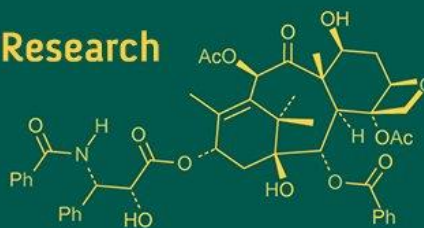


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(5): 563-566
www.biochemjournal.com
Received: 25-02-2026
Accepted: 29-03-2026

Ravindra Kumar Rekwar
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

Vinod Kumar Sharma
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

Surya Prakash Yadav
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

Chittar M Parihar
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

MC Meena
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

D Chakraborty
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

Mandira Barman
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

Kishan Kumar
Department of Agronomy,
Chandra Shekhar Azad
University of Agriculture and
Technology, Kanpur,
Uttar Pradesh, India

Corresponding Author:
Vinod Kumar Sharma
Division of Soil Science and
Agricultural Chemistry, ICAR-
Indian Agricultural Research
Institute, New Delhi, India

Dynamics of soil potassium fractions under conservation agriculture in maize-based cropping systems

Ravindra Kumar Rekwar, Vinod Kumar Sharma, Surya Prakash Yadav, Chittar M Parihar, MC Meena, D Chakraborty, Mandira Barman and Kishan Kumar

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i5Sg.8421>

Abstract

Continuous use of intensive conventional tillage has adversely affected soil health and reduced potassium (K) availability in maize-based cropping systems of the Indo-Gangetic Plains, leading to a decline in maize productivity over time. Hence, sustainable crop and soil management practices are required to restore soil fertility and maintain productivity. To evaluate the influence of conservation agriculture practices on soil K dynamics, a field experiment was conducted during 2018-2019 under an ongoing long-term study established in 2008 in the Inceptisols of the Indo-Gangetic Plains of India. The experiment was laid out in a split-plot design comprising three tillage practices in the main plots: permanent raised bed (PB), zero tillage-flat (ZT-flat), and conventional tillage-flat (CT-flat). Four maize-based cropping systems, namely maize-wheat-mungbean (MWMb), maize-chickpea-sesbania (MCS), maize-mustard-mungbean (MMuMb), and maize-maize-sesbania (MMS), were assigned to the subplots. The study revealed that PB and ZT-flat treatments significantly enhanced water-soluble, exchangeable, and non-exchangeable K fractions compared to CT-flat. Similarly, the MCS and MWMb cropping systems showed greater K availability than the other systems. Overall, the results indicate that conservation agriculture-based tillage practices along with diversified maize-based cropping systems can improve soil potassium availability and contribute to sustainable soil management.

Keywords: Tillage practices, cropping systems, K dynamics, conventional, tillage

Introduction

Maize is one of the most important cereal crops in the world after rice and wheat and contributes significantly to food and fodder production (Shiferaw *et al.*, 2011). Globally, maize is cultivated over 187 million hectares in 166 countries and accounts for nearly 40% of total grain production (FAOSTAT, 2019) [3]. In India, maize is grown on about 9.6 million hectares and plays an important role in crop diversification under different agro-climatic conditions (Dass *et al.*, 2020; Islam *et al.*, 2018) [1, 6]. Major maize-based cropping systems include maize-wheat, maize-mustard, maize-chickpea, and maize-maize. However, maize productivity in India is lower than the global average due to intensive conventional tillage and dependence on rainfed conditions, which deteriorate soil quality and increase production costs (Dass *et al.*, 2020; Nandan *et al.*, 2019; Sharma *et al.*, 2019) [1, 12, 13]. Conservation agriculture practices such as zero tillage (ZT) and permanent raised bed (PB) have emerged as sustainable alternatives for improving soil health, water use efficiency, and crop productivity (Friedrich *et al.*, 2012; Jat *et al.*, 2014) [4, 9].

Potassium (K) is an essential plant nutrient present in soil in four forms: water-soluble, exchangeable, non-exchangeable, and mineral K, which remain in dynamic equilibrium. Water-soluble and exchangeable K are readily available to plants, whereas non-exchangeable K acts as a reserve source under intensive cropping systems (Madar *et al.*, 2020) [11]. Tillage practices influence the distribution and availability of different K fractions due to soil disturbance and crop growth (Deubel *et al.*, 2011) [2].

To evaluate the effect of tillage and cropping systems on soil K dynamics, a long-term experiment initiated in 2008 was studied during 2018-19 in Inceptisols of the Indo-Gangetic Plains of India.

The experiment consisted of three tillage practices: permanent raised bed (PB), zero tillage-flat (ZT), and conventional tillage-flat (CT), along with four maize-based cropping systems, namely maize-wheat-mungbean (MWMB), maize-chickpea-sesbania (MCS), maize-mustard-mungbean (MMuMb), and maize-maize-sesbania (MMS). Soil samples collected from 0-5, 5-15, and 15-30 cm depths after harvest of summer crops were analyzed for different K fractions using standard methods described by Jackson (1967, 1973)^[7, 8], Hanway and Heidel (1952)^[5], and Wood and De Turk (1941)^[14].

Materials and Methods

Study Site Description

The experiment was conducted during 2018-19 at the research farm of ICAR-Indian Institute of Maize Research, located in New Delhi, India (28°40' N, 77°12' E; 229 m above mean sea level). The region has a semi-arid subtropical climate characterized by hot summers and cool winters. The average annual rainfall is around 707 mm, with nearly 80% received during July to September. During the study year, rainfall recorded was 854 mm in kharif, 143 mm in rabi, and 68 mm in the summer season. Temperature varied from about 40 °C during kharif to 11 °C during rabi. The experimental soil was sandy loam in texture, neutral in reaction (pH 7.8), and comprised 64.3% sand, 13.8% silt, and 22.0% clay. Initial soil properties recorded in 2008 included bulk density of 1.65 Mg m⁻³, soil organic carbon (SOC) of 4.31 g kg⁻¹, available nitrogen of 158 kg ha⁻¹, available phosphorus of 11.6 kg ha⁻¹, and available potassium of 248 kg ha⁻¹.

Experimental Design and Treatments

The study was laid out in a split-plot design with three replications. Main plot treatments consisted of three tillage and crop establishment practices: permanent raised bed with residue retention (PB), zero till flat with residue retention (ZT), and conventional till flat with residue retention (CT). Four maize-based cropping systems were assigned to subplots: maize-wheat-mungbean (MWMB), maize-chickpea-sesbania (MCS), maize-mustard-mungbean (MMuMb), and maize-maize-sesbania (MMS). Each subplot measured 16.5 m × 4.0 m. The long-term experiment was initiated in 2008, and observations for the present study were recorded during 2018-19.

Field Preparation and Crop Management

Initially, the experimental field was laser-leveled and deep tilled up to 30 cm depth to remove compact layers. Permanent beds of 67 cm width with 37 cm top width and 15 cm furrows were prepared and maintained annually using a raised-bed planter. Conventional tillage plots were prepared through disc harrowing, rotation, and tine cultivation before sowing, whereas crops in ZT plots were directly seeded using a zero-till multi-crop planter. Crop residue management was followed under conservation agriculture principles. From 2008 to 2015, nearly 30% crop residue was retained, while from 2015 onwards complete residues of mungbean and sesbania were incorporated or retained in the field. The quality protein maize hybrid HQPM-1 was sown during kharif and winter seasons using a seed rate of 20 kg ha⁻¹ with recommended crop spacing and management practices.

Collected soil samples were air-dried, ground, and processed for the determination of different potassium (K) fractions. Water-soluble K was extracted using a soil-to-water ratio of 1:5 following the procedure described by Jackson (1973)^[8]. Exchangeable K was determined by shaking the soil samples with neutral normal ammonium acetate solution (1:5 ratio) for 5 minutes as outlined by Hanway and Heidel (1952)^[5]. Boiling 1N HNO₃ in a 1:10 soil-to-solution ratio was used to extract HNO₃-soluble K according to the method of Wood and DeTurk (1941)^[14]. Potassium concentration in all extracts was measured using a flame photometer. Non-exchangeable K was calculated by subtracting available K from HNO₃-extractable K.

Results and Discussion

Tillage and crop establishment methods significantly affected different potassium (K) fractions at 0-5, 5-15, and 15-30 cm soil depths after eleven years of continuous experimentation. Water-soluble K (WS-K), the most readily available form of potassium for plants, was significantly higher under conservation agriculture practices compared to conventional tillage. Permanent raised bed (PB) tillage recorded the highest WS-K values of 36.1, 29.5, and 23.5 mg kg⁻¹ at 0-5, 5-15, and 15-30 cm depths, respectively, whereas the lowest values of 29.3, 24.2, and 18.0 mg kg⁻¹ were observed under conventional tillage-flat (CT-flat). Increased WS-K under PB and ZT-flat may be attributed to residue retention, reduced soil disturbance, improved soil aggregation, and enhanced mineral weathering under conservation agriculture practices. Similar findings were also reported under long-term conservation tillage systems due to better nutrient recycling and improved soil physical properties.

Cropping systems also exerted a significant influence on WS-K content. Among the cropping systems, maize-chickpea-sesbania (MCS) and maize-wheat-mungbean (MWMB) recorded significantly higher WS-K content across all soil depths, while maize-mustard-mungbean (MMuMb) showed the lowest values (28.7, 23.6, and 9.93 mg kg⁻¹ at 0-5, 5-15, and 15-30 cm depths, respectively). Inclusion of legumes such as chickpea, mungbean, and sesbania in the cropping sequence improved biomass addition, organic matter accumulation, and biological activity, which enhanced nutrient release and K availability in soil.

Exchangeable K, which serves as the immediately available K pool for crop uptake, was also significantly influenced by tillage and cropping systems. Higher exchangeable K was observed under PB and ZT-flat systems due to increased cation exchange capacity and improved retention of nutrients under conservation agriculture practices (Deubel *et al.*, 2011; Sharma *et al.*, 2009)^[2, 13]. Continuous residue retention and minimum soil disturbance under PB and ZT-flat enhanced soil organic carbon and reduced nutrient losses, thereby maintaining a greater amount of exchangeable K compared to CT-flat. These findings are in close agreement with the observations of Lakaria *et al.* (2012). Long-term conservation agriculture practices also significantly increased non-exchangeable K content in soil. Under PB tillage, non-exchangeable K increased from 1259 to 1514 mg kg⁻¹ at 0-5 cm depth, from 1177 to 1436 mg kg⁻¹ at 5-15 cm depth, and from 1128 to 1298 mg kg⁻¹ at 15-30 cm depth compared to CT-flat. The PB and ZT-flat treatments remained statistically at par and superior to CT-flat at all soil depths. Among the cropping systems, MCS

recorded the highest non-exchangeable K followed by MWMb and MMS. This could be due to better root growth and higher biomass contribution from legumes, which accelerated residue decomposition and released organic acids and carbon dioxide that facilitated the weathering of soil minerals and release of K into soil solution (Deubel *et al.*, 2011) [2]. Chickpea roots are also known to absorb and recycle greater amounts of K, contributing to improved K dynamics in soil (Katyal *et al.*, 1987) [10]. The distribution of K fractions clearly indicated nutrient stratification under conservation agriculture practices, with greater accumulation of available K forms in surface soil layers due to residue retention and minimal soil inversion. In contrast, conventional tillage resulted in comparatively lower K fractions because of intensive soil disturbance and faster depletion of nutrients. Total K content, however, did not vary significantly among tillage practices and cropping systems, suggesting that long-term cultivation practices had limited influence on total soil K reserves, which are largely governed by soil mineralogy. Moreover, the interaction effect between tillage practices and cropping systems on K fractions was non-significant, indicating that the independent effects of tillage and cropping systems were more dominant than their combined effects on soil K dynamics.

The study indicated that permanent raised bed (PB) and zero tillage-flat (ZT-flat) practices, along with maize-chickpea-sesbania (MCS) and maize-wheat-mungbean (MWMb) cropping systems, were the most effective in enhancing different forms of soil potassium in the Indo-Gangetic Plains. These conservation agriculture practices improved soil nutrient availability, created a favorable crop growth environment, and contributed to sustaining maize productivity over the long term.

Table 1: Long-term effect of tillage practices and diversified cropping systems on water-soluble potassium (mg kg^{-1}) in soil at 0–5 cm and 5–15 cm layer under maize-based cropping systems.

Treatments	0–5 cm	5–15 cm
Tillage		
PB	36.1 ^a	29.5 ^a
ZT-flat	32.5 ^b	27.2 ^b
CT-flat	29.3 ^b	24.2 ^b
LSD (0.05)	4.69	3.94
Cropping system		
MWMb	34.9 ^a	28.8 ^a
MCS	36.4 ^a	30.3 ^a
MMuMb	28.7 ^b	23.6 ^b
MMS	30.6 ^b	25.1 ^b
LSD (0.05)	2.18	1.68

Table 2: Long-term effect of tillage practices and diversified cropping systems on exchangeable potassium (mg kg^{-1}) in soil at 0–5 cm and 5–15 cm layer under maize-based cropping systems

Treatments	0–5 cm	5–15 cm
Tillage		
PB	113 ^a	101 ^a
ZT-flat	109 ^a	99.4 ^a
CT-flat	95.0 ^b	87.4 ^b
LSD (0.05)	12.7	11.1
Cropping system		
MWMb	113 ^a	103 ^a
MCS	120 ^a	107 ^a
MMuMb	91.0 ^b	83.4 ^b
MMS	91.0 ^b	83.4 ^b
LSD (0.05)	9.33	7.12

Table 3: Long-term effect of tillage practices and diversified cropping systems on non-exchangeable potassium (mg kg^{-1}) in soil at 0–5 cm and 5–15 cm layer under maize-based cropping systems.

Treatments	0–5 cm	5–15 cm
Tillage		
PB	1514 ^a	1436 ^a
ZT-flat	1438 ^a	1349 ^a
CT-flat	1259 ^b	1177 ^b
LSD (0.05)	166	141
Cropping system		
MWMb	1453 ^a	1374 ^a
MCS	1548 ^a	1472 ^a
MMuMb	1350 ^b	1258 ^b
MMS	1262 ^b	1178 ^b
LSD (0.05)	97.9	104

References

- Dass S, Jat SL, Chaikkappa GK, Parihar CM, Chaudhary M, Kumar R. Crop diversification to ensure and promote sustainable natural resources use. In: Souvenir and Book of Abstracts of National Seminar on “Maize for Crop Diversification under Changing Climatic Scenario”; Ludhiana, Punjab, India. 2020; p. 28-31.
- Deubel A, Hofmann B, Orzessek D. Long-term effects of tillage on stratification and plant availability of phosphate and potassium in a loess chernozem. *Soil Tillage Res.* 2011;117:85-92.
- FAOSTAT. Food and Agriculture Organization Statistics Database. Food and Agriculture Organization of the United Nations; 2019.
- Friedrich T, Derpsch R, Kassam A. Overview of the global spread of conservation agriculture. *Field Actions Sci Rep.* 2012;Spec Issue 6:1-7.
- Hanway JJ, Heidel H. Soil analysis methods as used in the Iowa State College Soil Testing Laboratory. *Iowa State Coll Agric Bull.* 1952;57:1-31.
- Islam M, Nath LK, Samajdar T. Sustainable diversification of maize (*Zea mays* L.)-legume cropping systems for productivity, profitability and resource-use efficiency in West Garo Hills of Meghalaya, India. *Legume Res.* 2020;43:427-431.
- Jackson ML. Soil chemical analysis: Advanced course. Madison: Department of Soils, University of Wisconsin; 1967.
- Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt Ltd; 1973.
- Jat RK, Sapkota TB, Singh RG, Jat ML, Kumar M, Gupta RK. Seven years of conservation agriculture in a rice-wheat rotation of Eastern Gangetic Plains of South Asia: Yield trends and economic profitability. *Field Crops Res.* 2014;164:199-210.
- Katyal JC. Influence of organic matter on the chemical and electrochemical characteristics of flooded soils. *Soil Biol Biochem.* 1987;9:259-266.
- Madar R, Singh YV, Meena MC, Das TK, Paramesh V, Al-Mana FA, *et al.* Residue and potassium management strategies to improve crop productivity, potassium mobilization, and assimilation under zero-till maize-wheat cropping system. *Agriculture.* 2020;10(9):401.
- Nandan R, Singh V, Singh SS, Kumar V, Hazra KK, Nath CP, *et al.* Impact of conservation tillage in rice-based cropping systems on soil aggregation, carbon pools and nutrients. *Geoderma.* 2019;340:104-114.

13. Sharma S, Padbhushan R, Kumar U. Integrated nutrient management in rice-wheat cropping system: An evidence on sustainability in the Indian subcontinent through meta-analysis. *Agronomy*. 2019;9(2):71.
14. Wood LK, DeTurk EE. The absorption of potassium in soils in non-replaceable forms. *Soil Sci Soc Am Proc*. 1941;5:152-161.