II. REVIEW OF LITERATURE

The subject of potassium fixation in soils has been reviewed by Brind (1949), Reitemeier (1951), Nama Moorhy et al (1952), Schuffelen and Marel (1955) and Agarwal (1960). A brief review is presented under the following heads for the purpose of this study:

1. Forms of potassium in soils;
2. Nature of potassium fixation in soils;
3. Factors affecting potassium fixation in soils;
4. Potassium fixation capacity of soils;
5. Methods of determination of potassium fixation in soils; and
6. Availability of fixed potassium to plants.

1. Forms of potassium in soils

The behaviour of potassium in the soil is rather complex. Its solubility ranges from easily soluble forms to insoluble forms such as primary and secondary minerals. The total potassium content of a soil, however, depends on the mineral composition of the parent material, leaching, type and degree of weathering.

The soil potassium can be divided into four categories:

1. Soluble potassium - The potassium existing at any one time, dissolved in water of a soil, under field moisture conditions and relatively unbound by cation exchange forces, is considered as soluble potassium. Its concentration, varies greatly from soil to soil and also in the same soil on different occasions, depending on several factors, such as the amount of adsorbed potassium, the water content of a soil, kind and concentration of other ions present, and absorption by plants. Anderson et al (1942) reported that in humid area soil samples contained between 1 to 10 p.p.m. of K₂O, which was about one per cent of the exchangeable potassium. The soluble potassium
is easily available to plants; yet, quantitatively it is not considered important owing to its small amount.

ii. Exchangeable potassium - The potassium which is adsorbed on the soil material and is replaceable with normal neutral salt solution, is named exchangeable potassium. The content of exchangeable potassium depends on such factors as the mineral composition of the exchange material, soil texture, water content, weathering and leaching conditions, fertilization, liming, kind and concentration of competing cations, etc. The content of exchangeable potassium in mineral soils is usually less than one per cent of the total potassium. In sandy soils the exchangeable potassium is usually less than in heavy soils owing to less weathering, lower exchange capacity and more leaching. The exchangeable potassium is considered completely available to plants either directly by contact exchange or indirectly by changing into soluble potassium.

iii. Fixed potassium - If potassium added to a soil is so firmly bound that it is not immediately replaceable with neutral salts it is said to be fixed. The fixed potassium is often included with the lattice potassium in the category of non-exchangeable potassium. The fixed potassium represents actually a natural, transitional stage between the exchangeable potassium and the lattice potassium from which it is impossible to distinguish it sharply. Fixed potassium is available to plants only to the extent to which it is released by defixation.

iv. Lattice potassium - The major portion of the total potassium in most mineral soils resides in the potassium bearing primary and clay minerals in non-exchangeable form. The primary minerals are muscovite, biotite and potash feldspars. Of the clay minerals only illite has a substantial potassium content. The lattice potassium is made available to plants by weathering and the amount released is, therefore, a function of the soil texture.
2. Nature of potassium fixation in soils

Many theories have been proposed to explain the mechanism of potassium fixation in soils. It has been shown rather conclusively that potassium fixation occurs in fine clay fractions of 2:1 type clay minerals (Page and Bauer 1940, Joffe and Levine 1947, Stanford 1948, Chatterjee and Ray 1954, Mitra et al 1958). The modern concept, based on the findings of Page and Bauer (1940), is that potassium fixation is due to the entrapping of exchangeable potassium in voids in dehydrated montmorillonite minerals. During the drying process of montmorillonite with solutions of potassium salts, the sheet of the lattice contracts. The potassium ions \((r = 1.33\text{Å})\) lose their shell of oriented water molecules and are forced into the open hexagonal holes between the layers \((r = 1.4\text{Å})\).

Stanford (1948) reported that micaceous minerals can fix the potassium under moist conditions. Wiklander (1954) concluded that in micaceous minerals fixed potassium is bound between the basal planes, in hexagonal oxygen cavities, normally occupied by potassium, as a lattice constituent. By leaching and weathering, a part of the lattice potassium close to the particle surface, is removed and substituted by other ions, more or less well fitted to these places. On addition of potassium salts, the K ions migrate back into these normal positions, thus rebuilding the lattice and becoming fixed.

Bailey (1942) and Wear and White (1951) presented evidence to show that minerals with stronger forces at the clay surface, such as beidellite or illite, fixed more potassium than minerals with less stronger forces, such as montmorillonite. Barshad (1954) reported that the magnitude of the interlayer charges rather than the origin of the charge, determines cation fixation in micaceous clays.

Wear and White (1951) noticed, that in illite a large amount of
potassium was already fixed between the planes, which decreases the subsequent fixation. Mareel (1954) found an illite, with open lattices, in Dutch basin soils, which strongly fixed potassium. He observed that in contrast with vermiculite, the open illite was resistant to strong acids and did not readily lose potassium fixation capacity by acid treatment.

Rama Moorthy et al (1952) attributed potassium fixation in Gangetic alluvial soils (India) to micaceous minerals of this region. Chatterjee and Ray (1954) found that, under alternate wetting and drying conditions, the clay fraction of montmorillonite soil fixed a considerable amount of potassium, when treated with a saturated potassium chloride solution in alkaline medium and fifteen per cent of montmorillonite, was converted into illite. Chatterjee and Ray (1958) reported that by potassium fixation, the potassium content of H-montmorillonite was increased from 0.5 to 3.0 per cent.

3. Factors affecting potassium fixation in soils

1. Potassium concentration - The increase in potassium concentration in soils generally leads to increase in the potassium fixation (Volk, 1934; Chamnade, 1936; Shaw and Mc Intire 1937; Levine and Joffe, 1947; Denizot and Matheiu, 1952; Karim and Malek, 1957) because more potassium goes into exchange complex by mass action, which is the first step of fixation. Wiklander (1954) stated that, in accordance with the equilibrium formula, both the capacity and rate of fixation should increase with the further concentration of added potassium salts. A soil, not fixing potassium at a certain concentration, may fix it at higher concentrations.

ii. Wetting and drying - Fixation of potassium in soils is strongly influenced by wetting and drying of soils. It is now evident that there may be either fixation or release of potassium in soils, when they are dried (Reitemeier, 1951). Generally fixation occurs when the initial level of
exchangeable and soluble potassium is high, while release occurs when the level of such potassium is low (Attoe 1947, Wiklander 1954 and Scott et al. 1957). Apparently the effects of drying are associated with the attainment of an equilibrium in distribution among the various forms in soils. Very little is known about the soil-potassium-moisture relations, that exist when soils are progressively wetted and dried with increasing amounts of added potassium.

iii. pH - The effect of pH on the fixation of potassium in soils, has been a controversial subject for many years. Results of a great number of experiments to determine the nature of the relationship between soil pH and potassium fixation have been contradictory in many cases. The problem is an extremely important one, because of the relationship it bears to liming in acidic soils management programme. In general, it is considered that an increase in pH of a soil leads to higher fixation, and a decrease of pH reduces the fixation which in hydrogen-saturated soils may become negligible (Wiklander 1950, Puffeles 1954, Karis and Malek 1957 and Misra 1958). However, all soils do not show increased potassium fixation, if their pH is increased (Worsham and Sturgis 1942, Peech and Bradfield 1943). Attoe (1947) concluded that pH affected potassium fixation in moist storage; but on drying the potassium-treated soils, it had no effect on fixation. Stanford (1948) found that on drying at 100°C bentonite fixed about 5 me potassium per 100 grams at pH 4.0 and 2.0 me potassium at pH 7-10, illite instead fixed 1 me, potassium per 100 grams at pH 4.0 and 4.0 me per 100 grams at pH 10.0.

iv. Exchangeable cations - In the study of potassium fixation in soils, the cations adsorbed on the exchange complex have not received due consideration from the workers, although it is of both practical and theoretical importance to find out the effect of adsorbed cations on the fixation of
subsequently added potassium. Joffe and Levine (1947) showed that potassium fixation was reduced when potassium had to compete with calcium for exchange positions and that fixation increased proportionally to the amount of potassium entering the exchange complex. Wiklander (1950) observed a great decrease in potassium fixation when micaceous clay was saturated with hydrogen, potassium and ammonium cations and increased when saturated with calcium, especially sodium.

v. Time — It is presumed that potassium fixation proceeds from the surfaces and edges to the interior of the soil particles and the rate of fixation depends on ion diffusion. Potassium fixation is likely to be rapid in the beginning and continues to slow down as the reaction proceeds towards the equilibrium point. DeTurk, Wood and Bray (1938), working with silt loam soil, observed that potassium fixation increased with time and reached an equilibrium in about six months. Chaminade (1936), Martin et al (1946) and Stanford and Pierre (1947) reported that potassium fixation occurred at a very fast rate, 80 to 90 per cent being fixed in 10 minutes. Karlson (1952) obtained 70 per cent fixation in two hours. Karim and Malek (1957), working on clay loam, loam, silt loam and sandy loam soils of East Pakistan, found that potassium fixation increased with time, within the limits of 60 days' period, the intensity of fixation being greatest in the last days.

4. Potassium fixation capacity of soils

It is very difficult to make a comparison of the figures given by various workers for the potassium fixation capacity of soils, as the amount fixed differs with the method used. The results obtained by some workers are given below:

Schuffelen and Marel (1955) reported, that Poona and Jalgaon soils
of India fixed 37 and 40 per cent of applied potassium (1000 ppm) under wet conditions and 58 and 55 per cent under dry conditions respectively. Schroeder (1955) noted that loess soil fixed 45 mg. potassium per 100 grams of soil. Karim and Malek (1957) found that clay loam, loam, silt loam and sandy loam soils of East Pakistan fixed during 60 days period 56.5, 61.8, 69.8 and 55.0 per cent of added potassium (240 lbs/A) respectively. Mitra et al (1958) reported that Karnal soil (Punjab) fixed 53 mg potassium per 100 grams of soil, i.e., 23.7 per cent of potassium added under wet conditions. DeWormrum (1958) observed that the weathered, black, red and yellow soils of prairies fixed 1000 to 3500 lbs potassium per acre. The dark soils had a higher fixing capacity than others.

5. Methods for determination of potassium fixation in soils

The methods used for the determination of potassium-fixing capacity of a soil are commonly based on the following principles:

A known amount of potassium chloride is added to a certain amount of a soil. After keeping the soil and the potassium solution for the desired time (wet fixation), the solution is filtered off. The soil is washed with the salt solution, which leaches out soluble and exchangeable potassium ions. In the filtrate potassium is determined. In an untreated sample of the soil the soluble and exchangeable potassium are determined by leaching with the same salt solution. From the amount of potassium added and potassium concentrations of both leachates, the amount of fixed potassium can be calculated. In case of dry fixation the soil and the solution, containing the potassium salt, are equilibrated and dried at a pre-determined temperature. It is also treated in the same way as the wet fixation.

The above procedure is purely conventional, as the amount of the added potassium solution, the amount of soil taken, the reaction time, the
drying procedure and the salt solution used to remove soluble and exchangeable potassium, are chosen arbitrarily (Schuffelen and Marel 1955).

6. **Availability of fixed potassium to plants**

The availability of fixed potassium to plants is a controversial subject, as the results of the experiments to determine availability of fixed potassium to plants are contradictory. This is of practical importance, as it determines the harmful effects of potassium fixation. The results obtained by various workers are as follows:

Chaminade (1936) found, in Neubauer’s experiments, that about 16 to 19 per cent of the fixed potassium could be removed by oat seedlings from a soil, which fixed potassium strongly and was treated before the experiment with potassium salts under moist conditions. Kolodny and Rubbins (1940) reported that fixed potassium by Wyoming bentonite was only slightly available to tomatoes. Fine (1941) observed that all of the potassium fixed by bentonite was available to corn and wheat and one-fourth of it became available to tobacco. Evans and Attoe (1948) calculated that oats grown in Mischlerich pots in nine months removed 24 to 47 per cent of potassium which was fixed. Attoe (1949) determined that 7 oat crops of heading stage in two years removed 78 to 98 per cent of the applied potassium from Miami and Spencer silt loam which fixed up to 56 per cent of the potassium which was applied at the rate of 50 and 100 lbs per acre.

Marel and Vanekamp (1955) observed that the potassium fixed by soil from potassium fertilizer application, was available to most of the plants but not to potatoes. Mortland et al (1957) observed that potassium fixed by vermiculite and montmorillonite was available for plant growth but not of illite. Marel (1959) studied potassium fixation by illite, vermiculite and montmorillonite and found that potassium was weakly held by illite, the most common
potassium fixing mineral, and may become available even in soils of high fixing capacity. Thus it seems that contradictory results have been reported by various workers.

The literature reviewed above shows that the behaviour of potassium in soils is very complex. Its fixation in soils and availability to plants depend on many factors, which require a thorough investigation.