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Phosphorus Availability and Balance as Affected by Continuous Application of Manures and Fertilizers in *Alfisols* under Finger Millet based Cropping Systems

Shilpa[1]* and B.G. Vasanthi[2]

[1]*Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi-110012, India*

[2]*AICRP for Dryland Agriculture, University of Agricultural Sciences, GKVK, Bangalore-560065, India*

**Corresponding Author's Email : shilpa9825@gmail.com*

Abstract

Phosphorus (P) nutrition has been designated as the key to human hunger as it plays critical functions in plant development. With the continuous application of fertilizers over the years phosphorus starts accumulating in the soils. Taking into consideration this fact, a field study was carried out at research farm of All India Co-ordinated Project for Dryland Agriculture (AICRPDA) in University of Agricultural Sciences, Bangalore, to access the availability of phosphorus in long run as affected by fertilizers and manures and P balance for the copping year 2019-20. Experiment was laid down in randomised completely block design (RCBD) with 10 treatments which were replicated four times. Higher availability of phosphorus (281.64 kg ha^{-1}) was recorded in plots receiving FYM @ 10 t ha^{-1} + 100 % RDF under finger millet-groundnut rotation (T_9), but positive balance of phosphorus (4.64 kg ha^{-1}) was recorded in plots receiving application of FYM 10 t ha^{-1} under finger millet-groundnut rotation (T_7) which indicates significance of applying manures for plant nutrition.

Key words : *Availability, phosphorus, phosphorus balance.*

Introduction

Phosphorus (P) is one of seventeen essential nutrients that plants require for growth and development. None of the other nutrient can perform its functions, thus a sufficient supply of P is needed for optimal growth and reproduction, maintenance of membrane structures, biomolecules synthesis, energy generation and as indispensable constituent of several plant structures such as phospholipids. It also assists in cell division, enzymes regulation and the metabolism of carbohydrates (1).

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 and is dominant in dryland regions. Crop yield limited by low P availability in soils but application of animal manure and chemical P fertilizers to agricultural land have improved soil P fertility and crop production but caused environmental damage in the past decades.

However, crop utilization of fertilizer phosphorus rarely exceeds 20-25 per cent of applied phosphorus and thus, continuous application of fertilizers in combination with organic manures leads to accumulation of phosphorus in soils (2). Among the major nutrient, the maintenance of adequate amount of phosphorus (P) through use of inorganic and organic P is critical for the sustainability of cropping system (3). The sustainability of long-term experiments can be accomplished through nutrient balance which represents the soil nutrient balance sheet (4). Positive relationships have been perceived between partial phosphorus balance (PPB), total P or plant-accessible P in soils (5). PPB can therefore provide a valuable tool to predict changes in soil P and can therefore prescribe the quantity of fertilizer to be applied to ultimately offset the removal of P by the harvested crop. Keeping all these factors in view, a study was conducted to know the availability of phosphorus and phosphorus balance under long-term fertilization in finger millet based cropping systems as 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} (6).

Materials and Methods

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 belong to *Vijaypura* series and 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.

Experimental design : The experiment was laid down in

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Table-1 : Physico-chemical properties of LTFE soilsat initiation of 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

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) was 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). 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 and plant 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 (7). Phosphorus uptake was calculated using the following formula :

Phosphorus uptake (kg/ha)

$$= \frac{\text{Nutrient concentration (\%)}}{100} \quad \text{Biomass (kg/ha)}$$

Nutrient balance for phosphorus : Balance sheet for phosphorus, for year 2019-20, was worked out by considering the initial soil available phosphorus values. To this amount, nutrients applied through manures and fertilizers was added. By subtracting the crop uptake from previous sum, expected balance of nutrients was calculated out. Actual balance was estimated by subtracting expected balance from initial balance calculated after harvest of finger millet (8).

Statistical analysis : Methods described by (9) were used for statistical analysis of data.

Results and Discussion

Results obtained on availability of phosphorus and phosphorus balance after continuous application of manures and fertilizers under finger millet based cropping systems, are represented in Table-2.

Availability of phosphorus : Available phosphorus content of surface soil was significantly influenced by different treatments. Significantly higher available phosphorus in surface soil was observed with application of FYM @ 10 t ha^{-1} + 100 % RDF under finger millet-groundnut rotation (273.92 and 281.64 kg ha^{-1}, respectively) and it was on par with FYM @ 10 t ha^{-1} + 100 % RDF under finger millet- monocropping (265.36 and 271.83 kg ha^{-1}, respectively) before sowing and after harvest. Higher availability of P with application of FYM along with 100 % RDF might be due to solubilizing effect of organic acids (product of decomposition of organic manures) which release P from insoluble fractions, reduction of P fixation in the soil because of chelation of P fixing cations like Ca, Fe and Al, and also due to the enhanced microbial activities (10). In addition, long-term application of diammonium phosphate (DAP) also contributed to the increased available phos- phorus in soil. Also, organic matter tends to form a coating over P fixing sesquioxide and makes them inactive, thus, reduced P fixing capacity of soils with concomitant increase in plant available P (11).

Phosphorus balance : Significantly higher total uptake of phosphorus (11.35 kg ha^{-1}) by grains and straw of of finger millet was recorded under T_9 receiving FYM @10 t ha^{-1} + 100 % RDF under finger millet- groundnut rotation. Higher

Table-2 : Effect of continuous application of organic manures and inorganic fertilizers on available phosphorus and phosphorus balance in soils under finger millet based cropping system.

Treatment	Initial amount* (kg ha^{-1}) (1)	Applied amount (kg ha^{-1}) (2)	Total applied amount (kg ha^{-1}) (1+2)	Total uptake (kg ha^{-1}) (3)	Expected balance (kg ha^{-1}) [(1+2)-3] = (4)	Actual balance/ Available (kg ha^{-1}) P* (5)	Net Gain/ loss (kg ha^{-1}) (4-5)
T_1 : Control under finger millet monocropping	31.15	0	31.15	0.32	30.83	22.46	-8.37
T_2 : FYM @ 10 t ha^{-1} under finger millet mono cropping	79.62	20	99.62	4.78	94.84	87.1	-7.74
T_3 : FYM @ 10 t ha^{-1} + 50% RDF under finger millet monocropping	151.86	45	196.86	7.23	189.63	161.49	-28.14
T_4 : FYM @ 10 t ha^{-1} + 100% RDF under finger millet mono cropping	265.36	70	335.36	9.61	325.75	271.83	-53.92
T_5 : 100% RDF under finger millet mono cropping	56.07	50	106.07	3.29	102.78	63.88	-38.90
T_6 : Control under finger millet-groundnut rotation	30.61	0	30.61	0.89	29.72	27.1	-2.62
T_7 : FYM @ 10 t ha^{-1} under finger millet-groundnut rotation	97.89	20	117.89	7.23	110.66	115.3	4.64
T_8 : FYM @ 10 t ha^{-1} + 50% RDF under finger millet-groundnut rotation	188.09	45	233.09	9.01	224.08	196.54	-27.54
T_9 : FYM @ 10 t ha^{-1} + 100% RDF under finger millet-groundnut rotation	273.92	70	343.92	11.35	332.57	281.64	-50.93
T_{10} : 100% RDF under finger millet-groundnut rotation	61.69	50	111.69	4.57	107.12	67.49	-39.63

uptake was due to higher yield and use of inorganic fertilizers in combination with FYM which sustained nutrient supply and better utilization of applied nutrients through improved microbial activity that involved nutrient transformation and fixation due to organic manuring (12).

Positive phosphorus balance (4.64 kg ha^{-1}) was observed with application of FYM @ 10 t ha^{-1} under finger millet- groundnut rotational cropping (T_7). In general, negative balance of phosphorus was observed under all treatments except T_7 which received 100 % nutrition with organic FYM under finger millet rotational cropping with groundnut. Phosphorus loss might be attributed to higher crop uptake and also due to the transformation of the applied phosphorus into different fractions and fixation. Higher depletion in the form of plant uptake was reported from INM plots with balanced application of nutrients and higher fixation capacity of red soils. Positive balance might be due to lower uptake of phosphorus against total applied P and also due to lower fixation. Similar results were compiled by (13).

(14) recorded positive phosphorus balance under rice-wheat sequence under integrated nutrient application while (15) recorded negative phosphorus balance in LTFE experiments.

Conclusions

Application of higher but balanced amount of FYM @ 10 t ha^{-1} + 100 % RDF under finger millet- groundnut rotation (T_9) increased the availability of phosphorus in long run. But positive balance was recorded only in case of organics which imply that application of organics either alone or in combination with fertilizers can result in the improvement in soil fertility.

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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.

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