The Pharma Innovation Journal 2022; 11(8): 2089-2093

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(8): 2089-2093

www.thepharmajournal.com
Received: 23-06-2022
Accepted: 30-07-2022

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Effect of long term fertilizer and FYM application on soil potassium fractions in a Vertisol under soybean-wheat cropping system

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Abstract
The present study was conducted during 2019-20 at the Research Farm of the Department of Soil Science, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India to study the various potassium fractions from 48-year-old long term fertilizer experiment on a Vertisol under soybean–wheat cropping system. The experiment consists of ten treatments i.e. T_1 50% NPK, T_2 100% NPK, T_3 150% NPK, T_4 100% NPK + HW, T_5 100% NPK + Zn, T_6 100% NP, T_7 100% N, T_8 100% NPK+FYM, T_9 100% NPK–S and T_{10} control with four replications in a randomized block design. The findings showed that applications of inorganic fertilizers with or without organic manure significantly increased the organic carbon, available potassium and different K fractions *i.e.* water soluble-K, exchangeable-K, non-exchangeable-K, lattice-K and total-K as compared to control plot and without K input (100% NP & 100% N alone) treatments. Among the various K fractions lattice K was dominant K fraction. The highest values of these fractions were found in 100% NPK + 5 t FYM ha^{-1} treatment. While the lowest values were observed in control plot. The relative contents of these fractions were in order: lattice-K > non-exchangeable K > exchangeable K > water soluble K.

Keywords: LTFE, inorganic fertilizers, organic manure, potassium fractions, Vertisols

Introduction
Potassium (K) is one of the third most important macronutrients in soils which are required relatively larger amounts for plant growth. There are four different fractions of potassium *viz.*, water solution K, exchangeable K, non-exchangeable K and mineral or structural K exist in soil which are in a state of dynamic equilibrium with each other (Johnston and Goulding, 1990) [8]. Potassium is considered the most dynamic nutrient and have different functions in plant metabolism. Generally, the total potassium are large in reserve content, but only small quantities of them are instantly or slowly available to plants. The supply of crop with potassium is considered a complex phenomenon including various fractions of potassium in the soil. The amount of potassium in soils or its fraction mainly depends on the mineralogical composition of the parent material, degree of weathering, and the mechanical composition of soil. The different forms of potassium and their relative proportion in soils show a significant relationship among each other. Long term fertilizer experiment gives the valuable information on effect of continuous application of different levels of fertilizer nutrients alone and in combination with and without organic manure under intensive cropping on soil fertility and crop productivity. In continuous cropping, use of imbalance nutrients (N or NP alone) or without K application through inorganic fertilizers cannot sustain the desired level of crop production (Dubey *et al.*, 2016; Suman *et al.*, 2018) [3, 20]. Therefore, the long-term fertilizer experiment provides very good opportunity to address the issue. Keeping this in view, a study on various K fractions was planned in a 48 years old long term fertilizer experiment with soybean–wheat cropping system on a Vertisol of Jabalpur (M.P.) – India.

Materials and Methods
The ICAR funded All India Coordinated Research Project on Long Term Fertilizer Experiment was initiated in the year 1970 at the Department of Soil Science, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (INDIA). The soils of the experimental field is a medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic Haplustert and had the soil pH 7.6, electrical conductivity 0.18 dS m^{-1} (1: 2.5 soil:

water ratio), soil organic carbon 5.7 g kg^{-1}, available N 193 kg ha^{-1}, available P 7.6 kg ha^{-1}, available K 370 kg ha^{-1} and available S 15.6 kg ha^{-1}, respectively. The textural class of soil is clay. The experiment included 10 treatments *viz.*, T_1 - 50% NPK, T_2 - 100% NPK, T_3 - 150% NPK, T_4 - 100% NPK + Hand Weeding, T_5 - 100% NPK + Zn, T_6 - 100% NP, T_7 - 100% N, T_8 - 100% NPK + 5 t FYM ha^{-1}, T_9 - 100% NPK – S (Sulphur-free) and T_{10} - control, each replicated four times in a randomized block design. The recommended N, P and K dose, based on initial soil test value was 20 kg N, 80 kg P_2O_5 and 20 kg K_2O ha^{-1} for soybean crop and 120 kg N, 80 kg P_2O_5 and 40 kg K_2O ha^{-1} for wheat. The sources of N, P and K used were urea, single superphosphate and muriate of potash. In sulphur-free treatment (T_9), diammonium phosphate (DAP) was used instead of SSP as source of P. The zinc application @ 20 kg ZnSO4 ha^{-1} in alternate years to wheat crop was followed till 1987. Due to high build-up of Zn, its addition is discontinued till date. Farmyard manure was applied @ 5 t ha^{-1} year^{-1} only to soybean crop during kharif season. In 100% NPK + HW treatment, weeding was done manually, whereas in other treatments chemical weed control (herbicide) was followed. All packages of practices were followed to raise soybean and wheat crops as per recommendations.

For the different potassium fractionation studies soil samples were collected after harvest of wheat crop from 0-20 cm depths in the 48th cropping year (2019-20) and were analyzed for the different soil potassium fractions determined by flame photometer. The water soluble K was estimated in 1:5 (soil: water suspension) as described by Black (1965) [2], exchangeable-K was extracted by neutral ammonium acetate (1 *N*) extraction in 1:5 ratio. Non-exchangeable-K was estimated by boiling soil with 1*N* HNO_3 extractable K in 1:10 (soil: acid suspension) for 10 minutes as described by Black (1965) [2]. For the total-K determination, soil was digested with hydrofluoric (48%) and perchloric (70-72%) acid in platinum crucible by the method outlined by Black (1965) [2] and estimated in solution after digestion. Lattice-K was estimated by difference between total-K and sum of water soluble, exchangeable and non-exchangeable K. The data generated on soil analysis was statistically analyzed to draw suitable inference as per standard method described by Panse and Sukhatme (1954) [12].

Results and Discussion

Basic Soil Properties (pH, EC and Organic Carbon)

The basic soil properties (pH, EC and organic carbon) are presented in Table 1. The soil pH values (7.38 to 7.60) showed considerable variation at different treatment levels. There were no significant differences could be noticed with soil reaction (pH) due to different treatment of fertilizers and manure (Table 1). The soil pH did not significantly show any visible trend in all the treatment after harvest of the crop. The highest pH value 7.60 was recorded in 100% NPK + FYM treatment and lowest value 7.38 in control plot. This could be due to the high buffering capacity of the soil and presence of appreciable content of free calcium carbonate (Sharma *et al.*, 2013) [18]. Similarly soil EC value was also found to be no changed over initial which ranged between 0.15 to 0.19 dSm^{-1}. It was found that imposition of various doses of fertilizers and manure did not affect significantly to electrical conductivity of soil in a Vertisol (Keram *et al.*, 2014) [9]. The continuous use of inorganic fertilizers over a long period of time had no marked influence on EC of the soil and conjoint use of FYM and fertilizer might cause meager change which could be due to addition of organic manure which increased the buffering capacity of the soil reported by Nagwanshi *et al.*, 2018) [11]; Gupta *et al.*, (2019) [7]; Dwivedi and Dwivedi (2015) [5].

The organic carbon content significantly increased with increasing levels of fertilizer application (Table 1). The lowest value was noted in control (5.6 g kg^{-1}) which was increased to 6.9, 8.0 and 9.1 g kg^{-1} due to application of recommended dose of 50% NPK, 100% NPK, and 150% NPK respectively. However, the highest value (9.2 g kg^{-1}) was recorded with 100% NPK+FYM treatment. This increase in organic carbon content is due to increase in productivity which resulted incorporation of larger residual biomass through root, leaves, stubble and Rhizo-deposition (Singh *et al*, 2012) [19]. The highest increase in organic carbon content was recorded on incorporation of FYM which is due to addition of additional carbon through FYM and larger productivity. Patel *et al.*, (2018) [14] reported that integration of FYM with fertilizer built up soil organic carbon and also (Dwivedi and Rawat, 2013; Meshram *et al.*, 2018) [4, 10] observed that application of FYM with fertilizer maintained soil health which in turn helped in sustaining the productivity (Panwar *et al.*, 2017; Bairwa *et al.*, 2021 and Dwivedi *et al.*, 2016) [13, 1, 6].

Available Potassium

The data of available K indicated a declining trend (228 to 335 kg ha^{-1}) from its initial level (370 kg ha^{-1}) which indicates considerable mining of available soil K after 48 years of soybean – wheat intensive cropping (Table 1). The maximum decline was observed in case of control followed by 100% N alone; the magnitude of decline decreased with increasing levels of NPK application. Among the inorganic fertilizers, continuous application of N or NP had depressive effect on available K content of the soil which may be due to nutrient imbalance in the soil. Continuous omission of K in crop nutrition caused mining of its native pools that caused reduction in the crop yields (Thakur *et al.*, 2011 and Pathariya *et al.*, 2022) [23, 15]. However, the highest available K status of soil found associated with 100% NPK+FYM followed by 150% NPK treatments. The application of organic manure may have caused reduction in K fixation and consequentially increased K content due to interaction of organic matter with clay besides the direct addition to the available K pools of soil (Sawarkar *et al.* 2015) [17].

Table 1: Effect of long term nutrient management on basic soil properties and available potassium

Treatments	Soil pH	EC (dSm^{-1})	Organic Carbon (g kg^{-1})	Available K (kg ha^{-1})
T_1 = 50% NPK	7.55	0.18	6.9	253
T_2 = 100% NPK	7.50	0.18	8.0	284
T_3 = 150% NPK	7.48	0.19	9.1	326
T_4 = 100% NPK+ HW	7.55	0.17	7.9	292
T_5 = 100% NPK + Zn	7.58	0.16	7.5	297

T_6 = 100% NP	7.53	0.17	7.1	249
T_7 = 100% N	7.55	0.17	6.4	242
T_8 = 100% NPK + FYM	7.60	0.15	9.2	335
T_9 = 100% NPK (– S)	7.53	0.18	7.7	288
T_{10} = Control	7.38	0.15	5.6	228
CD (P=0.05)	NS	NS	0.81	7.67
Initial Value (1972)	7.60	0.18	5.7	370

Potassium Fractionations in a Vertisol

The data pertaining to different K fractions are presented in table 2 and illustrated in figure 1 found that the after forty-eight-year continuous application of inorganic fertilizers alone and/or in combination with organic manure enhanced the different K fractions in a Vertisol. The relative contents of these fractions were in order: Total K > Lattice K > Non-Exchangeable K > Exchangeable K > Water Soluble K (Figure 2). The findings of the present investigation on various K fractions are discussed in the following sub heads:

Water Soluble Potassium

The effect of long term continuous fertilizer and manure application in different treatment plots are presented in table 2 and indicated that the water soluble-K contents increased successively with an increment of dose of fertilizer from 50% NPK, 100% NPK and 150% NPK treatments (21.2, 22.1 and 23.0 mg kg^{-1}, respectively). The highest value of water soluble K was found in 100% NPK + FYM (24.6 mg kg^{-1}), followed by 150% NPK treatments. While, the lowest content of water soluble-K was confined in 100% NP (15.3 mg kg^{-1}) followed by 100% N (15.7 mg kg^{-1}). The result revealed that the highest water soluble K content was observed in 100% NPK + FYM plots. There was a further increase in water soluble-K under 100% NPK+FYM amended plots over the NPK treated plot. Such an increase in the content of water soluble-K might be due to addition of organic material as reported earlier (Sawarkar *et al.* 2013) [16].

Table 2: Effect of long term nutrient management on soil potassium fractions (mg kg^{-1})

Treatments	WS-K	Exch.-K	Non-Excha-K	Lattice-K	Total-K
T_1 = 50% NPK	21.2	107.0	765	3883	4775
T_2 = 100% NPK	22.1	119.1	779	3951	4871
T_3 = 150% NPK	23.0	119.6	820	4258	5220
T_4 = 100% NPK+ HW	20.5	115.3	770	3949	4854
T_5 = 100% NPK + Zn	19.8	112.4	762	3980	4873
T_6 = 100% NP	15.3	82.4	728	3715	4544
T_7 = 100% N	15.7	85.7	733	3737	4572
T_8 = 100% NPK + FYM	24.6	122.8	863	4322	5335
T_9 = 100% NPK (– S)	19.1	115.1	752	4015	4923
T_{10} = Control	16.3	90.1	737	3804	4647
CD (P=0.05)	5.6	5.9	23.8	219	185

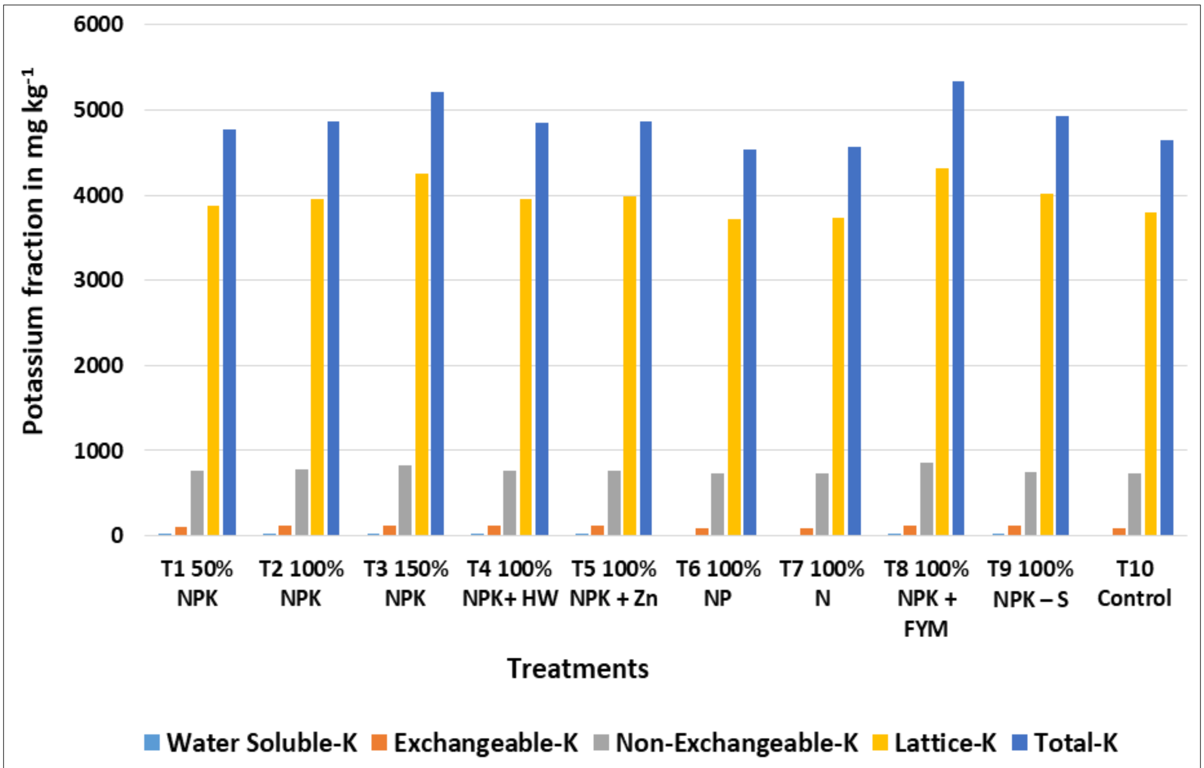

Fig 1: Effect of long term nutrient management on soil potassium fractions

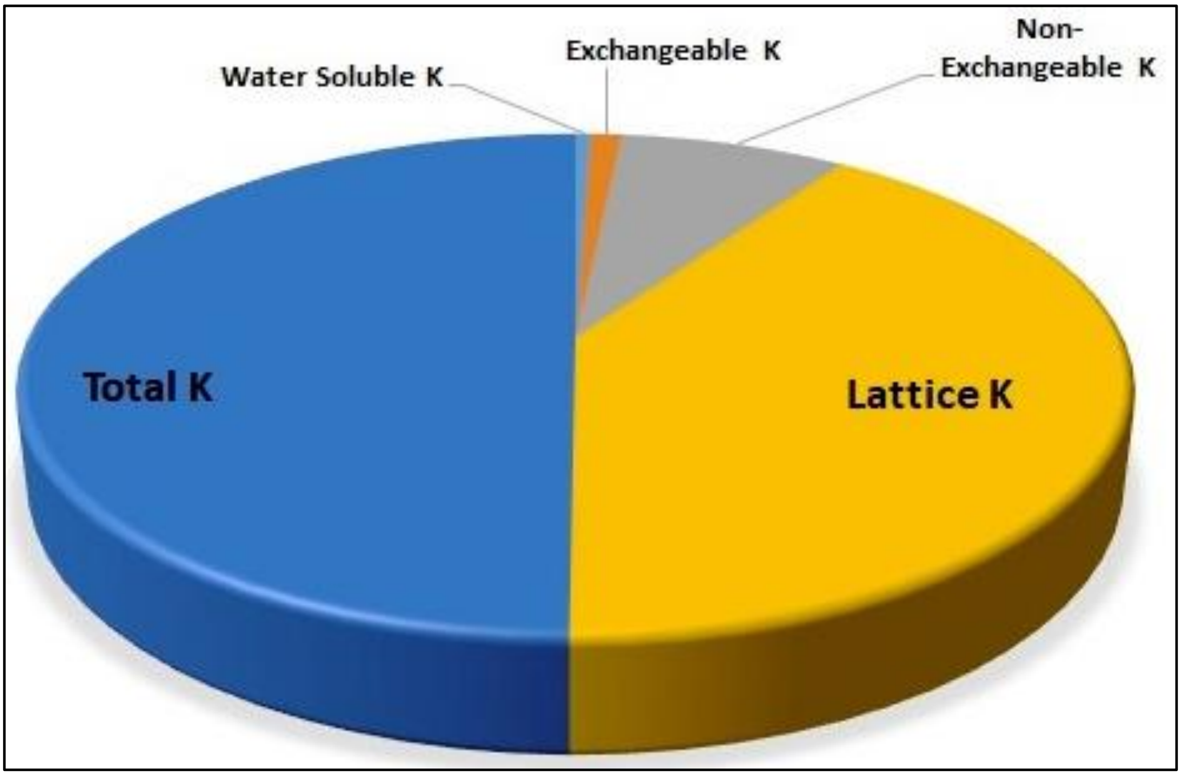

Fig 2: The order of K fractions in Vertisols

Exchangeable Potassium

The data of exchangeable K (Table 2 and Figure 1) revealed that after 48-years continuous cropping and fertilization (organic and inorganic) showed significant change in exchangeable K. The Exch-K contents ranged between 82.4 to 122.8 mg kg^{-1} and the highest content was noticed in 100% NPK+FYM (122.8 mg kg^{-1}) treatment followed by 150% NPK (119.6 mg kg^{-1}) treatment. The treatment 100% NPK, 100% NPK+ HW, 100% NPK + Zn and 100% NPK – S show at par value. However, the lowest content was found in 100% NP (82.4 mg kg^{-1}) followed by 100% N alone (85.7) and control plot (90.1 mg kg^{-1}). Further, results indicated that the higher amounts of exchangeable- K in the FYM treated plots over the years may be due to the fact that FYM addition could increase the CEC of soil which was responsible for holding more amount of exchangeable-K and helped in the release of exchangeable-K from non-exchangeable pool (Sawarkar *et al.*, 2015 and Pathariya *et al.*, 2022) [17, 15].

Non-Exchangeable Potassium

Result revealed that the maximum non- exchangeable-K (Table 2 and Figure 1) form was observed in 100% NPK + FYM (863 mg kg^{-1}) followed by 150% NPK (820 mg kg^{-1}), while the minimum content of non-exchangeable-K was found in 100% NP (728 mg kg^{-1}) followed by 100% N alone (733 mg kg^{-1}) and in control it was found to be 737 mg kg^{-1}. The treatment 100% NPK - S, 100% NPK + Zn and 100% NPK+ HW show at par result values of 752 mg kg^{-1}, 762 mg kg^{-1} and 770 mg kg^{-1}, respectively. Similar findings were also reported by Sawarkar *et al.* (2013) [16].

Lattice Potassium

The data lattice- K contents are presented in Table 2 and indicated that the lattice- K contents successively increased with the increasing fertilizer doses from 50% NPK (3883 mg kg^{-1}), 100% NPK (3951 mg kg^{-1}) and 150% NPK (4286 mg kg^{-1}). Further, the highest content was observed in 100% NPK + FYM treatment (4322 mg kg^{-1}), while, the lowest content was recorded in 100% NP treatment (3715 mg kg^{-1}). The result revealed that the highest content of lattice K due to continuous application of fertilizers and manure was recorded in 100% NPK+FYM treatment, it is due to Vertisols have high clay content and when FYM applied to clay it forms combination with organic material and sustain more lattice K in clay (Sawarkar *et al.,* 2013 and Sawarkar *et al.,* 2015) [16, 17].

Total potassium

The data of total K (Table 2 and Figure 1) revealed that the total K was varied from 4544 to 5335 mg kg^{-1}. The highest content was noticed in 100% NPK+FYM (5335 mg kg^{-1}) treatment followed by 150% NPK (5220 mg kg^{-1}) treatment. The treatment 100% NPK, 100% NPK+ HW, 100% NPK + Zn and 100% NPK – S show at par value. However, the lowest content was found in 100% NP (4544 mg kg^{-1}) followed by 100% N alone (4572 mg kg^{-1}) and control plot (4647 mg kg^{-1}). The similar findings have also been reported by Sawarkar *et al.*, 2013 and Pathariya *et al.*, 2022 [16, 15].

Conclusions

From the present investigation it may be concluded that the continuous application of inorganic fertilizers alone and/or in combination with organic manure for the last 48 years in Vertisols enhanced the various K fractions over control. Continuous cropping without fertilization proved deleterious to soil health as it resulted in a marked depletion of various K fractions in a Vertisol. The relative contents of these fractions were in order: lattice-K > non-exchangeable K > exchangeable K > water soluble K. Thus, results of the present study indicate that the depleting K reserves even at its optimal application rates point towards a relook at the existing recommendation for soybean and wheat crops.

Acknowledgement
Authors greatly acknowledge, ICAR funded project on AICRP – LTFE, Department of Soil Science, J.N.K.V.V., Jabalpur (Madhya Pradesh), to provide all necessary facilities for conduction of research trail.

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