Interventions to Improve Potassium Availability in light textured Alfisols supporting FCV tobacco

ABSTRACT

Aim: To investigate the effect of soil inversion in conjugation with combined application of SOP with cheaper potassium supplements like tobacco stalk biochar (TS biochar) and barn wood ash (BWA) on potassium fractions in light textured sandy loam soils supporting FCV tobacco.

Study Design: Split plot design

Place and Duration of Study: ICAR-CTRI RS, Jeelugumilli, Andhra Pradesh, India.

Methodology: A field experiment was conducted with two main plots and seven sub-plots which are replicated thrice. The two main plots are consisting of soil inversion practices i.e., (i) soil inversion with MB plough (ii) without soil inversion and seven sub plot treatments *viz.,* one without potassium, two sulphate of potash treatments at the rate of 100 % and 75 % of recommended dose of fertilizer (RDF), two TS Biochar treatments along with SOP and two BWA treatments along with SOP at the rate of 100 % and 75 % RDK each. Soil Samples were collected at 60 DAP to study various potassium fractions in the soil.

Results: Results indicated that mean water-soluble potassium has been increased from 17.90 mg kg^{-1} in without soil inversion to 27.61 mg kg^{-1} in with soil inversion respectively and among the potassium input management practices highest mean water-soluble potassium of 26.60 mg kg^{-1} was observed in S_4 [100% K through SOP + Tobacco Stalk Biochar (1:1)] treated plots which is on par with S_2 [100% K through SOP]. An increase in soil mean exchangeable potassium from 40.07 mg kg^{-1} without soil inversion to 58.79 mg kg^{-1} with soil inversion was observed and among the potassium input management practices the highest available potassium was observed in S_4 [100% K through SOP + Tobacco Stalk Biochar (1:1)] treated plots with a mean value of 60.14 mg kg^{-1} which was on par with S_6 [100% K through SOP + Barn wood ash (1:1)].

Conclusion: Both soil inversion and potassium input management has improved the water soluble, exhangeable K in soil while no much influence on non-exchangeable and total K were observed.

Keywords: K fractions, water soluble K, exchangeable K, non-exchangeable K and Total K, TS Biochar, Barn Wood Ash

1.Introduction

Potassium (K) is the key nutrient required in large quantity for optimum yield and quality of FCV tobacco. Tobacco is known as luxury user of potassium. Flue cured tobacco (FCV) produced under irrigated conditions in Northern Light Soils of Andhra Pradesh is considered semi-flavorful and quality tobacco [7]. Among various tobacco types, the export quality flue-cured tobacco requires fairly higher dose of potassium. On an average, a tobacco crop yielding 2000 kg ha^{-1} takes up 100 to 120 kg K ha^{-1}. Alfisols supporting FCV tobacco under NLS region have low native K fertility and require liberal input of K. As the FCV tobacco is sensitive to chloride, the source of potassium used is sulphate of potash (SOP) instead of muriate of potash. The sulphate of potash is very costly fertilizer as its availability totally depends on imports from foreign countries. The SOP market has been greatly impacted by the outbreak of COVID-19 in several parts of the world since the pandemic began. Potassium (K) can be easily lost by the leaching process. The low cation exchange capacity of these sandy loam soils of the NLS associated with the highly soluble sources of potassium (K), may lead to high losses through leaching. In periods of high rainfall intensity or excessive irrigation, there may be percolation of water into the profile, which favors the downward movement of potassium ions, thus acts as one of the major factors for loss of potassium to lower depths and also the conventional tillage practices using rotavator and cultivator which are usually followed by tobacco farmers in NLS region of Andhra, results in increasing bulk density due reduced pore spaces, leading to formation of perched water table in plough layer (22.5 cm), thus restricting the root growth and water movement. In this scenario, soil inversion with mould board plough to a depth of 25 cm in fields will promote root growth and also facilitates the plant to take up the available nutrients especially potassium from lower depths, as sub soil will come to the top layers, so that it will minimize the K requirement through fertilizers to a certain extent. Inversion thus favors the better utilization of nutrients which in turn helps in improving the crop yield. Keeping in view of these situations field experiment was conducted to study the impact of soil inversion in conjunction with other cheaper sources of K like Tobacco stalk biochar (TS Biochar) and Barn wood Ashes (BWA) in combination with SOP on various K fractions.

2.Materials and Methods

The experiment was conducted at ICAR-CTRI, Resarch Station, Jeelugumilli with FCV tobacco variety FCJ 11 as a test crop. The experiment was laid out in split plot design with two tillage practices in main plots and three different potassium inputs SOP, TS Biochar and barn wood ash were applied at different levels in seven sub plots. The experiment was replicated thrice.

Main Plots: Tillage practices

- **M_1 With Soil Inversion**
- **M_2 Without Soil Inversion**

Sub Plots: Potassium input management

- **S_1 No K**
- **S_2 100% K through SOP**
- **S_3 75% K through SOP**
- **S_4 100% K through SOP + Tobacco Stalk Biochar (1:1)**
- **S_5 75% K through SOP + Tobacco Stalk Biochar (1:1)**
- **S_6 100% K through SOP + Barn Wood Ash (1:1)**
- **S_7 75% K through SOP + Barn Wood Ash (1:1)**

Note: Recommended dose of fertilizers for tobacco: 120-60-120 N: P_2O_5: K_2O kg ha^{-1} supplied through Ammonium sulphate, Di Ammonium phosphate and Sulphate of Potash respectively. Di Ammonium phosphate will be applied as basal. Ammonium sulphate, Sulphate of potash, physical mixture biochar and wood ashes with SOP will be applied in three splits at 10,30 and 45 days after transplanting.

Thus, there were 2 main plot treatments and 7 sub plot treatments.

Soil samples were collected 60 DAP to study the K fractions in the soils affected due to soil inversion in conjunction with different alternate sources of K.

FORMS OF POTASSIUM

Water soluble K (mg kg^{-1})

Water soluble potassium was determined in 1:10 soil: water extract as explained by [6] 2.5 g of 2 mm sieved oven dried soil was taken in a 50 ml centrifuge tubes and 25 ml of distilled water was added and the contents were shaken on a mechanical shaker for 1 hour followed by centrifugation for 10 minutes at 10000 rpm. The supernatant was filtered through Whatman No. 1 filter paper and the potassium concentration was determined using Flame photometer.

Available K (mg kg^{-1})

5g of finely ground soil was taken in 150 ml conical flask and 25 ml of 1N normal ammonium acetate (pH 7) was added and to be shaken on mechanical shaker for 5 minutes. K was determined with Flame photometer [6].

Exchangeable K (mg kg^{-1})

The exchangeable potassium was determined by deducting the water-soluble potassium from the available potassium [4].

Fixed K (mg kg^{-1})

Nitric acid soluble potassium (1N HNO_3 soluble K): The soil was extracted with 1 N HNO_3 in the ratio of 1:10 (Soil: HNO_3) and boiled for 10 minutes as per the procedure described by [15].

Non – Exchangeable K (mg kg^{-1})

The non-exchangeable potassium was determined by deducting the available potassium from fixed potassium.

Total K (mg kg^{-1})

The total K content in soil was determined by taking 0.1 grams of oven dried (at 100 ºC) soil sample into 30 ml platinum crucible and is heated on sand bath to dryness by adding few drops of water, 0.5 ml perchloric and 5 ml hydrofluoric acid (48%), the colourless substance thus obtained is dissolved completely in 5 ml of 6 N HCl by heating for 20 minutes the extract is then filtered and then the K concentration was estimated by using Flame photometer [6].

STATISTICAL ANALYSIS

The data were statistically analyzed following the analysis of variance method as described by [11]. Statistical significance was tested by applying F-test at 0.05 level of probability. Critical difference at 0.05 probability level was worked out for the effects that were significant.

3. Results and Discussion

The data related to various potassium factors like water soluble K, Available K, Exchangeable K, fixed or HNO_3 extractable K, non-exchangeable and Total K was presented below.

3.1 Water soluble K (mg kg^{-1})

The data pertaining to water soluble potassium at 60 days after planting (DAP) is presented in the table 1 and fig 1. Examination of the data reveals that the soil inversion and potassium input management practices have shown a significant effect on water soluble potassium at both surface and subsurface depths while their interaction was also significant.

Analysis of the soil samples collected at 60 DAP of tobacco crop revealed that the mean water-soluble potassium has been increased from 17.90 mg kg^{-1} without soil inversion to 27.61 mg kg^{-1} with soil inversion respectively and among the potassium input management practices highest mean water-soluble potassium of 26.60 mg kg^{-1} was observed in S_4 [100% K through SOP + Tobacco Stalk Biochar (1:1)] treated plots which is on par with S_2 [100% K through SOP].

The coarse-textured soils are usually high in water soluble K content than other potassium fractions due to their low CEC and less potassium-fixing mineral concentration [1]. In this context, the available water-soluble K in our experimental soils is also high but prone to leaching losses owing to the low CEC and high macro porosity of the experimental soils. These losses are minimized upon soil inversion with MB plough as it helps in reducing the bulk density of soil and also improve its water holding capacity and minimizing nutrient leaching loses from the soils. This is in line with the observations of [5] mouldboard ploughing has resulted in lower bulk density, improving porosity and also 11% more available water capacity compared to ring cutter tillage and non-inversion. The influence of potassium input management on water-soluble K content in soils is because with the increase in the rate of potassium application the availability of water-soluble K is enhanced due to direct addition of K^+ ions to the soil. These results were in close relationship with that of [2] The increase in water soluble K content in the biochar treated plots is due to the use of potassium rich biochar produced through high pyrolysis temperature which was in accordance with [12] that the potassium gets concentrated in the biochar with the increase in pyrolysis temperature (65ºC) and the inorganic form of K, in the organic residues and produced biochar, may be released easily into the soluble and exchangeable fractions upon addition of biochar to the soil. Even though the wood ash is a rich source of K, that K gets dissolved in water completely making it prone to leaching [9].

Table. 1 Effect of soil inversion in conjunction with potassium interventions on water soluble potassium (mg kg^{-1}) in irrigated Alfisols supporting FCV tobacco.

PIM	60 DAP (0-15 cm)		
	M_1	**M_2**	**Mean**
S_1	22.38	14.00	**18.19**
S_2	30.98	20.80	**25.89**
S_3	28.99	16.87	**22.93**
S_4	31.92	21.28	**26.60**
S_5	25.99	18.59	**22.29**
S_6	28.39	18.15	**23.27**
S_7	24.62	15.61	**20.11**
Mean	**27.61**	**17.90**	
	SEm±	**CD (*P*= .05)**	**CV %**
M	0.35	2.12	7.01
S	0.50	1.45	5.34
M x S	0.70	2.05	
S x M	0.74	2.19	

Sub Plots:

S_1 No K
S_2 100% K through SOP
S_3 75% K through SOP
S_4 100% K through SOP + Tobacco Stalk Biochar (1:1)
S_5 75% K through SOP + Tobacco Stalk Biochar (1:1)
S_6 100% K through SOP + Barn Wood Ash (1:1)
S_7 75% K through SOP + Barn Wood Ash (1:1)

Main Plots:

M_1 With Soil Inversion
M_2 Without Soil Inversion

3.2 Exchangeable K (mg kg^{-1})

In the table 2, fig 1 data related to exchangeable K in the soil at 60 days after planting of tobacco was presented. The data reveals that the soil inversion and potassium input management practices have shown a significant effect on exchangeable potassium in the soils, while their interaction was not significant. An increase in soil mean exchangeable potassium from 40.07 mg kg^{-1} without soil inversion to 58.79 mg kg^{-1} with soil inversion was observed and among the potassium input management practices the highest available potassium was observed in S_4 [100% K through SOP + Tobacco Stalk Biochar (1:1)] treated plots with a mean value of 60.14 mg kg^{-1} which was on par with S_6 [100% K through SOP + Barn wood ash (1:1)]. Soil inversion with mould board plough has resulted in increased potassium concentration due to more homogenous distribution of nutrients owing to soil inversion. [8] stated that the high surface negative charge, specific surface area and pore structure of biochar makes it a potential source for retention of K and ammonium as exchangeable fractions. While [17] observed an increase in soluble and exchangeable K upon biochar application, due to transformation of K-bearing minerals by biochar which induced the growth of K-solubilizing microorganisms. It is also supported by [10].

Table. 2 Effect of soil inversion in conjunction with potassium interventions on Exchangeable Potassium (mg kg^{-1}) in irrigated Alfisols supporting FCV tobacco

PIM	60 DAP (0-15 cm)		
	M_1	**M_2**	**Mean**
S_1	39.67	31.15	**35.41**
S_2	63.40	43.04	**53.22**
S_3	50.20	39.17	**44.69**
S_4	71.51	48.78	**60.14**
S_5	60.21	39.74	**49.97**
S_6	70.06	49.50	**59.78**
S_7	51.28	32.05	**41.66**
Mean	**58.05**	**40.49**	
	SEm±	**CD (p=0.05)**	**CV %**
M	1.54	9.36	14.31
S	1.93	5.64	9.61
M x S	2.73	7.98	
S x M	2.96	8.88	

Sub Plots:

S_1 No K
S_2 100% K through SOP
S_3 75% K through SOP
S_4 100% K through SOP + Tobacco Stalk Biochar (1:1)
S_5 75% K through SOP + Tobacco Stalk Biochar (1:1)
S_6 100% K through SOP + Barn Wood Ash (1:1)
S_7 75% K through SOP + Barn Wood Ash (1:1)

Main Plots:

M_1 With Soil Inversion
M_2 Without Soil Inversion

3.3 Non-exchangeable K (mg kg^{-1})

The data in the table 3, fig 1, revels that the soil inversion has no significant effect on non-exchangeable potassium whereas among the potassium input management practices a slight variation in the non-exchangeable K is seen but not to the significant levels. While, no significant interaction was observed in between the potassium input management practices and soil inversion with respect to non-exchangeable K. This was in accordance with the findings of [14] that no obvious effect of biochar could be observed on Non-ex-K in the Alfisol, which remained close to the initial value across treatments. Addition of K through biochar, wood ash and potassium fertilizers increase the soil solution K which gradually enters the interlayer spaces of potassium- fixing minerals, forming non exchangeable K. This fixation varies with clay content and clay mineralogy of the soils [18]. The coarse- textures soils with low CEC and potassium fixing minerals resulted in low non exchangeable K as seen in our experimental sandy loam soils.

Table. 3 Effect of soil inversion in conjunction with potassium interventions on Non-Exchangeable Potassium (mg kg^{-1}) in irrigated Alfisols supporting FCV tobacco

PIM	60 DAP (0-15 cm)		
	M_1	**M_2**	**Mean**
S_1	133.41	126.58	**129.99**
S_2	134.55	129.89	**132.22**
S_3	130.54	129.82	**130.18**
S_4	143.64	143.87	**143.75**
S_5	143.53	140.94	**142.23**
S_6	133.27	128.35	**130.81**
S_7	138.24	128.21	**133.22**
Mean	**136.74**	**132.52**	**134.63**
	SEm±	**CD (p=0.05)**	**CV %**
M	1.59	9.68	5.41
S	4.96	14.48	9.03
M x S	7.02	20.48	
S x M	6.69	19.14	

Sub Plots:

S_1 No K
S_2 100% K through SOP
S_3 75% K through SOP
S_4 100% K through SOP + Tobacco Stalk Biochar (1:1)
S_5 75% K through SOP + Tobacco Stalk Biochar (1:1)
S_6 100% K through SOP + Barn Wood Ash (1:1)
S_7 75% K through SOP + Barn Wood Ash (1:1)

Main Plots:

M_1 With Soil Inversion
M_2 Without Soil Inversion

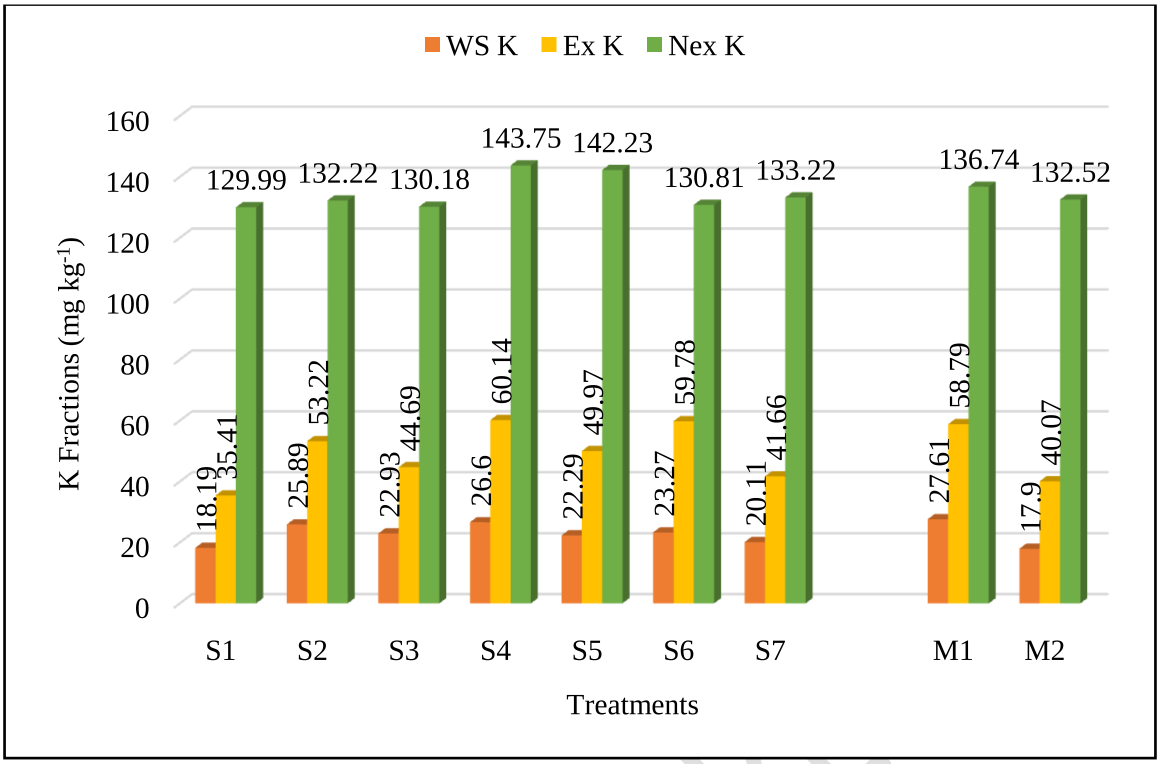

Figure 1: Effect of soil inversion in conjunction with potassium interventions on potassium fractions (mg kg^{-1}) in irrigated Alfisols supporting FCV tobacco

3.4 Total K (mg kg^{-1})

The data related to the effect of soil inversion and potassium input management practices on total potassium (mg kg^{-1}) in soil at 60 days after planting of tobacco is presented in the table 4. From the data it was clear that no significant effect of neither soil inversion nor potassium input management practices was observed in case of total soil potassium and their interaction was also not significant. Total K is the most stable form of K, nearly 90-98% of total K is present inside phyllosilicates (*e.g.*, mica) and tectosilicates (*e.g.*, feldspars) as structural K, which are mainly concentrated in silt and sand fractions [13]. [3] and [17] also reported that no significant change in Total K content of soils was observed with application of fertilizers and also biochar over a period of time.

Table. 4 Effect of soil inversion in conjunction with potassium interventions on Total Potassium (mg kg^{-1}) in irrigated Alfisols supporting FCV tobacco

PIM	60 DAP (0-15 cm)		
	M_1	**M_2**	**Mean**
S_1	5333.18	5349.85	**5341.51**
S_2	5346.51	5316.51	**5331.51**
S_3	5129.85	5383.18	**5256.51**
S_4	5449.85	5283.18	**5366.51**

S_5	5443.18	5239.85	**5341.51**
S_6	5336.51	5436.51	**5386.51**
S_7	5203.18	5289.85	**5246.51**
Mean	**5320.32**	**5328.42**	
	SEm±	**CD (p=0.05)**	**CV %**
M	81.21	494.18	6.99
S	141.08	411.78	6.49
M x S	199.52	582.35	
S x M	201.78	590.99	

Sub Plots:

S_1 No K
S_2 100% K through SOP
S_3 75% K through SOP
S_4 100% K through SOP + Tobacco Stalk Biochar (1:1)
S_5 75% K through SOP + Tobacco Stalk Biochar (1:1)
S_6 100% K through SOP + Barn Wood Ash (1:1)
S_7 75% K through SOP + Barn Wood Ash (1:1)

Main Plots:

M_1 With Soil Inversion
M_2 Without Soil Inversion

4. CONCLUSION

It is concluded that soil inversion and potassium input management practices *Viz.,* TS Biochar along with SOP and BWA along with SOP have shown a significant effect on water soluble potassium, exchangeable potassium in the soils. Whereas non-exchangeable K and Total K were not affected. Soil inversion with mould board plough facilitated increased potassium concentration due to more homogenous distribution of nutrients owing to improvement in soil potassium fractions.

REFERENCES

1. Ghiri MN, Abtahi A, Owliaie H, Hashemi SS, Koohkan H. Factors affecting potassium pools distribution in calcareous soils of southern Iran. Arid land research and management. 2011;25(4):313-27.
2. Afroz, D, Abedin Mian, MJ. Hossain MA and Rashid ES. 2009. Effects of split application of potassium on yield and potassium balance for boro rice (BRRI dhan 29). International Journal of Biological Research, 7: 73-79
3. Habib F, Javid S, Saleem I, Ehsan S, Ahmad ZA. Potassium dynamics in soil under long term regimes of organic and inorganic fertilizer application. Soil & Environment. 2014;33(2).
4. Hanway JJ and Heidel H. Soil analysis methods as used in Iowa state college soil testing laboratory. *Iowa Agriculture*. 1952; 57: 1-31.

5. Hofbauer M, Bloch R, Bachinger J, Gerke HH. Effects of shallow non-inversion tillage on sandy loam soil properties and winter rye yield in organic farming. Soil and Tillage Research. 2022; 222:105435.
6. Jackson ML. *Soil Chemical Analysis*. Prentice Hall of Inco. New York, USA. 1973;498.
7. Krishna SK, Reddy SK, Krishnamurthy V, Rao CC, Anuradha M. Effect of N and K levels on growth, yield and nutrient uptake of FCV tobacco cv. Kanchan. Indian Journal of Agricultural Sciences. 2015; 86(5): 691–5.
8. Major J, Lehmann J, Rondon M, Goodale C. Fate of soil-applied black carbon: downward migration, leaching and soil respiration. Global Change Biology. 2010; 16(4):1366-79.
9. Odlare M, Pell M. Effect of wood fly ash and compost on nitrification and denitrification in agricultural soil. Applied Energy. 2009; 86(1):74-80.
10. Oram NJ, van de Voorde TF, Ouwehand GJ, Bezemer TM, Mommer L, Jeffery S, Van Groenigen JW. Soil amendment with biochar increases the competitive ability of legumes via increased potassium availability. Agriculture, Ecosystems & Environment. 2014; 191:92-8.
11. Panse VG, Sukhatme PV. Statistical methods for agricultural workers 3rd edition. Indian Council of Agricultural Research Publication, New Delhi.1954;361.
12. Rasuli F, Owliaie H, Najafi-Ghiri M, Adhami E. Effect of biochar on potassium fractions and plant-available P, Fe, Zn, Mn and Cu concentrations of calcareous soils. Arid Land Research and Management. 2022; 36(1):1-26.
13. Simonsson M, Andersson S, Andrist-Rangel Y, Hillier S, Mattsson L, Öborn I. Potassium release and fixation as a function of fertilizer application rate and soil parent material. Geoderma. 2007;140(1-2):188-98.
14. Wang L, Xue C, Nie X, Liu Y, Chen F. Effects of biochar application on soil potassium dynamics and crop uptake. Journal of Plant Nutrition and Soil Science. 2018; 181(5):635-43.
15. Wood LK and De Turk EE. The absorption of potassium in soil in non-replaceable form. Soil Science Society of America, Proceeding. 1941; 5: 152- 161.
16. Zhang A, Liu Y, Pan G, Hussain Q, Li L, Zheng J, Zhang X. Effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain. Plant and soil. 2012; 351:263-75.
17. Zheng H, Wang Z, Deng X, Herbert S, Xing B. Impacts of adding biochar on nitrogen retention and bioavailability in agricultural soil. Geoderma. 2013; 206:32-9.
18. Ghiri MN, Boostani HR, Hardie AG. Investigation of biochars application on potassium forms and dynamics in a calcareous soil under different moisture conditions. Archives of Agronomy and Soil Science. 2022; 68(3):325-39.