PYROPHOSPHATE AND POLYPHOSPHATES AS SOURCES OF PHOSPHORUS FOR PLANT

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1- INTRODUCTION

In recent years considerable efforts are being made to develop salts of polyphosphoric acids as phosphatic fertilizers. Since the polyphosphates are more concentrated in phosphorus than orthophosphates they can be transported at less cost per unit of nutrient than orthophosphate-based-fertilizers.

Other advantages attributed to the use of polyphosphate based fertilizers compared with orthophosphate are: Lower shipping cost per unit of plant food, Less problem of sludge formation in shipping and application equipment, Ability to incorporate higher concentrations of some micronutrients (Fe, Mn, Zn. & Ca) into liquid fertilizers.

The primary disadvantage of polyphosphates is that they have been more expensive than orthophosphates. The price differential, however, continues to decrease with better technology. Some questions have arisen as to the efficiency of polyphosphate as a plant nutrient. Tests conducted over a variety of soils and crops have shown it to be as effective as orthophosphate as a source of phosphorus to the plant.

While the efficiency of these materials as a source of phosphorus for plants has been evaluated in a number of experiments by Tennessee Valley Authority (Huffman (1968), little information is available on its agronomic performance on Egyptian soils. Thus, the aim of the peresent investigation is to study the following points :

a) The rate at which condensed phosphates are hydrolyzed in soils, and the effect of soil moisture and temperature on its hydrolysis.

b) The adsorption of condensed phosphates and orthophosphate by selected Egyptian soils.

c) The effectiveness of condensed phosphate as a plant nutrient source for phosphate as comparing with the orthophosphate fertilizer .

2- REVIEW OF LITERATURE

Polyphosphate-based fertilizers are gaining wide accptance as a source of phosphorus in the fertilization of field crops. Until several years ago, nearly, all the phosphorus used as a plant nutrient was of the ortho-phosphate type. In the past several years, polyphosphate have received wide publicity and moderate use as a source of P, Hossner and Phillips (1971).

The differences between the orthophosphate and polyphosphates has to do with their chemical structure. Orthophosphate contains only one phosphate atom per molecule. The polyphosphates as represented by pyro-, tri-poly-, and trimetaphosphate, always contain two or more phosphate atoms per molecule.

The value of polyphosphates as an immediate source of phosphorus to plant depend upon its hydrolysis to ortho-phosphate, and its reaction with soil constituents, Sutton & Larsen (1964) and Sutton *et al.* (1966).

It was suggested to classify the review to the following points : -

2-1- Hydrolysis of condensed phosphates :

The increasing use of condensed phosphates (polyphosphates) in fertilizers has simulated interest in their behaviour in soils. The value of pyrophosphate as an immediate source of phosphorus is largely dependent on its rate of hydrolysis to orthophosphate. Pyrophosphate and polyphosphate hydrolyze to orthophosphate at variable rates depending on soil, temperature, moisture, pH and biological activity, Blancher & Hossner (1969) , Van Wazer (1958) and Fleming (1969).

2-1-1- Effect of temperature on the hydrolysis of condensed phosphates :

Hossner & Phillips (1972) and (1971) reported that the hydrolysis of pyrophosphate increased with increasing temperature. At 35°C the pyrophosphate was completely hydrolyzed after 4 days under flooded conditions, Sutton *et al.* (1966) reported that hydrolysis of pyrophosphate was slow at 30-35°C. They also stated that the effect of temperature on the pyrophosphate hydrolysis was related to the biological activity of the studied soils. They found that inefficient production of the appropriate enzyme and low temperature restricted the hydrolysis of pyrophosphate. The same study showed that the increase of soil temperature from 10 to 30°C approximatly doubled the hydrolysis of pyrophosphate in the soil of lower biological activity.

Hashimoto and Wakefield (1974) reported that the rate of hydrolysis of pyrophosphate is dependent on both temperature and the properties of the soil. They found that the time required for hydrolysis of 50 percent of the pyrophosphate to orthophosphate was 25 to 60 days at 5°C, 4 to 13 days at 25°C, and at temperature between 25 and 40°C , there was a moderate decrease in the rate of hydrolysis.

2-1-2-Effect of soil moisture on the hydrolysis of condensed phosphates :

Many investigators reported that soil moisture affects the hydrolysis of condensed phosphates. Hossner and Phillips (1971) found that when the soil was flooded, hydrolysis was more rapid than at 1/3 atm. moisture content and the hydrolysis of pyrophosphate tended to go to completion. The tendency of hydrolysis not to go to completion at 1/3 atm. moisture has been shown by other studies, Gilliam & Sample (1968) and Hassner & Melton (1970).

Racz and Savant (1972) suggested that the increase in pyrophosphate activity in the flooded soils may be the reason for the difference which was observed between the hydrolysis in flooded and soil maintained at field capacity moisture content.

2-1-3- Effect of pH on the hydrolysis of condensed phosphate :

An attempt was made by Sutton and Larsen (1964) to correlate the half-life of pyrophosphate in the soil with several soil properties including pH, percent clay and biological activity. They reported that most of the variation in hydrolysis rates could be explained by variations in biological activity and soil pH. As both soil pH and CO_2 evolution increased, the rate of hydrolysis increased. They attributed the pH effect which they observed to a positive correlation between pH and biological activity.

Gilliam and Sample (1968), reported that the rates of hydrolysis of pyrophosphate varied according to the pH values of these investigated soils. The decreasing of the rate of pyrophosphate hydrolysis was much greater ~~when soil pH was increased to values above pH 7.~~

Hossner and Melton (1970) found that hydrolysis of pyrophosphate was more rapidly in acid soils than in basic soils, this is in contrast to the results of Sutton and Larsen (1964) who found a positive correlation between hydrolysis rate of pyrophosphate and increasing soil pH.

2-1-4- Effect of soil chemical properties on the hydrolysis of condensed phosphates :

Hossner and Melton (1970) found that soil properties such as mineralogy, clay percent, extractable Al and free iron oxides did not have a noticeable effect on the hydrolysis of applied pyrophosphate. They also treated soils with $CaCO_3$ and found that $CaCO_3$ redused the pyrophosphate hydrolysis. The mechanism of $CaCO_3$ in reducing pyrophosphate in acid soils is unknown .

Hashimoto et al. (1969) suggested that colloided gell and clay minerals catalyze the hydrolysis of pyrophosphate. In very dilute solutions, Kaolinite, Montmorrillonite, and particulary Goethite showed some degree of this catalytic activity, but gibbsite had no such effect. Racz and Savant (1972) proposed that the pyrophosphate hydrolysis in soil is largely a pyrophosphatase - catalysed reaction. However when pyrophosphate is added to soil it is adsorbed by the soil complex and/ or chemically precipitated. They added that the chemical precipition of the added pyrophosphate decreased its rate of hydrolysis.

2-2- Uptake of phosphorus from condensed phosphate fertilizers :

Although plants have been shown to utilize some condensed phosphates directly, the adsorption of phosphorus from these phosphates is usually as orthophosphate after being following hydrolyzed (Savant and Racz (1972).

The effects of condensed phosphate on final yield of a particular crop will thus be a complex interaction between the rate of hydrolysis in the soil, the time of maximum requirement for phosphate by crops, and the phosphate status of the soil. Sutton and Larsen (1964) determined the availability of pyrophosphate to plant in short-term water-culture experiments and in pot culture. They found that, in soils where the biological activity is not restricted, pyrophosphate did not persist long enough for hydrolysis. In a soil where pyrophosphate persisted, however, the P-uptake recorded was lower than that from orthophosphate. The same authers (1966) studied the P-uptake by barley from the ortho- and pyrophosphate fertilizers labelled with ^{32}P and observed that uptake of P from pyrophosphate was lower than from orthophosphate. Engelstad and Allen (1971) reported that triammonium pyrophosphate was found to be less effective than monoammonium orthophosphate when both were added as sources of P for corn (Zea mays L.) grown in cool soil (16°C). No differencess was found between these sources when applied to warm soil (24°C). Also, El-Nennah and El-Kadi (1976), determined the availability of pyrophosphate to alfalfa plants as compared with orthophosphate in alluvial and calcareous soils. They found that total P-uptake and Y-values were lower from pyrophosphate than that from orthophosphate. Besides, the $CaCO_3$ in calcareous soil was not favourable for the availability status of both ortho- and pyrophosphate.

On the other hand, Blancher and Hossner (1969) found an equal effect of sodium salts of orthophosphate and pyrophosphate as a P sources for corn. Similar results was found by Gilliam (1970), who reported that pyrophosphate and orthophosphate solutions were equally effective in supplying P to wheat (Triticum vulgare), corn (Zea mays L.) and barley (Hordeam vulgare L.).

Selke and Ebert (1965) foud that the initial uptake of P by plants was lower from water-soluble condensed phosphates than from dicalcium phosphate ($CaHPO_4$), this difference almost disappeared as the time was proceeded.

Moreovers Takefuji (1966) found that the effects of potassium polyphosphate as fertilizers on short-term crops such as bush beans and oats were somewhat less than those of superphosphate.

Experiments carried out by Terman and Engelstad (1966) showed that ammonium polyphosphate (APP) was usually equal to or slightly superior to monoammonium phosphate (MAP) as a source of P. Besides, both (APP) and ammonium orthophosphate were usually superior to concentrated superphosphate (CSP) and other calcium phosphates for early growth response. There was some evidence that APP tends to be a superior source of P on soils having pH values near 7 rather than on soil either much more acid or alkaline. Yanishovskii et al. (1968), found that