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Effect of *Dalbergia sissoo* (Sissoo) and *Gmelina arborea* (Gambhar) based agroforestry system on potassium fractions of an acidic inceptisol under tropical climatic situation of eastern India

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Abstract
An experiment was carried out using the existing Field of AICRP on Agroforestry Project in Central Research Station of O.U.A.T, Bhubaneswar at a Latitude $20^0$15' N and longitude of 85^0 52' E in order to study the effect of agroforestry system on K fractions in the surface soil.In the year 2013, the system had two tree species *Dalbergia sissoo* and *Gmelina arborea* along with 4 intercrops such as pineapple, mango ginger, turmeric and arrowroot. Soil samples were collected after 13 years of agroforestry system in the post harvest period during 2014-15 for potassium fractionation study. The growth parameters of intercrops and the K uptake by the crops were also studied. The results on changes in total K in the surface soil revealed that open field caused huge loss of K to the tune of 726 kg ha^{-1} $year^{-1}$ as compared to 436 kg ha^{-1} $year^{-1}$ with *Dalbergia sissoo* and 374 kg ha^{-1} $year^{-1}$ with *Gmelina arborea* without inter crops and 118-172 kg ha^{-1} $year^{-1}$ with the intercropped system. Among the intercrops highest K content of all fractions was maintained in pineapple followed by mango ginger, turmeric and least with arrowroot. The three root spices, mango ginger, turmeric and arrow root accumulated more K (40-60%) in their economic part rhizome as compared to only 2% in the fruit of pine apple. Thus more site displacement of K from soil was made through the root crops. Pine apple crop recycled a major part of the absorbed K causing more accumulation of K in all the fractions. Among all forms of agroforestry systems evaluated, Gmelina arborea + pineapple system was the most effective system for recycling and conserving more potassium in surface soil.

Keywords: Agroforestry system, K fractions, intercrops, trees

1. Introduction
Agroforestry system has good ecological, social and economic benefits in comparison with traditional forestry. They contribute to the sustainability of soil nutrient and water cycles and act as a buffer to climatic extremes. So they are very important in maintaining sustainability of ecological system and sustainable development of social–economic system (Rao and Ong, 2000, Huxley, 1983, Rao and Reyes, 1990) [16, 7, 17]. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982) [11]. The growth and development of root system of multipurpose tree governs the nutrient pumping in agroforestry systems. It is considered that the deep root system act as 'safety net' and absorb leached nutrients, and pumped it to the aboveground growing part of the tree (Suprayogo *et al.* 2010, Kumar 2011) [21, 9]. The roots of trees take up nutrients from the soil, convert and utilize them for the production of plant material and then return them to the soil in the form of tree litter. This litter is transformed into humus and later incorporated into the soil. In a well managed agroforestry system, the relatively more efficient nutrient cycle minimizes the leakages of nutrients from the site.

Growing trees and agricultural crops together is a better land use option in terms of productivity, maintenance of soil conditions and economics. Intercropping in agroforestry brings higher energy efficiencies, and also good economic returns to farmers. Generally shade loving crops are chosen for intercrops under agroforestry system. Shade loving crops such as pineapple, mango ginger, turmeric and arrowroot are the common crops grown as intercrops with trees like *Dalbergia sissoo* (Sissoo) and *Gmelina arborea* (Gambhar) under tropical climatic situation of Odisha. Silvi-pastoral system was reported to have higher nitrogen, phosphorus and organic carbon as compared to the open field (Shankarnarayan, 1984 and Hazara, 1990) [19, 6].

Under agroforesstry system involving *Populus deltoids* and *Eucalyptus* hybrid canopies, enhancement in soil nutrient was 33-83% organic carbon, 38-69% available Nitrogen, 3-33% available Phosphorus (Anonymous 1987) [3]. Further Aggarwal (1980) [1] indicated greater nutrient amount in soil under Prosopis based agroforestry system than that of open field. So far the works on the effect of these systems on soil fertility arerestricted to soil organic carbon, available nitrogen and phosphorus. Under this system thus almost no work or very little research has been done in respect of potassium which is an important essential nutrient for the intercrops especially the root crops which are commonly grown in the eastern part of the country. As compared to N and P, all these crops require more K which plays very important role in achieving the potential yield and ensure quality of the produce.
In soil potassium is present in four different forms viz, water soluble K, exchangeable K, non exchangeable K and mineral K which are in dynamic equilibrium. Plant absorbs K from water soluble and exchangeable form which are formed from non exchangeable and mineral form of potassium. All the fractions play important role in potassium supplying capacity of soil. Under different trees and intercrops, there are different microclimates which affect the K fractions and their availability. For sustainable and profitable production system information on the these fractions are very important as they depend on the recycling capacity of trees and nutrient balance on the surface soil from which the intercrops draw their nutrient. Therefore, this investigation was made in an existing 13 year old agroforestry system to study the various fractions of potassium maintained under different tree-intercrop combination and their effect on K nutrition of the intercrops. This will help ineffectively managing K nutrition in different agroforestry systems in the region.

2. Materials and Methods
2.1 Location of the Experimental Field
The experimental field is located in Central Research Station of O.U.A.T, Bhubaneswar at a Latitude $20^0$15’ N and longitude of 85^0 52’ E. The climate of experimental site is hot and humid with mean annual rainfall of 1493.7mm.

2.2 Details of the Experiment
Existing system of agroforestry system was started in 2001 under the aegis of AICRP on Agroforestry of ICAR, New Delhi with two tree species *Dalbergia sissoo* (Sissoo) and *Gmelina arborea* (Gambhar) which continued with different intercrops which got changed time to time. In the year 2013, the system included 4 intercrops such as pineapple, mango ginger, turmeric and arrowroot. The initial physico-chemical properties of the surface soil are presented in the table1.The soil is sandy loam on surface layers with acidic pH (4.85) and low organic carbon (3.9gkg-1) and medium available K(138.5 kg ha^{-1}). For the present investigation the Experiment was conducted with 11 treatments as T_1-control (without tree and intercrop), T_2- *D. sissoo*, T_3- *G. arborea*, T_4- *D. sissoo* + Pineapple, T_5- *D. sissoo* + mango ginger, T_6- *D. sissoo* + turmeric, T_7- *D. sissoo* + arrowroot, T_8- *G. arborea* + pineapple, T_9- *G. arborea* + mango ginger, T_{10}-*G. arborea* + turmeric and T_{11}- *G. arborea* + arrowroot in RBD with 3 replications. Surface soil samples were collected in the post harvest period of the year 2014-15 (after 13 years of agroforestry system), processed and analysed potassium fractions and other relevant soil properties. The growth parameters of both trees and intercrops were recorded along with uptake of K by the intercrop. Potassium fractionation was done following standard methods as detailed below.

2.3 Potassium Fractionation
2.3.1 Water Soluble-K
The soil and water was taken in 1:2 ratio in a conical flask, shaked for 2 hours and allowing the suspension to stand for an additional 16 hours, after filtering through Whatman filter paper No.42 K was determined by flame photometer (Maclean,1961).

2.3.2 NH_4OAc extractable K
Five gm of processed soil was taken in a 150 ml conical flask and shaked with 25 ml 1N neutral ammonium acetate for 5 minutes in a mechanical shaker (reciprocating type). Then, the suspensions were filtered through Whatman no 1 filter paper and filtrate was collected in 50ml beaker. The K concentration of the filtrate was determined by Flame photometer after suitable dilution (Jackson, 1967) [8].

2.3.3 Exchangeable K
The exchangeable K was calculated from the difference between available potassium and water soluble potassium (Jackson 1967) [8].

2.3.4 Boiling nitric acid extractable potassium
By taking 2.5 g of finely ground soil in a 125 ml conical flask, 25 ml of 1N HNO_3 was added to it. The flask was heated over a hot plate at 90 °C. It was boiled exactly for 10 minute. Then after cooling the extract was filtered to a 100 ml volumetric flask by washing with 0.1 N nitric acid and volume was made up to 100 ml. The digested sample was diluted 5 fold and potassium concentration was determined in flame photometer using K standards prepared by 0.1NHNO_3 (Wood and Deturk, 1940) [22].

2.3.5 Non-exchangeable K
It was calculated by deducting1N neutral NH_4OAc extractable K from 1N HNO_3 extractable potassium (Jackson, 1967) [8].

2.3.6 Total potassium
Total K was determined by wet digestion method using tri acid (HNO_3- HF- $HClO_4$ in Teflon beaker. 1.0 g soil sample was taken in a Teflon beaker. Initially the material was digested with 10 mL concentrated HNO_3 for half an hour and cooled. Then 10 ml of 70% perchloric acid was added, boiled gently for 1 h on a hot plate at about 235 °C, and cooled. Then, 10 ml of HF (50%) was added, heated till intense white fumes, and taken nearly to dryness. After cooling, 25 mL of 1 N HNO3 were added to the contents of the beaker and gently boiled to dissolve any residues present. The volume was made up to 50 mL by distilled water and K reading was taken by flame photo meter (McKeague 1978) [14].

2.4 Statistical Analysis
The potassium fractions data were subjected to analysis of variance following statistical procedure of (Gomez and Gomez, 1984) [5]. It was done by DMRT to know the difference among the treatments and contrasting to know the difference between the individual tree and intercrops within the group under agroforestry system. Step wise regression

was also performed to know the contribution of each fraction to K uptake by the intercrop.

3. Results and Discussion

3.1 K fractions

Soil of experimental field was acidic, low in organic carbon and available nitrogen, medium in available phosphorus and medium in potassium with sandy-loam in texture on the surface layer (0-15 cm) which was presented in table 1.

3.1.1 Water soluble K

Data on various forms of potassium at surface soil (0-15 cm) after harvest of the intercrops during 2014-15 was presented in table 2. It revealed that the water soluble K is the smallest form among the fractions and the content of water soluble K varied from 29.3 kg $ha^{-1}$to 66.5 $kgha^{-1}$ with mean value of 47.9 $kgha^{-1}$ in different treatments. The highest content was maintained in the treatment of pineapple under *Gmelina arborea* (66.5 kg ha^{-1}), which was 55.9% more than that of control treatment (29.3 kg ha^{-1}). The content of water soluble K at 0-15 cm was observed more in pineapple followed by mango ginger, turmeric and arrowroot under *Gmelina arborea* than *Dalbergia sissoo* treatments. Sharma *et al*. (2009) [20] found that the wsK constituted 0.12% of total K in surface soils as negligible contribution to the total potassium of soils. The wsK was relatively higher in surface soils than the subsurface soils due to upward translocation of K by capillary rise.

3.1.2 Available (NH_4OAc- extractable) K

The content of NH_4OAc Kvaried from 103.0 kg $ha^{-1}$to 191.6 $kgha^{-1}$ with mean value of 147.3 $kgha^{-1}$ in different treatments. The highest amount was measured in the treatment of pineapple under *Gmelina arborea* (191.6 kg ha^{-1}), which is 46.2% more than that of control treatment (103.0 kg ha^{-1}). Comparison of intercrops revealed that the content of NH_4OAc K was highest in pineapple intercropping followed by mango ginger, turmeric and least in arrowroot under *Gmelina arborea* than *Dalbergia sissoo* treatments.

3.1.3 Exchangeable K

Exchangeable K which was determined from the difference between Available K and Water soluble K varied from 73.7 kg $ha^{-1}$to 125.1 $kgha^{-1}$ with mean value of 99.4 $kgha^{-1}$ in different treatments. The highest amount was measured in the treatment of pineapple under *Gmelina arborea* (125.1 kg ha^{-1}), which was 41.1% more than that of control treatment (73.7 kg ha^{-1}). Same order of the intercrop treatments as measured in respect of available and water soluble K was also maintained with respect to the content of exchangeable K. Between the trees on an average, *Gmelina arborea* always maintained significantly higher content of water soluble K and exchangeable K in the surface soil than *Dalbergia sissoo*. Reza *et al.* (2014) in a study of different pedons of inceptisol at agro-ecological regions of north east India has found that in acid soils there is decrease in exchangeable K with depth up to 60cm, then there is increase in K fractions.

3.1.4 1N hot HNO_3 extractable K

In different treatments, the content of 1N hot HNO_3 extractable K varied from 228.8 kg $ha^{-1}$to 506.2 $kgha^{-1}$ with mean value of 367.5 $kgha^{-1}$ with highest value recorded in the treatment of pineapple under *Gmelina arborea* (506.2 kg ha^{-1}). This was 54.8% more than that of control without any crop (228.8 kg ha^{-1}). Between the trees, among the intercrops, on an average, highest content of HNO_3 extractable K was measured in pineapple followed by mango ginger, turmeric and least in arrowroot and between the trees *Gmelina arborea* recorded significantly more of this fraction than *Dalbergia sissoo*.

3.1.5 Non Exchangeable K

The content of non- exchangeable K which was the difference between 1N HNO_3 K and Available K varied from 125.8 kg ha^{-1} to 314.6 $kgha^{-1}$ with mean value of 220.2 $kgha^{-1}$ in different treatments. The highest amount was observed in the treatment of pineapple under *Gmelina arborea* (314.6 kg ha^{-1}), which is 60% more than that of control treatment (125.8 kg ha^{-1}). The content of non-exchangeable K on an average, was highest in the surface soil under pineapple intercrop followed by mango ginger, turmeric and least under arrowroot. Between the trees, *Gmelina arborea* always recorded significantly higher non-exchangeable K than *Dalbergia sissoo.* Mazumdar *et al*. (2014) [13] found that the non-exchangeable K ranged from 704 mg kg^{-1} to 1168 mg kg^{-1} and 745 mg kg^{-1} to 1188 mg kg^{-1} in surface and sub-surface soil, respectively.

3.1.6 Mineral K

The content of mineral K varied from 6292 kg ha^{-1} to 7286 $kgha^{-1}$ with the mean value of 6789 $kgha^{-1}$ in different treatments with the highest measured in the treatment of pineapple under *Gmelina arborea* (7286 kg ha^{-1}), which was 13.6% more than that of control treatment (6292 kg ha^{-1}). Between the trees. *Gmelina arborea* always registered significantly higher mineral K than *Dalbergia sissoo* on an average. Among the intercrops, highest mineral K was recorded under pineapple followed by mango ginger, turmeric and least in arrowroot under a particular tree species. Gangopadhyay *et al*. (2005) [4] reported that the lattice K in soils of Ranchi plateau varied from 0.11 to 2.01% with a mean value of 0.77% which is 96 % of total K

3.1.7 Total K

In surface soil, total K varied from 6521 kg $ha^{-1}$to 7792 $kgha^{-1}$ with mean value of 7157 $kgha^{-1}$ in different treatments with the highest measured in the treatment of pineapple under *Gmelina arborea* (7792 kg ha^{-1}), which was 16.3% more than that of control (6521 kg ha^{-1}). Between the trees. *Gmelina arborea* always registered significantly higher surface soil total K than *Dalbergia sissoo* on an average. Among the intercrops, highest was recorded under pineapple followed by mango ginger, turmeric and least in arrowroot under a particular tree species. Lungmuana *et al.* (2014) [10] revealed the distribution and variation of potassium in red and laterite soils of West Bengal and observed that the total K contents of these soils were high in the surface soils (37.3 cmol(p^+) kg^{-1}) than the sub surface soil (36.2 cmol(p^+) kg^{-1}) with the mean value of 36.8 cmol(p^+) kg^{-1} soil.

3.2 Changes in K fractions within two years (2013-2015)

3.2.1 Change in Water soluble K

The change in the content of different fractions of K in the surface soil within two years presented in Table 3 revealed that there was 1.8 to 18.2 kg ha^{-1}increase in water soluble K in all planted treatments as compared to a decrease of 19.0 kg

ha^{-1}in control without trees or intercrops. Highest increase of 18.2 kg ha^{-1} was measured in pineapple with *Gmelina arborea* treatment. Between the trees *Gmelina arborea* was more efficient in bringing more positive change in WsK than *Dalbergia sisoo.* Considering the mean value the intercrops with respect to increase in WsK were in the order pineapple > mango ginger> turmeric > arrowroot.

3.2.2 Change in Exchangeable K
Results presented in Table 3 revealed that there was 2.5 to 34.9 kg ha^{-1} increase in exchangeable K in all planted treatments as compared to a decrease of 16.5 kg ha^{-1} in control without trees or intercrops. Highest increase of 34.9 kg ha^{-1} was measured in pineapple with *Gmelina arborea* treatment. Like WsK more increase in Exchangeable K was registered by *Gmelina arborea* than *Dalbergia sissoo* and the intercrops with respect to increase in Exchangeable K in surface soil were in the order pineapple > mango ginger > turmeric > arrowroot.

3.2.3 Change in Non-Exchangeable K
Non exchangeable K also registered increase in all planted treatments which varied from 6.0 to 144.4 kg $ha^{-1}$and a decrease of 44.4 kg ha^{-1} in non-planted control. The highest increase of 144.4 kg ha^{-1} was measured in pineapple under *Gmelina arborea* treatment and intercrops followed the same order as observed with Exchangeable K.

3.2.4 Change in Mineral K and Total K
Mineral K which constituted about 95% of the total K however registered a decrease in its content irrespective of treatments. Highest decrease of 1372 kg ha^{-1} was measured in unplanted control plot in two years which might be through erosion loss of surface soil of barren land without vegetation. In planted treatment there was decrease but to alesser extent that varied from 378 to 426 kg ha^{-1} in all intercropped soils because of surface cover and 792 to 882 in treatments with only trees but no intercrop. Higher decrease might be due to loss through erosion from no intercrop surface.
Change in total K of surface soil followed the same pattern as observed with mineral K. Highest total K loss was measured in unplanted control (1452 kg ha^{-1}) followed by treatments with only trees (748-872 kg ha^{-1}) and least with the intercropped treatments (236-344 kg ha^{-1})

3.3 Effect of individual Groups on K fractions Through Contrasting
Data on contrasting in statistics to compare the effects between or among groups of population (Table 4) reveal that on an average planted soil registered accumulation of more surface K of all fractions than non-planted soil. Similarly *Gmelina arborea* registered more K than *Dalbergia sissoo*. Evaluating the effect of intercrops it is observed that the intercrops are in order of pineapple > mango ginger > turmeric > arrowroot with respect to fractions of K in the surface soil. The content of potassium in non-intercropped system is lower than intercropped system. It was graphically represented in fig 1. This might be due to potassium loss due to more erosion and leaching in soil without vegetation.

3.4 Effect on Biomass Yield and K uptake
From the biomass yield and content of K the uptake of K has been calculated. Data on biomass yield and K uptake by the intercrops presented in table 5 reveal that there is highest uptake by pine apple crop followed by turmeric, mango ginger and least with arrow root under the tree species *Dalbergia sissoo*. Ahmed *et al*. (2006) [2] studied in peat soil of Malaysia that the most of the K uptake in pineapple was found in leaves and fruit. The total uptake of K in pine apple crop was 519.7 kg $ha^{-1.}$ But under *Gmelina arborea* the intercrops are in the sequence of pineapple> mangoginger > turmeric > arrowroot with respect to total K uptake. When partitioning of K is taken into account all the three intercrops were found to accumulate more K (around 40-60% of total K) in the economic parts which are surely displaced from the field.

3.5 Relationship of K fractions with K uptake
Regression equation describing the relationship between various surface soil fractions with K uptake (Table 6) reveal that among the fractions, exchangeable K and non-exchangeable K significantly contributed +vely to K uptake (R2 = 0.756) by all the intercrops. Between exchangeable and non-exchangeable K fractions, the contribution of exchangeable K was more. Each unit of additional increase in exchangeable K resulted in 9.029kg of K uptake as compared to 1.224 kg in case of non-exchangeable K.

Table 1: Initial Physical and chemical properties of surface soil

Soil characteristics	0-15 cm
Sand (%)	74.8
Silt (%)	10.4
Clay (%)	14.8
Textural class	Sandy loam
BD (kgm^{-3})	1.54
pHw (1:2.5)	4.85
EC (dSm^{-1})	0.127
OC (gkg^{-1})	3.9
NH_4OAc Extractable K ($kgha^{-1}$)	138.5
Water Soluble K ($kgha^{-1}$)	48.3
Exchangeable K ($kgha^{-1}$)	90.2
HNO_3 Extractable K ($kgha^{-1}$)	308.7
Non Exchangeable K ($kgha^{-1}$)	170.2
Mineral K ($kgha^{-1}$)	7664
Total K ($kgha^{-1}$)	7973
Alkaline $KMnO_4$Oxidizable N ($kgha^{-1}$)	181.6
Available P ($kgha^{-1}$)	27.5

Table 2: Distribution of different K fractions (kg ha^{-1}) in surface soil (0-15cm) during 2014-15

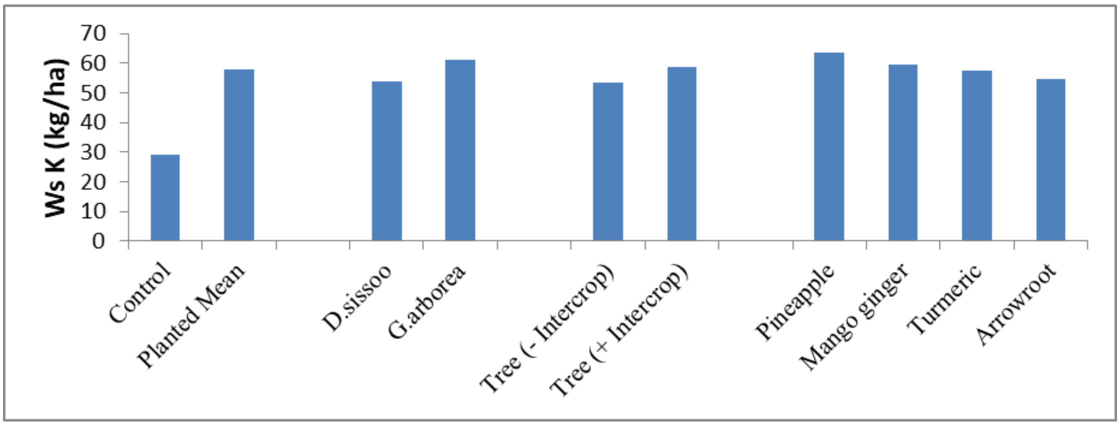
Treatments	Content of different K fractions (kg ha^{-1})						
	NH_4OAc K (kgha^{-1})	Water soluble K (kgha^{-1})	Exchangeable K (kgha^{-1})	1N HNO_3 K (kgha^{-1})	Non Exchangeable K (kgha^{-1})	Mineral K (kgha^{-1})	Total K (kgha^{-1})
T_1- Control (without tree and intercrop)	103.0$_h$	29.3 $_h$	73.7 $_e$	228.8 $_k$	125.8 $_i$	5292 $_h$	5521 $_h$
T_2- *Dalbergia sissoo* without intercrop	142.8 $_g$	50.1 $_g$	92.7 $_d$	319.0 $_j$	176.2 $_h$	6782 $_g$	7101 $_g$
T_3- *Gmelina arborea* without intercrop	159.6$_{ef}$	56.5 $_{de}$	103.1$_c$	350.8 $_i$	191.2 $_g$	6874 $_f$	7225 $_f$
T_4- Pine apple under *Dalbergia sissoo*	173.4 $_d$	60.5 $_c$	112.9$_b$	463.7 $_c$	290.3 $_b$	7273 $_b$	7737 $_b$
T_5- Mango ginger under *Dalbergia sissoo*	161.6 $_e$	55.1 $_e$	106.5$_c$	443.1 $_e$	281.6 $_c$	7261 $_c$	7704 $_c$
T_6- Turmeric under *Dalbergia sissoo*	157.5 $_f$	53.3 $_f$	104.2$_c$	417.0 $_g$	259.4 $_e$	7249 $_d$	7666 $_d$
T_7- Arrowroot under *Dalbergia sissoo*	144.9 $_g$	51.2 $_g$	93.7 $_d$	391.5 $_h$	246.5 $_f$	7238 $_e$	7629 $_e$
T_8- Pine apple under *Gmelina arborea*	191.6 $_a$	66.5 $_a$	125.1$_a$	506.2 $_a$	314.6 $_a$	7286 $_a$	7792 $_a$
T_9- Mango ginger under *Gmelina arborea*	187.6 $_b$	63.9 $_b$	123.7$_a$	475.1 $_b$	287.6 $_b$	7269$_{bc}$	7744 $_b$
T_{10}-Turmeric under *Gmelina arborea*	177.0 $_c$	61.6 $_c$	115.3 $_b$	452.1 $_d$	275.1 $_d$	7262 $_c$	7714 $_c$
T_{11}- Arrowroot under *Gmelina arborea*	161.7 $_e$	57.8 $_d$	103.9 $_c$	420.7 $_f$	259.0 $_e$	7246 $_{de}$	7666 $_d$
SEm(±)	1.16	0.55	1.27	0.75	1.31	3.33	3.38
CD $_{(0.05)}$	3.41	1.62	3.76	2.20	3.86	9.82	9.98
Initial (2013)	138.5	48.3	90.2	308.7	170.2	7664	7973

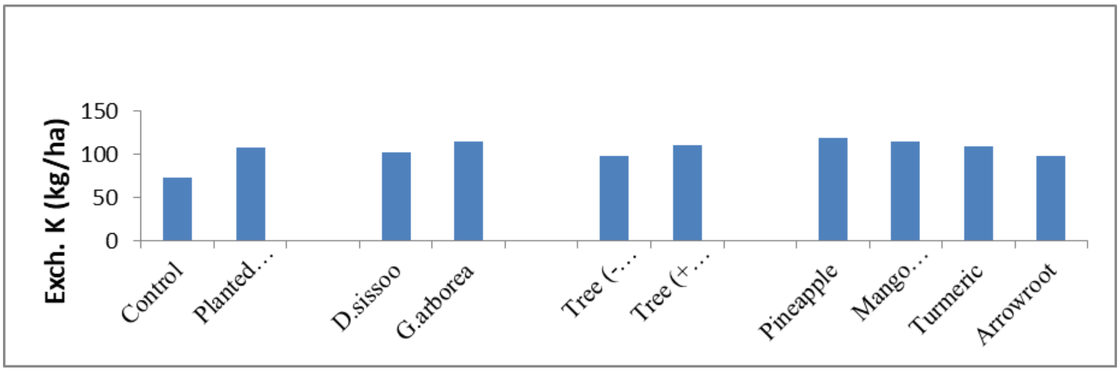
Table 3: Changes of content of different K fractions (kg ha^{-1}) in surface soil (0-15cm) during 2013-15

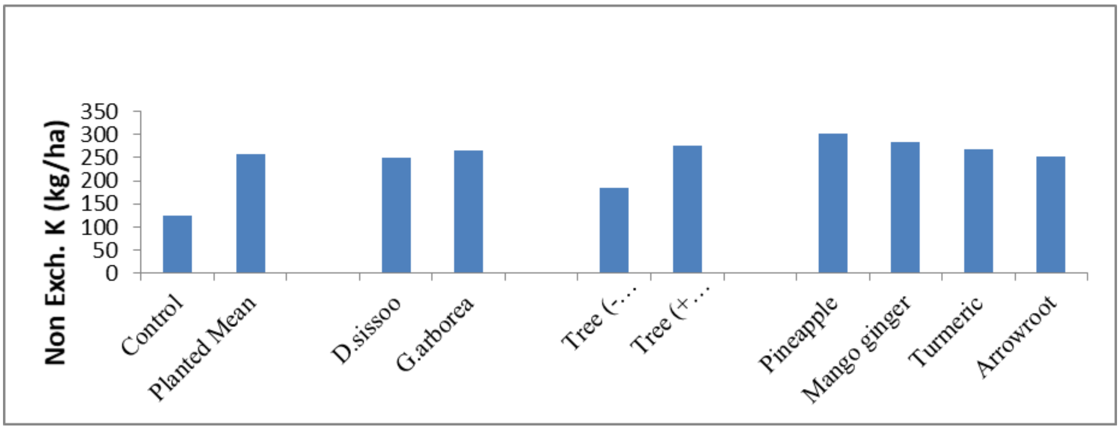
Treatments	Water soluble K (kgha^{-1})	Exchangeable K (kgha^{-1})	Non-Exchangeable K (kgha^{-1}	Mineral K (kgha^{-1})	Total K (kgha^{-1})
T_1- Control (without tree and intercrop)	-19.0	-16.5	-44.4	-1372	-1452
T_2- *Dalbergia sissoo* without intercrop	1.8	2.5	6.0	-882	-872
T_3- *Gmelina arborea* without intercrop	8.2	12.9	21.0	-790	-748
T_4- Pine apple under *Dalbergia sissoo*	12.2	22.7	120.1	-391	-236
T_5- Mango ginger under *Dalbergia sissoo*	6.8	16.3	111.4	-403	-269
T_6- Turmeric under *Dalbergia sissoo*	5.0	14.0	89.2	-415	-307
T_7- Arrowroot under *Dalbergia sissoo*	2.9	3.5	76.3	-426	-344
T_8- Pine apple under *Gmelina arborea*	18.2	34.9	144.4	-378	-181
T_9- Mango ginger under *Gmelina arborea*	15.6	33.5	117.4	-395	-229
T_{10}- Turmeric under *Gmelina arborea*	13.3	25.1	104.9	-402	-259
T_{11}- Arrowroot under *Gmelina arborea*	9.5	13.7	88.8	-418	-307

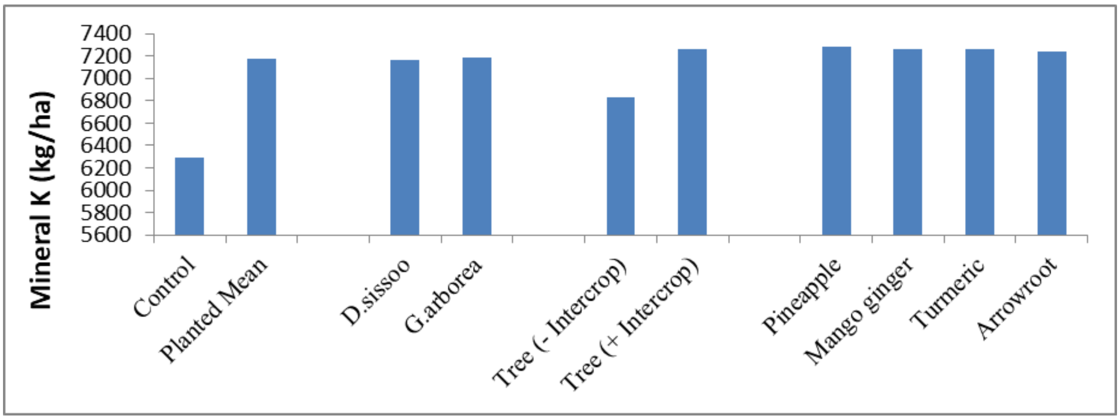
Table 4: Contrasting of effects of groups on different fractions of K (kg ha^{-1}) in soil (0-15cm) under agroforestry system during 2014-15

Contrasting of different fractions of K (kg ha^{-1})					
Control vs. planted mean					
	Water Soluble K (kg ha^{-1})	**Exch. K (kg ha^{-1})**	**Non Exch.K (kg ha^{-1})**	**Mineral K (kg ha^{-1})**	**Total K (kg ha^{-1})**
Control	29.3	73.7	125.8	6292	6521
Planted Mean	57.7	108.1	258.2	7174	7598
SEm (±)	0.58	1.34	1.37	3.49	3.55
CD $_{(0.05)}$	1.20	2.79	2.86	7.29	7.40
D. sissoo vs G. arborea					
D. sissoo	54.0	102.0	250.8	7161	7568
G. arborea	61.3	114.2	265.5	7187	7628
SEm (±)	0.35	0.81	0.83	2.11	2.14
CD $_{(0.05)}$	0.73	1.68	1.73	4.39	4.46
Only tree vs. Tree + Intercrops					
Tree (- Intercrop)	53.3	97.9	183.7	6828	7163
Tree (+ Intercrop)	58.7	110.7	276.8	7261	7707
SEm (±)	0.43	1.01	1.03	2.63	2.68
CD $_{(0.05)}$	0.91	2.10	2.16	5.49	5.58
Difference among intercrops (4)					
Pineapple	63.5	119.0	302.5	7280	7765
Mango ginger	59.5	115.1	284.6	7265	7724
Turmeric	57.5	109.8	267.3	7256	7690
Arrowroot	54.5	98.8	252.8	7242	7648
SEm (±)	0.55	1.27	1.31	3.33	3.38
CD $_{(0.05)}$	1.15	2.66	2.73	6.95	7.06


Ws K (kg/ha)
70
60
50
40
30
20
10
0
Control
Planted Mean
D.sissoo
G.arborea
Tree (- Intercrop)
Tree (+ Intercrop)
Pineapple
Mango ginger
Turmeric
Arrowroot


Exch. K (kg/ha)
150
100
50
0
Control
Planted…
D.sissoo
G.arborea
Tree (-…
Tree (+…
Pineapple
Mango…
Turmeric
Arrowroot


Non Exch. K (kg/ha)
350
300
250
200
150
100
50
0
Control
Planted Mean
D.sissoo
G.arborea
Tree (-…
Tree (+…
Pineapple
Mango ginger
Turmeric
Arrowroot


Mineral K (kg/ha)
7400
7200
7000
6800
6600
6400
6200
6000
5800
5600
Control
Planted Mean
D.sissoo
G.arborea
Tree (- Intercrop)
Tree (+ Intercrop)
Pineapple
Mango ginger
Turmeric
Arrowroot

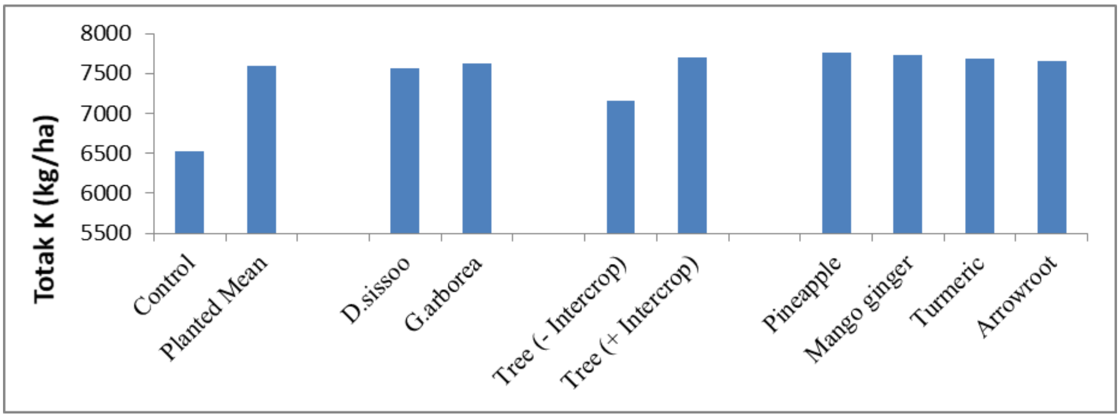


Fig 1: Contrasting of different fractions of K (kg ha^{-1}) in surface soil

Table 5: Biomass Yield and K uptake of intercrops during 2014-15

Treatments	Biomass of intercrops (dry) (kgha^{-1})	Yield of intercrops (kgha^{-1})	K uptake (kgha^{-1})		
			Biomass of intercrops (kgha^{-1})	Yield of intercrops (kgha^{-1})	Total uptake (kgha^{-1})
T_1- Control (without tree and intercrop)					
T_2-*Dalbergia sissoo* without intercrop					
T_3-*Gmelina arborea* without intercrop					
T_4- Pine apple under *Dalbergia sissoo*	8055 c	6845 c	256.9 a	5.5 f	262.4 a
T_5- Mango ginger under *Dalbergia sissoo*	6333 f	2877 g	120.9 c	93.5 d	214.4 d
T_6- Turmeric under *Dalbergia sissoo*	6667 e	4215 e	106.7 e	112.9 a	219.6 c
T_7- Arrowroot under *Dalbergia sissoo*	9333 a	7382 a	38.3 g	98.3 c	136.5 g
T_8- Pine apple under *Gmelina arborea*	7667 d	6252 d	246.9 b	5.0 f	251.9 b
T_9- Mango ginger under *Gmelina arborea*	6000 h	2765 h	115.8 d	90.7 e	206.5 e
T_{10}-Turmeric under *Gmelina arborea*	6111 g	3878 f	100.2 f	104.3 b	204.5 f
T_{11}-Arrowroot under *Gmelina arborea*	8866 b	7024 b	38.1 g	94.8 d	132.9 h
SEm(±)	0.60	9.21	0.54	1.10	1.03
CD (0.05)	1.83	27.93	1.66	3.35	3.11

Table 6: Stepwise Regression equation for relationship between K uptake and K fractions (0-15cm)

	Regression equation	Adjusted R^2
K uptake	Y=45373.3-10.019wsK+9.029 Exch.K+1.224 Non Exch.K-6.342Min K	0.756

4. Conclusion

Between the trees, *Gmelina arborea* maintained higher level of available K, watersoluble K, exchangeable K, non exchangeable K, mineral K and total K on top soil than *Dalbergia sissoo*. Inclusion of intercrops maintained a better available status of K in surface soil than non intercropping system. Among the intercrops highest K content of all fractions was maintained in pineapple followed by mango ginger, turmeric and least with arrowroot. The three root spices, mango ginger, turmeric and arrow root accumulated more K (40-60%) in their economic part rhizome as compared to only 2% in the fruit of pine apple. Thus more site displacement of K from soil was made through the root crops. Pine apple crop recycled a major part of the absorbed K causing more accumulation of K in all the fractions.

Open field caused huge loss of K 726 kg ha^{-1} year^{-1}as compared to 436 kg ha^{-1} year^{-1} with *Dalbergia sissoo* and 374 kg ha^{-1} year^{-1} with *Gmelina arborea* without inter crops and 118-172 kg ha^{-1} year^{-1}with the intercropped system.Among the fractions, exchangeable K and non exchangeable K contributed +vely to K uptake (R^2 = 0.756). Between exchangeable and non exchangeable K, the contribution of exchangeable K was more. Each unit of additional exchangeable K resulted in 9.029kg of uptake as compared to 1.224 kg in case of non exchangeable K. *Gmelina arborea* + pine apple system was the best effective system for recycling and accumulating more potassium in all forms in surface soil.

5. Future scope

As tree roots penetrate deeper into soil and collect K from lower layers. Potassium fraction study of bottom layers is also very important and K balance of each fraction at different layers is needed to get more conclusive results to correctly evaluate the agroforestry system under tropical climatic condition where there is more precipitation and high temperature.

6. Acknowledgement

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7. Competing Interest

Authors declare that no competing interest exist for the work.

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