}^{-1})}{\text{Amount of phosphorus applied (kg ha}^{-1})}$

ii. Apparent Recovery: $\dfrac{\text{NU (fertilized plot) -NU (control)}}{\text{Amount of phosphorus applied}}$

iii. Agronomic Efficiency: $\dfrac{\text{GY (fertilized plot) -GY (control)}}{\text{Amount of phosphorus applied}}$

(**Note:** NU: nutrient uptake; GY: Grain yield)

Partial factor productivity (PFP_P) and agronomic efficiency (AE_P) were expressed as kg kg^{-1}, while apparent recovery (AR_P) as percentage (%).

Statistical analysis

Methods described by Gomez and Gomez (1984) [8] were used for statistical analysis of data. The level of significance used in 'F' and 't' test was p = 0.05. Critical difference (CD) values were calculated for p = 0.05 whenever 'F' test was found significant.

Results and Discussion

Results obtained on grain yield of finger millet, phosphorus uptake by grains of finger millet and phosphorus use efficiency in terms of partial factor productivity (PFP_P), agronomic efficiency (AE_P) and apparent recovery (AR_P) after continuous application of manures and fertilizers under finger millet based cropping systems, are represented in Table 2.

Table 2: Effect of continuous application of organic manures and inorganic fertilizers on grain yield, phosphorus uptake by grains and phosphorus use efficiency of finger millet under finger millet based cropping system

Treatments	Grain yield	Nutrient applied	Grain uptake	PFPP	AEP	ARP
	(q ha^{-1})	(kg ha^{-1})		(kg kg^{-1})		(%)
T_1: Control under finger millet monocropping	1.51	0	0.17	0.00	0.00	0.00
T_2: FYM @ 10 t ha^{-1} under finger millet monocropping	15.86	20	2.70	79.30	71.75	12.65
T_3: FYM @ 10 t ha^{-1} + 50 % RDF under finger millet monocropping	23.12	45	4.16	51.38	48.02	8.87
T_4: FYM @ 10 t ha^{-1} + 100 % RDF under finger millet monocropping	26.29	70	5.52	37.56	35.40	7.64
T_5: 100 % RDF under finger millet monocropping	12.14	50	1.82	24.28	21.26	3.30
T_6: Control under finger millet- groundnut rotation	3.28	0	0.43	0.00	0.00	0.00
T_7: FYM @ 10 t ha^{-1} under finger millet- groundnut rotation	22.10	20	4.20	110.50	94.10	18.85
T_8: FYM @ 10 t ha^{-1} + 50 % RDF under finger millet- groundnut rotation	24.32	45	5.35	54.04	46.76	10.93
T_9: FYM @ 10 t ha^{-1} + 100 % RDF under finger millet- groundnut rotation	28.27	70	6.78	40.39	35.70	9.07
T_{10}: 100 % RDF under finger millet- groundnut rotation	15.57	50	2.49	31.14	24.58	4.12
S.Em. ±	1.14	-	0.17	-	-	-
CD (P = 0.05)	3.32	-	0.50	-	-	-

Note: PFPP: Partial factor productivity of P; AEP: Agronomic efficiency of P; ARP: Apparent recovery of P.

Yield and phosphorus uptake by grains of finger millet

Application of different sources of nutrients showed significant difference on grain yield of finger millet as well as phosphorus uptake by grains of finger millet under different cropping systems. Significantly higher grain yield (28.27 q ha^{-1}) was recorded with application of FYM @10 t ha^{-1} + 100 % RDF under finger millet- groundnut rotation (T_9) and it was at par with T_4 (26.29 q ha^{-1}) receiving same dosses of fertilization under finger millet mono cropping. Significantly higher uptake of phosphorus (6.78 kg ha^{-1}) by grains of finger millet was recorded under T_9 receiving FYM @10 t ha^{-1} + 100 % RDF under finger millet- groundnut rotation.

Higher yield due to inorganic fertilizers in combination with FYM due to sustained nutrient supply and better utilization of applied nutrients through improved microbial activity that involved nutrient transformation and fixation due to organic manuring (Shirale *et al.*, 2014) [12]. Similar yield increments as a result of continuous release of available nutrients during the crop growth due to INM was also reported by Ravankar *et al.* (2004) [11] in wheat and Bhattacharyya *et al.* (2008) [2] in rainfed soybean-wheat system. Inclusion of legume in rotation, integrated application of organics and inorganics had a positive impact on soil productivity and sustainability.

Nutrient uptake tends to positively correlate with the biomass produced and organic materials produced from decomposition of FYM would have formed chelates with Al^{3+} and Fe^{3+}, lowering phosphorus fixing capacity and thus increasing its availability to plants (Kumari *et al*., 2017) [9].

Phosphorus use efficiency

With respect to grain yield and total amount of phosphorus applied, partial factor productivity of phosphorus (PFP_P) was much higher ranging from 24.28 kg kg^{-1} in 100 % RDF under finger millet monocropping (T_5) to 110.50 kg kg^{-1} in FYM @ 10 t ha^{-1} under finger millet- groundnut rotation (T_7). Agronomic efficiency of phosphorus (94.10 kg kg^{-1}) and Apparent recovery of phosphorus (18.85 %) were also considerably higher application of FYM @ 10 t ha^{-1} under finger millet- groundnut rotation (T_7). The relative performance of different treatments in terms of phosphorus use efficiency over the control can be represented as $T_7 > T_2 > T_8 > T_3 > T_9 > T_4 > T_{10} > T_5$.

In general, phosphorus use efficiency was quite higher with lower application rate of phosphorus and decreased with incremental rate of nutrient application. Plots receiving organics were having lower content of available phosphorus compared to integrated application of manures and fertilizers. This might be ascribed to the higher response and better utilization by finger millet to applied phosphorus in later plots. Further application beyond this point was non-beneficial and non-economical as plants utilized a smaller proportion of applied phosphorus, leaving the remaining amount fixed in the soil. These results are in accordance with work of Chandrakala (2014) [4].

Higher phosphorus use efficiency in case of organically maintained treatments may be due to higher biomass production as compared to nutrient input supplied and improvement of soil physico-chemical and biological properties with the use of organic FYM and rotational cropping. Similar findings were reported by Tarik and Mani (2017) [14] and Zhu *et al*. (2012) [12].

Conclusion

From the study conducted at AICRPDA, it was found that integrated application of manure and fertilizers as FYM @ 10 t ha^{-1} + 100 % RDF under finger millet- groundnut rotation (T_9) recorded higher grain yield along with the uptake of phosphorus by grains of finger millet. But phosphorus use efficiency was much higher with application of FYM @ 10 t ha^{-1} under finger millet- groundnut rotation (T_7) which indicates the importance of organic fertilizers in sustaining the production systems.

Acknowledgments

The authors are filled with gratitude towards Indian Council of Agricultural Research (ICAR), New Delhi, India and University of Agricultural Sciences (UAS), Bangalore, India for providing financial support to the study.

Competing interests

Authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in association with all authors. Author Shilpa designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author B. G. Vasanthi managed the analyses of the study. All the authors read and approved the final manuscript.

References

1. Anonymous. Socio-economic statistical information about agriculture in India 2018. [Available at http://www.indiaagristat.com/]
2. Bhattacharyya R, Kundu S, Prakash P, Gupta HS. Sustainability under combined application of mineral and organic fertilizers in a rainfed soybean–wheat system of the Indian Himalayas. European Journal of Agronomy 2008;28(1):33-46.
3. Bray RH, Kurtz LT. Determination of total, organic, and available forms of phosphorus in soils. Soil Science 1945;59:39-45.
4. Chandrakala M. Status and revalidation of phosphorus requirement for finger millet- maize cropping system in soils of Eastern Dry Zone of Karnataka, Ph.D. Thesis, University of Agricultural Sciences, Bangalore, Karnataka, India 2014.
5. Dobermann A. Nutrient use efficiency-measurement and management. Fertilizer Best Management Practices 2007, 1.
6. Frossard E, Demaria P, Sinaj S, Schärer M. A flow-through reactor to assess potential phosphate release from agricultural soils. Geoderma 2014;219:125-135.
7. Gilbert N. Environment: the disappearing nutrient. Nature 2009;461:716-718.
8. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley & Sons 1984.
9. Kumari R, Kumar S, Kumar R, Das A, Kumari R, Choudhary CD *et al*. Effect of long-term integrated nutrient management on crop yield, nutrition and soil fertility under rice-wheat system. Journal of Applied and Natural Science 2017;9(3):1801-1807.
10. Piper CS. Soil and Plant Analysis. Hans Publisher, Bombay 1966.
11. Ravankar HN, Bhagwat V, Sarap PA. Forms of phosphorus under long term fertilization to sorghum-wheat sequence on *Vertisols* and their relationship with yield. Indian Journal of Agricultural Research 2004;38(3):184-189.
12. Shirale ST, Kide DS, Meshram NA. Influence of INM on soil quality, yield and uptake by safflower in soybean-safflower crop sequence in *Vertisol.* Journal of Soils and Crops 2014;24(2):379-390.
13. Srivatsava PK, Maruthi Sankar GR, Vijaya Kumar P, Singh SP, Rani N, Singh A *et al*. Effects of organic and inorganic fertilizers on soil and plant nutrients and yields of pearl millet and wheat under semi-arid *Inceptisols* in India. Communications in Soil Science and Plant Analysis 2015;46(20):2595-2614.
14. Tarik M, Mani PK. Effect of organic amendments on rice yield trend, phosphorus use efficiency, uptake and apparent balance in soil under long- term rice-wheat rotation. Journal of Plant Nutrition 2017;40(9):1312-1322.
15. Vance CP, Uhde-Stone C, Allan D. Phosphorus acquisition and use: critical adaptation by plants for securing non-renewable resources. New Phytologist 2003;157(3):423-447.
16. Zhu XK, Li CY, Jiang ZQ, Huang LL, Feng CN, Guo WS *et al*. Responses of phosphorus use efficiency, grain yield, and quality to phosphorus application amount of weak-gluten wheat. Journal of Integrative Agriculture 2012;11(7):1103-1110.