Effect of potassium on soil conservation and productivity of maize/cowpea based crop rotations in the north-west Indian Himalayas

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Abstract: Plots under conservation tillage may require higher amount of potassium (K) application for augmenting productivity due to its stratification in upper soil layers, thereby reducing K supplying capacity in a medium or long-term period. To test this hypothesis, a field experiment was performed in 2002-2003 and 2006-2007 to study the effect of K and several crop rotations on yield, water productivity, carbon sequestration, grain quality, soil K status and economic benefits derived in maize (Zea mays L)/cowpea (Vigna sinensis L.) based cropping system under minimum tillage (MT). All crops recorded higher grain yield with a higher dose of K (120 kg K2O ha−1) than recommended K (40 kg K2O ha−1). The five years’ average yield data showed that higher K application (120 kg K2O ha−1) produced 16.4% (P<0.05) more maize equivalent yield. Cowpea based rotation yielded 14.2% (P<0.05) higher production than maize based rotation. The maximum enhancement was found in cowpea-mustard rotation. Relationship between yield and sustainable indices revealed that only agronomic efficiency of fertilizer input was significantly correlated with yield. Similarly, higher doses of K application not only increased the water use efficiency (WUE) of all crops, but also reduced runoff and soil loss by 16.5% and 15.8% under maize and 23.3% and 19.7% under cowpea cover, respectively. This study also revealed that on an average 16.5% of left over carbon input contributed to soil organic carbon (SOC). Here, cowpea based rotation with the higher K application increased carbon sequestration in soil. Potassium fertilization also significantly improved the nutritional value of harvested grain by increasing the protein content for maize (by 9.5%) and cowpea (by 10.6%). The oil content in mustard increased by 5.0% and 6.0% after maize and cowpea, respectively. Net return also increased with the application of the higher K than recommended K and the trend was similar to yield. Hence, the present study demonstrated the potential yield and profit gains along with resource conservation in the Indian Himalayas due to annual additions of higher amount of K than the recommended dose. The impact of high K application was maximum in the cowpea-mustard rotation.

Keywords: Potassium application; Crop rotations; Minimum tillage water balance; Runoff and soil loss; Carbon sequestration; Soil K status; Net return

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Introduction

Among the major nutrients, K is considered as a quality dependent element because of its important role in grain shape, size, colour, shelf life, increasing protein content in cereals, pulses and oil content in oil seed crops (Tiwari et al. 2002). Several previous studies executed in ago-ecological region 14 of the north-west Indian Himalaya reported potassium (K) deficiency, even with recommended K application, in dominant cropping sequences of intensive rainfed farming (Ghosh et al. 1998; Bhattacharya et al. 2006). Hill and mountain agriculture evolved over centuries with the application of farmyard manure (FYM) ranging from 5-15 tonnes ha\(^{-1}\) along with inorganic NPK application hardly exceeds 20.0 kg ha\(^{-1}\) as against national average of 115.0 kg ha\(^{-1}\) yr\(^{-1}\) of which K fertilizer application is virtually nil. The available K status in the soils of this region is low to medium in textural class of sandy loam to silty clay loam with dominant muscovite mica mineral (Ghosh and Hasan 1976). Higher productivity of hill and mountain ecosystem needs application of higher doses of K than the recommended doses, because of less release rate than removal (Ghosh and Singh 2001) besides losses of about 10%-25% of applied K in sediment and runoff water (Sharda and Singh 2004).

Maize and cowpea based crop rotations are the dominant cropping systems in sloping land of north-west Indian Himalayas. Extreme imbalance fertilization of N: P: K 15.5:5.0:1 in this region against ideal consumption ratio of 4:2:1 exhibit lower water use efficiency (WUE) of most of the cropping system under rainfed conditions. Balanced fertilizer application not only increases carbon sequestration in soil, but also enhances water use by the crops with higher soil water retention (Ghosh et al. 2007) by reducing runoff and soil loss. Tony and Janovick (2001) reported that long-term minimum tillage (MT) fields required higher amount of K application to maintain K supplying capacity in subsurface layer, because of its immobile nature which causes stratification in the surface layer. Soil test crop response revealed K response up to 135 kg ha\(^{-1}\) on dominant cropping system of rice-wheat, maize-wheat and soybean–wheat in this agro ecological region (Singh et al. 2002). Of the tillage practices, MT is recommended in this region owing to its beneficial effects of productivity and soil and water conservation (Bhattacharya et al. 2004). Soil conservation, water productivity and quality (protein and oil content) enhancement are the priority issues for increasing food and nutritional security in this region. But information on K application higher than the recommended K under MT and its subsequent benefit to soil conservation, quality of crops and resource conservation are lacking. The primary objective of this study was to examine the K application and crop rotations impact on yield, water productivity, humification rate constant of added C, grain quality, soil K status and benefit of K application under MT in maize/cowpea based rotations.

1 Material and Methods

1.1 Site details and soil analysis

The experiment was initiated in 2002 on field size runoff plots that were under maize-wheat rotation with recommended K (40 kg K\(_2\)O ha\(^{-1}\)) for long time with conventional tillage (CT) at the CSWRT&I Research Farm, Selakui, Dehradun, India located at 30°20’40”N latitude, 77°52’12”E longitude and 516.5 m above mean sea level. Soil samples (0-15 cm) were collected before the execution of treatments and analyzed for pH by pH meter in 1:2.5 soil: water suspension (Jackson 1973), organic carbon by the method of Walkley and Black (1934), available N by standard procedure using a FOSS Tecator (Model 2200), available P following the method of Olsen et al. (1954) and available K extracted by 1 N NH4OAC using a flame photometer (Hanway and Hidel 1984). The bulk density of soils was measured using a core sampler. The soil characteristics at the start of the experiment were: silty loam (with clay 12.5% and silt 38.5%) in texture, soil pH 5.8, oxidizable soil organic carbon 6.4 g kg\(^{-1}\), alkaline permanganate oxidizable N 280.5 kg ha\(^{-1}\), 0.5 M NaHCO\(_3\) extractable- P 20.1 kg ha\(^{-1}\) and 1 N NH\(_4\)OAC- K 104 kg ha\(^{-1}\), CEC – 9.72 c mol (p+)/kg, CaCO\(_3\) – nil and porosity 51.0%. Bulk density values were: 1.36, 1.39, 1.44 Mg m\(^{-3}\) for 0-15, 15 – 30 and 30-45 cm soil depths, respectively. The soils of the experimental site were classified as Typic