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Effect of potash management through Gliricidia green leaf manuring on potassium fractions and their relationship with yield of soybean in Vertisols

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Abstract
A field experiment was conducted to assess the effect of potash management through gliricidia green leaf manuring on potassium fractions and the relationship of different potassium fractions with yield of soybean in Vertisols at Research field of AICRP for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during *kharif* 2018. The experiment comprised of six treatments and four replications laid out in Randomized Block Design. The treatments comprised of control, 100% RDF (30:75:30 NPK kg ha^{-1}), 75% and 50% N and 100% P through chemical fertilizers and the combinations of 15 and 30 kg K ha^{-1} through Gliricidia green leaf manure at 30 DAS and remaining recommended dose of potassium as basal dose through inorganic fertilizers. The results indicated that the significant improvement in potassium fractions was recorded with application of 75% N +100% P+15 kg K through chemical fertilizers +15 kg K through Gliricidia and among the various potassium fractions, the water soluble K was highly correlated with soybean grain yield.

Keywords: Gliricidia green leaf manure, potassium fractions, Vertisols

Introduction
Potassium is an essential plant nutrient and is required in large amounts for proper growth and reproduction of plants. It is considered second only to nitrogen, when it comes to nutrients needed by plants, and is commonly considered as the "quality nutrient." It affects the plant shape, size, colour, taste and other measurements attributed to healthy produce. It plays a major role in the regulation of water in plants (osmoregulation); both uptake of water through plant roots and its loss through the stomata are affected as well as it improves drought resistance. It is essential at almost every step of the protein synthesis. In starch synthesis, the enzyme responsible for the process is activated by potassium. Potassium has an important role in the activation of many growth related enzymes in plants.
Gliricidia sepium plant belongs to leguminous family with subfamily Papilionoideae. It is a leguminous multipurpose tree and adopts very well in a wide range of soils. The leaves of gliricidia contain N (2.4%), P (0.1%), K (1.8%) and these leaves decompose relatively fast, providing nitrogen and potassium. Gliricidia as green leaf manure plays important role in increasing the fertility status of soils and helps in conserving soil through reduced soil erosion also. Patil (1989) [18] stated that 1 tonne dry weight of leaves was equivalent to 27 kg N while Kang and Mulongoy (1987) [11] reported that up to 15 t/ha/year of gliricidia leaf biomass could be produced on good soils in Nigeria providing the equivalent of 40 kg N/ha/year.
Based on the degree of availability to crops, soil potassium can be classified into four forms *i.e*. soil solution K, exchangeable K, non-exchangeable K and mineral K (Darunsontaya *et al.*, 2012) [5]. The primary source of potassium absorbed by plant roots is that which is present in soil solution. The concentration of the readily available K forms are relatively small at any time and do not provide a good indication of long-term ability of soils to supply K to plants. Exchangeable potassium, which is held by the negative charges on soil clay and organic matter exchange sites, soil solution and exchangeable potassium are in equilibrium and collectively known as the readily available potassium pool (Shaikh *et al.,* 2007) [26]. The bio-available K pools contain only a minor fraction of the total soil potassium reserve (Huang, 2005) [8]. Soil fixed (non-exchangeable) K is an important contribution to plant K supply. It is held as fixed ion in the lattice structure of clay minerals. Because of continuous removal of potassium by

crop uptake and leaching in soil, the static equilibrium among different K fractions in soil is probably never obtained. There is a continuous but slow transfer of potassium in the primary minerals to the exchangeable and slowly available forms.

Most of the black soils were thought to be well supplied with K and thus it was presumed that they do not need K application. However, in view of potential of newly released high yielding varieties of crops these soils may not be well supplied with K. In view of the high potassium content in swell shrink soils it was not recommend like regular application of N and P fertilizers. Among the major nutrients, potassium not only improves yields but also benefits various aspects of quality. Although the potassium content of Vertisols and associated intergrades is high, many crops have been found to give good response to application of potassium. Most crops absorb as much or more K than they absorb N from the soil, which resulted into higher nutrient removal. The potash balance in Maharashtra is negative and mining of soil K reserves is going on at an alarming pace.

Materials and Methods

A field experiment conducted on Vertisols was initiated on the research field of AICRP for Dryland Agriculture, Dr. PDKV, Akola since 2015-16. The present study was undertaken during 2018-19 with six treatments replicated four times with soybean as a test crop. The treatments comprised of T_1-Control, T_2-100% RDF (30:75:30 NPK kg ha^{-1})

T_3-75% N +100%P+15 kg K(inorganic)+15 kg K through gliricidia, T_4-75% N +100%P+30 kg K through gliricidia, T_5-50% N +100%P+30 kg K through gliricidia and T_6-100% K through gliricidia.

Total K extracted by HF digestion method, Water soluble K extracted by shaking soil and water suspension (1:5) for 1 hour, Exchangeable K extracted by using 1N neutral ammonium acetate, Non-exchangeable K determined by treating with 1 N HNO_3 in 1:10 ratio and boiling for 10 minutes and K was estimated with the help of flame photometer as described by (Pratt, 1965) [20], Lattice K was calculated by subtracting the sum of above three fractions from the total potassium content (Ranganathan and Satyanarayana, 1980) [21].

Results and Discussion

Yield of soybean

The data on grain and straw yield of soybean (Table 1) was significantly influenced by various treatments. The significantly higher soybean grain yield (1738.67 kg ha^{-1}) was observed with application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia(T_3) and it was on par with the application of 75% N +100% P+30kg K through gliricidia (T_4), application of 100% RDF(30:75:30 NPK kg ha^{-1}) (T_2) and application of 50% N +100% P+30kg K through gliricidia (T_5). The increase in grain yield of soybean with application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia(T_3)was 41.96 % and 8.13% higher as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2) treatments respectively. The lowest soybean grain yield (1224.27 kg ha^{-1}) was recorded in treatment T_1 *i.e.* control.

The significantly higher soybean straw yield (2173.34 kg ha^{-1}) was observed with the application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3) and it was on par with application of 75% N +100% P+30kg K through gliricidia (T_4). The increase in straw yield of soybean with application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia(T_3) was 61.38 % and 21.49 % higher as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2)treatments respectively. The lowest (1346.70 kg ha^{-1}) soybean straw yield was recorded in treatment T_1 *i.e.* control.

Higher soybean yield with conjunctive application of gliricidia green leaf manure along with chemical fertilizers may be due to balanced supply of nutrients to the crop throughout the crop growth period. Green leaf manure undergo decomposition during which series of nutrient transformation takes place which helps in their higher availability to the crops and higher uptake of nutrients by the crops will result in higher yield.

Table 1: Effect of potash management through Gliricidia green leaf manuring on soybean yield

Treatment		Soybean yield (kg ha^{-1})	
		Grain	Straw
T_1	Control	1224.27	1346.70
T_2	100% RDF (30:75:30 NPK kg ha^{-1})	1597.21	1788.88
T_3	75% N +100% P+15kg K (inorganic) + 15 kg K through Gliricidia	1738.67	2173.34
T_4	75% N +100% P+30kg K through Gliricidia	1659.97	1991.96
T_5	50% N +100% P+30kg K through Gliricidia	1517.48	1745.10
T_6	100% K through Gliricidia	1365.73	1529.62
	SE (m) ±	101.69	117.92
	CD at 5%	306.47	355.38

The results are in conformity with the findings of Channabasappa and Prabhakar (2003) [3], Laxminarayan and Pritam (2006) [13], Sangakkara *et al.* (2008) [24],Regar *et al.* (2009) [23], Ghalavand *et al.* (2009) [7], Manral and Saxena (2010) [15],Odyuo *et al*. (2015) [16], Shariff *et al.*(2017) [27] and Jadhao *et al*. (2018) [10].

Potassium fractions in soil

The availability of potassium to plant depends on relative mobility of the different forms of K in soil. A knowledge regarding the various forms of K in soil and the condition controlling its availability to soybean crop is important for the appraisal of the available potassium. Therefore, it is necessary to study the transformation of applied K in different forms and their influence on the yield of soybean in vertisol.

Data pertaining to distribution of various potassium fractions *viz*., water soluble (WSK), exchangeable (EX- K), non-exchangeable (NEK), lattice K (LK) and total K (TK) and per cent contribution of different potassium fractions to total K are presented in Table 2.

Water soluble potassium

Soil solution K is the form of K that is directly taken up by plants and microbes and also is the form subject to most leaching in soil.

The effect of potash management through gliricidia green leaf manuring on water soluble potassium was significant. Significantly highest water soluble potassium (21.50 mg kg^{-1}) was recorded with the application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3)and it was on par with application of 75% N +100% P+30 kg K through gliricidia (T_4). It was also noted that 38 % and 11.68% increase in water soluble potassium content was observed with application of 75% N +100% P+15 kg K(inorganic)+15kg K through gliricidia(T_3) as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2) respectively. The lowest water soluble potassium (15.50 mg kg^{-1}) was recorded in control treatment (T_1).

This might be due to the fact that gliricidia leaves contains higher amount of K and it is deposited in the soil and due to applied K through gliricidia green leaf manure, the solubilizing action of certain organic acids produced during decomposition results in greater capacity to hold K in the available form. Yaduvanshi *et al*. (2013) [34] reported that available K comprising water soluble K increased in treatments receiving green manure or FYM.

The contribution of water soluble K to total K ranged between 0.17% to 0.18% indicating almost least contribution in comparison with other K fractions.

These results are in agreement with the findings of Sharma and Verma (2000) [29], Singh *et al*. (2005) [31], Babar *et al*. (2007) [1], Singh *et al.* (2014) [30], Sharma and Paliyal (2015) [28] and Sujata *et al.* (2017) [32].

Exchangeable potassium

Exchangeable K has been generally regarded as reliable index of K removal by crops. It is held by virtue of the negative charges of organic matter and clay minerals in soil. It is easily exchanged with other cations and is relatively easily available to plants.

The effect of potash management through gliricidia green leaf manuring on exchangeable potassium was found to be significant. Significantly highest exchangeable potassium (266.00 mg kg^{-1}) was recorded with the application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3)and it was on par with application of 75% N +100% P+30 kg K through gliricidia (T_4) and application of 50% N +100% P+30kg K through gliricidia(T_5). It was also noted that 53.22% and 13.09% increase in exchangeable potassium content was observed with application of 75% N +100% P+15 kg K(inorganic)+15kg K through gliricidia(T_3) as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2) respectively. The lowest exchangeable potassium (173.60 mg kg^{-1}) was recorded in control treatment (T_1).The various fertilizer and manure treatments significantly improved the exchangeable K status, among the treatments combined application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3) exhibited higher exchangeable K. The higher amount of exchangeable K in the green leaf manure treated plots over the years can be attributed to the fact that GLM 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 K.

The contribution of exchangeable K to total K ranged between 1.87% to 2.40% which was slightly higher as compared to water soluble K.

These results are in agreement with the findings of Bachkaiya (2005) [2], Babar *et al*. (2007) [1], Singh *et al.* (2014) [30], Sujata *et al.* (2017) [32].

Non-exchangeable potassium

Non-exchangeable potassium is held between adjacent tetrahedral layers of dioctahedral and trioctahedral micas, vermiculites and intergrade clay minerals. It is also found in wedge zones of weathered micas and vermiculites. Non-exchangeable K is moderately to sparingly available to plants.

The effect of potash management through gliricidia green leaf manuring on non-exchangeable potassium was significant. Significantly highest non-exchangeable potassium (910.00 mg kg^{-1}) was recorded with the application of 75% N +100% P+30 kg K through gliricidia (T_4) and it was found to be on par with application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3). It was also noted that 23.80% and 6.74% increase in non-exchangeable potassium content was observed with application of 75% N +100% P+30 kg K through gliricidia (T_4) as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2) respectively. The lowest non-exchangeable potassium (735.00 mg kg^{-1}) was recorded in control treatment (T_1). Sawarkar *et al.* (2013) [25] while studying distribution of potassium fractions under soybean-wheat cropping system also reported the non-exchangeable potassium in the range of 736 to 885 mg kg^{-1} in Vertisols. The non-exchangeable potassium varied from 730 to 830 mg kg^{-1} in Vertisols of Maharashtra (Pharande and Sonar, 1996) [19].

The contribution of non-exchangeable K to total K ranged between 7.54% to 8.18% which was higher as compared to water soluble K and exchangeable K.

The contribution of non-exchangeable K to total K indicate that, this form appreciably contributed to total pool indicating fixation of potassium in the interlayer, which suggest the need of application of organics, which help in release of K. The inclusion of green manure along with chemical fertilizers was found beneficial in improving the non-exchangeable K status of soil.

These results are in agreement with the findings of Pannu *et al.* (2001) [17], Bachkaiya (2005) [2], Babar *et al*. (2007) [1],Dhar *et al.* (2009) [6] and Singh *et al.* (2014) [30].

Table 2: Effect of potash management through Gliricidia green leaf manuring on potassium fractions (mg/kg) in soil

Treatment		WSK	Exch. K	Non-Ex K	Total K	Lattice K
T_1	Control	15.50 (0.17)	173.60 (1.87)	735.00 (7.90)	9296	8372 (90.06)
T_2	100% RDF (30:75:30 NPK kg ha^{-1})	19.25 (0.18)	235.20 (2.26)	852.50 (8.18)	10416	9309 (89.37)
T_3	75% N +100% P+15kg K(inorganic)+15 kg K through Gliricidia	21.50 (0.18)	266.00 (2.26)	887.50 (7.54)	11760	10585 (90.01)
T_4	75% N +100% P+30kg K through Gliricidia	20.75 (0.18)	263.20 (2.33)	910.00 (8.04)	11312	10118 (89.45)
T_5	50% N +100% P+30kg K through Gliricidia	18.75 (0.17)	257.60 (2.40)	827.50 (7.69)	10752	9648 (89.73)
T_6	100% K through Gliricidia	17.50 (0.18)	229.60 (2.33)	790.00 (8.01)	9856	8819 (89.48)
	SE (m) ±	0.35	8.30	8.08	246.51	247.14
	CD at 5%	1.06	25.02	24.34	742.91	744.81

Note: Figures in parentheses indicate percent contribution of potassium fractions to total K

Lattice potassium
It is fraction of K that gets fixed in lattice space of 2:1 clay minerals. This form of K is distinct form of mineral K in that, it is not bonded covalently within the crystal structure of soil mineral particle but held between adjacent tetrahedral layers of dioctahedral and trioctahedral wedge zones of weathered micas and vermiculite.

The effect of potash management through gliricidia green leaf manuring on lattice potassium was significant. Significantly highest lattice potassium (10585 mg kg^{-1}) was recorded with the application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3)and it was on par with application of 75% N +100% P+30 kg K through gliricidia (T_4). It was also noted that 26.43% and 13.74% increase in lattice potassium content was observed with application of 75% N +100% P+15 kg K(inorganic)+15kg K through gliricidia(T_3) as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2) respectively. The lowest lattice potassium (8372 mg kg^{-1}) was recorded in control treatment (T_1).

The contribution of lattice K to total K was found to be 89.37% to 90.06% indicating dominant K fraction which contributed substantially to total K.

The increased lattice-K content maintained under a long run integrated nutrient management might be due to the addition of gliricidia green leaf manure which have larger amount of potassium content. Similar results were also noted by Babar *et al*. (2007) [1], Jadhao *et al.* (2015) [9] and Lokya *et al*. (2018) [14].

Total potassium
The knowledge of K fertility status is of prime importance as it indicates the total reserve of K which may become available to plants. More than 90 per cent of total K in soil is within the crystal lattice of silicate minerals, which on weathering slowly releases K in soil for plant utilization. Data pertaining to distribution of total potassium are presented in Table 2.

The effect of potash management through gliricidia green leaf manuring on total potassium was found to be significant. Significantly highest total potassium(11760 mg kg^{-1}) was recorded with the application of 75% N +100% P+15kg K(inorganic)+15 kg K through gliricidia (T_3)and it was on par with application of 75% N +100% P+30 kg K through gliricidia (T_4). It was also noted that 26.5% and 12.9% increase in total potassium content was observed with application of 75% N +100% P+15 kg K(inorganic)+15kg K through gliricidia(T_3) as compared to control (T_1) and 100 % RDF (30:75:30 NPK kg ha^{-1}) (T_2) respectively. The lowest total potassium (9296 mg kg^{-1}) was recorded in control treatment (T_1).

The combined application of manures and fertilizers (NPK+GLM) resulted in larger amount of SOC which adds additional amount of K and also provide sorption site for K on application of organic manure along with mineral fertilizer. These results are in agreement with the findings of Singh *et al.* (2014) [30], Jadhao *et al*. (2015) [9] and Lokya *et al*. (2018) [14].

Correlation among yield and various potassium fractions
The data on correlation among yield and various potassium fractions are presented in Table 3. The soybean grain yield was significantly and positively correlated with all the potassium fractions. The coefficient of correlation ranged between 0.473** to 0.705**. The water soluble K (r=0.705**) was highly correlated with soybean grain yield indicating influence of this fraction on soybean grain yield.

The correlation among various potassium fractions indicated that, all the K fractions showed significant and positive correlation with water soluble K indicating rapid establishment of equilibrium between these forms. Comparatively high degree of correlation of Total K with Lattice K (r=0.998**) followed by water soluble K with non exchangeable K (r=0.919**) showed the rapid establishment of equilibrium between these forms. Similar type of correlation was reported by Lal *et al*. (1990) [12], Chaudhary and Prasad (1997) [4], Ravankar *et al*. (2001) [22], Babar *et al*. (2007) [1], Swapana *et al.* (2012) [33], Jadhao *et al*. (2015) [9].

Table 3: Correlation among yield and various potassium fractions

	Yield	WS K	Ex. K	N.E. K	Total K	Lat. K
Yield	1.000					
WS K	0.705**	1.000				
Ex. K	0.473*	0.823**	1.000			
NE. K	0.608**	0.919**	0.847**	1.000		
Total K	0.692**	0.826**	0.763**	0.814**	1.000	
Lat. K	0.690**	0.799**	0.728**	0.780**	0.998**	1.000

* Significant at 5 % level of significance

** Significant at 1 % level of significance

Conclusion
It is concluded that the integrated application of 75% N +100%P+ 50% K through chemical fertilizer and 50% K through gliricidia green leaf manuring at 30 DAS resulted in improvement in potassium fractions and yield of soybean grown in Vertisols under rainfed conditions.

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