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Use of Silicate and Rice Straw on the Availability of Si and P under Submerged Soil

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ABSTRACT

This experiment was conducted at NRC to study the effect of three treatments, namely submergence alone, submergence + rice straw (7.0 gm/kg soil) and submergence + sodium meta silicate (467 mg Si/kg soil) on Si and P availability in Sakha clay loam soil under flooding and incubation for 30 days at 30°C $\pm$ 2.The results showed that available Si increased after 10 days from submergence as affected by waterlogging alone then decreased gradually with time to the minimum after 30 days from submergence and under incubation at 30°C$\pm$2.The effect of submergence + rice straw treatment took the same previous tend of waterlogging alone, although all the Si values were higher than those obtained by submergence alone. The effect of waterlogging + sodium meta silicate application was the best for obtaining more available Si compared with submergence alone and submergence + rice straw treatments. Available P responded positively to waterlogging, straw and sodium meta silicate application and increased gradually from (0) time (dry) to 30 days from submergence under 30°C $\pm$ 2. The highest P values were obtained by waterlogging + sodium meta silicate followed by waterlogging + straw and waterlogging alone in decreasing order.

Key words: Submergence, rice straw, P, available, incubation, silicate.

Introduction

Rice (*Oryza sativa* L.) root systems play an important role in uptake of water and nutrients from soil (Yang *et al*., 2004).

Flooding a soil sets in motion a a series of physical, chemical and biological processes of oxygen in the flooded soils are triggered by lack of oxygen in the flooded soils system, the soil gets reduced for which energy is provided by mineralization of organic carbon. The reduction process is regulated by the presence and availability of electron acceptors (mainly Fe^{+3} and SiO_4) and electron donors (OM), soil reduction is accompanied by change in the pH, Eh, specific conductance, sorption, desorption, ion exchange and exchange equilibrium, which in turn greatly influence the availability of plant nutrients, uptake and utilization by wetland rice (Sharawat, 2005).

On the other hand, the need for supplying crops with organic and inorganic fertilizers was proved to be very essential production of higher yield and for improving its quality (Permuzic *et al*., 2002 ; El-Ashry *et al*., 2008). Furthermore, addition of OM to the different soils clearly increased the water soluble Si in percolation solution more than Si values obtained under submergence alone (Siam *et al*., 2015 ; Tong *et al*., 2011).

Organic fertilizer affected pH values in soil solution than of inorganic fertilizers. Also, use of organic matter for rice growing has an advantage to improve the pH buffering capacity of soil and nutrients availability and retention of soil. Furthermore, the addition of organic fertilizer decreased of Eh as compared with inorganic fertilizer and control (Siam *et al*., 2015 ; Grybos *et al*., 2009). They added also that pH values decreased gradually after 45 days after starting (DAS) till the end of rice growing period and these decrease were also in very little range and varied with the moisture regimes.

It is second most abundant element in the soil Silicon (Si) exists mainly as monosilicilc acid (H_4SiO_4) at concentrations ranging from 0.1 to 0.6 mM in the soil solution and the concentration of the soluble SiO_2 in the extracts always well flew solubility of amorphous silica Balakhnina and Borkowska, (2013), which is taken up by plants in this form (Ma and Takahashi, 2002). After the uptake, Si accumulates in the epidermis of various tissues, mainly as polymer of hydrated amorphous silica.

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The aim of our work was to study the effect of submergence, rice straw and sodium meta silicate on the availability of Si and P.

Materials and Methods

Sakha soil sample was chosen to carry out this experiment to study Effect of Submergence, Rice Straw and Sodium Meta Silicate on the availability of Si and P. This soil is low in available phosphorous 2.5 ppm P according to Olsen *et al*. (1954).

Soil samples at depth of (0-30 cm) from the surface layer of clay loam soil has a pH of 8.00; 1.8% O.M; 2.7% $CaCo_3$; 26.7% sand, 39.6% silt and 33.7% clay. Plastic pots, contain air dried soil were arranged in a complete randomize design. Soil sample determination was conducted by Jackson (1982) and Cottenie *et al*. (1982).

The experiment consists of three treatments as follows:

a) Submergence alone, b) Submergence + 7.0 g rice straw/kg soil and c) submergence + 467 mg Si/kg soil (added as sodium meta silicate).

Ten g of 2 mm samples of each soil were transferred to 50 ml plastic centrifuge tubes and submergence with 25 ml of distilled water then incubated in the dark at 30 $\pm$ 2°C for 30 days; 4 replicates from each soil treatment were drawn at 0 (dry soil), 10,20 and 30 days after submergence and centrifuged. The supernatants were analysed for phosphorus and silicon colorimetrically (Weaver *et al*., 1968).

Results and Discussion:

Effect on water soluble Si:

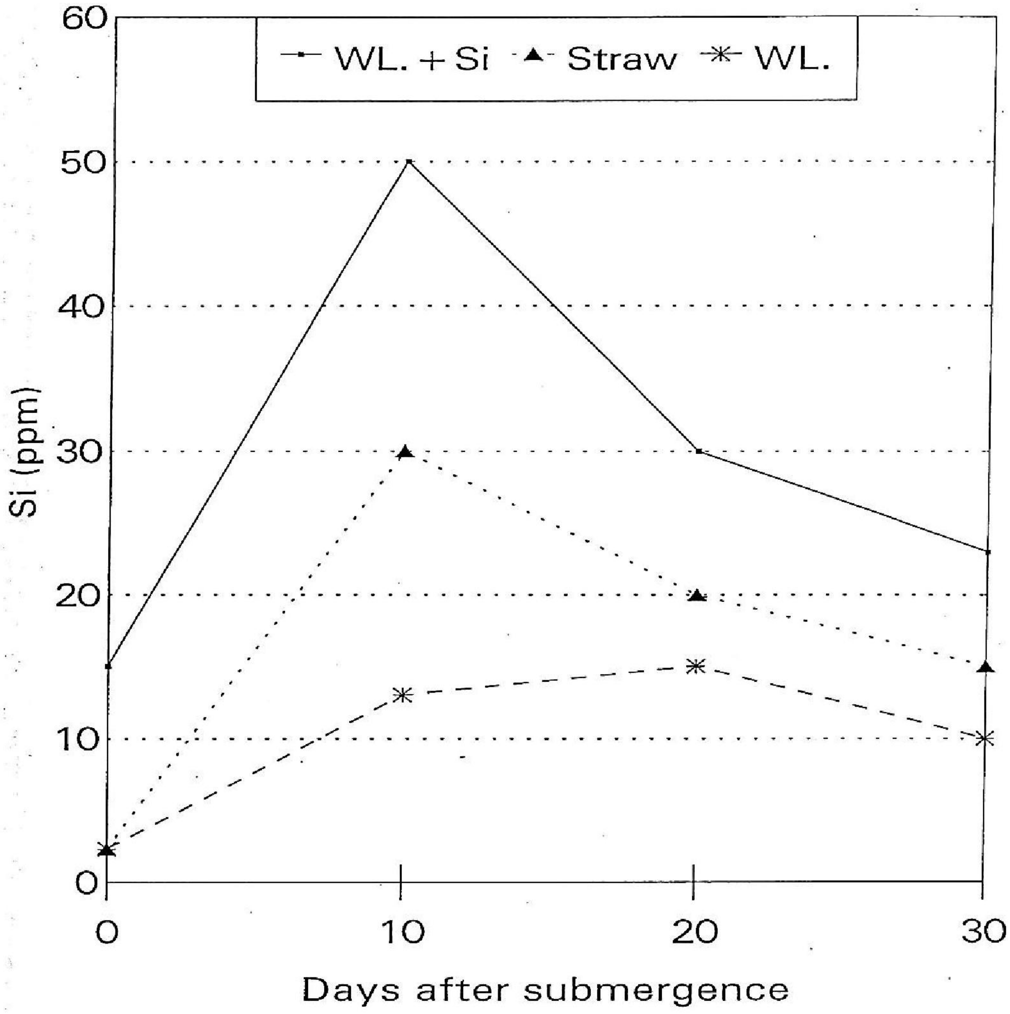
Data presented in Table (1) and illustrated in Fig. (1) show that soluble Si increased as affected by waterlogging alone from 2.3 ppm (at 0 time) to 13 and 15 ppm after 10 and 20 days while in clay loam soil Si increased during the first 10-20 days, and then decreased in all the studied soil till 30 days from submergence. These results are in full agreement with those obtained by Holah, (1989) ; Pathak *et al*., (2010) from submergence, respectively. Then Si decreased and reached 10 ppm after 30 day from submergence. Results reveal that the highest Si values were obtained during the first 10-20 days. The increase in the Si concentration after flooding may be due to the release of silica by the following factors: a) reduction of hydrous oxides of Fe (III) sorbing silica, and b) action of CO_2 on aluminosilicates Venterea *et al*. (2005), who stated that the pH values of submerged sodic soil are lower than those of aerobic soil because of accumulation of CO_2. They added the pH of alkaline soils is highly sensitive to changes in the partial pressural CO_2 (PCO_2).

The subsequent decrease may be the result of recombination with aluminosilicates, following the decrease in PCO2. In this respect, results obtained in this experiment are in good agreement with those obtained by Nayar *et al.* (1982) who reported that, upon flooding, silica increased in all the extractants during the first 10-20 days and then decreased.

Data in Table (1) and illustrated in Fig. (1) show that addition of rice straw to submerged and incubated soil for 30 days at 30°C $\pm$ 2 increased the water soluble Si in percolating water from 2.3 ppm (at 0 time) to 30 ppm after 10 days from submergence and then decreased to 20 and 15 ppm after 20 and 30 days from submergence, respectively.

Table 1: Effect of waterlogging, rice straw and sodium meta silicate on the availability of Si and P in Sakha clay loam soil.

Submergence Periods in days	Treatments					
	Submergence alone		Submergence + rice straw		Submergence + sodium meta silicate	
	Si	P	Si	P	Si	P
	(ppm)		(ppm)		(ppm)	
0 (dry soil)	2.3	0.1	2.3	0.1	15.0	0.1
10	13.0	0.3	30.0	0.9	50.0	1.1
20	15.0	0.7	20.0	1.5	30.0	2.0
30	10.0	1.0	15.0	2.0	23.0	2.9



Si=1000 mg sodium meta silicate/kg soil. WL. = waterlogging alone

Fig. 1: Influence of waterlogging, rice straw and sodium meta silicate addition to Sakha caly loam soil on the availability of silicon.

The obtained values of Si in the waterlogging + rice straw treatment were clearly higher than those obtained under waterlogging treatment alone. These results indicate that straw application promoted the soil reduction more than waterlogging alone. In this concept, data also reveal that addition of OM to the three soils clearly increased the water soluble Si in percolation solutions more than Si values obtained under submergence alone (Holah *et al.* 2015 ; Pathak *et al.*, 2010). These results confirm those of Tong *et al.* (2011), Subramanian and Gopalswamy, (1991) and Takahashi (1981) reported that the amount of water soluble silicate increased with the development of reduction in the flooded soils. This fact suggests that the effect of the increased soil reduction caused by straw application on the availability of soil Si is time dependent. The effect of straw addition in this experiment may be due to the pH of the used soil (Sakha soil pH 8.0). In these concern the addition of OM to the submerged soils clearly decrease pH values after 10 days from submergence, then they slightly increased till 30 days. The pH values of the all studied soils after 30 days were low than those of pH values at (0) time. Generally, data indicate that all pH values under the combination of submergence and OM addition were lower than those obtained under submergence alone. Xie *et al.*, (2012) and Zhang, (1984) stated that the pH value affect the release of Si in percolation water and found that the addition of straw to soils differing in their pH values, induced Si release from about 0.5% in the soil with pH 5.6 and 20% in the soil with pH 7.3, regardless of the added rate. They also stated that the pH values of flooded alkali, calcareous soils and acid soils after reduction can be explained quantitatively by one or more of the following equilibria: Na_2CO_3-H_2O=CO_2, $CaCO_3$-H_2O- -CO_2, $MnCO_3$-H_2O-CO_2, $Fe_3(OH)_8$- H_2O-CO_2 Yang, (2004). Furthermore when 3% organic matter (starch) was added to the different submerged soils as a source of actively decomposing organic matter, the reduction of waterlogged soils and change of Eh values were faster and sharper compared with those under submergence treatment alone especially after 10 days from submergence date. They slightly increased with increasing submergence period (Holah *et al*., 2015; Favre *et al*., 2002).

Results obtained in this work are in good agreement with the findings of Ma and Takahashi, (1991b) ; Sumida and Ohyama (1991) who stated that the straw treatment increased the Si concentration in the percolating water as compared to the control (waterlogging alone), then it significantly decreased with the time of submergence.

Table (1) and Fig (1) show that addition of sodium meta silicate to waterlogged Sakha clay loam soil increased Si concentration in percolation solution from 15 ppm (at 0 time) to 50 ppm after 10 days from submergence date. Afterwords Si concentration decreased gradually to reach 23 ppm after 30 days. Results show that all Si concentration values obatined under the waterlogging + sodium meta silicate application, were clearly higher compared with those obtained under the waterlogging + rice straw, or waterlogging alone. These results may be due to the lower release of Si from rice straw as compared with this released from sodium meta silicate. Also, not all the Si content in rice straw was released in the percolation solution during the submergence period. Ma and Takahashi, (1991b) confirmed these results, and stated that + Si straw application increased the Si concentration in the percolating water, the Si content of rice shoots and soil available silicate. However, compared to the Si contained in added straw, the release of Si from the + Si straw was only about 6% in the first cultivation and 3% in the second cultivation respectively. Also, they found that Si in the + Si straw was lower than that of silica gel, while rice plant absorbs Si in the form of silicic acid, the availability of Si in rice straw to rice plants depends on transformation rate of silica gel to silicic acid in soil., Also, the decomposition of rice straw in submerged soil differs from that in a well drained soil in two respects, it is slower and the end products are different (Ponnamperuma, 1972).

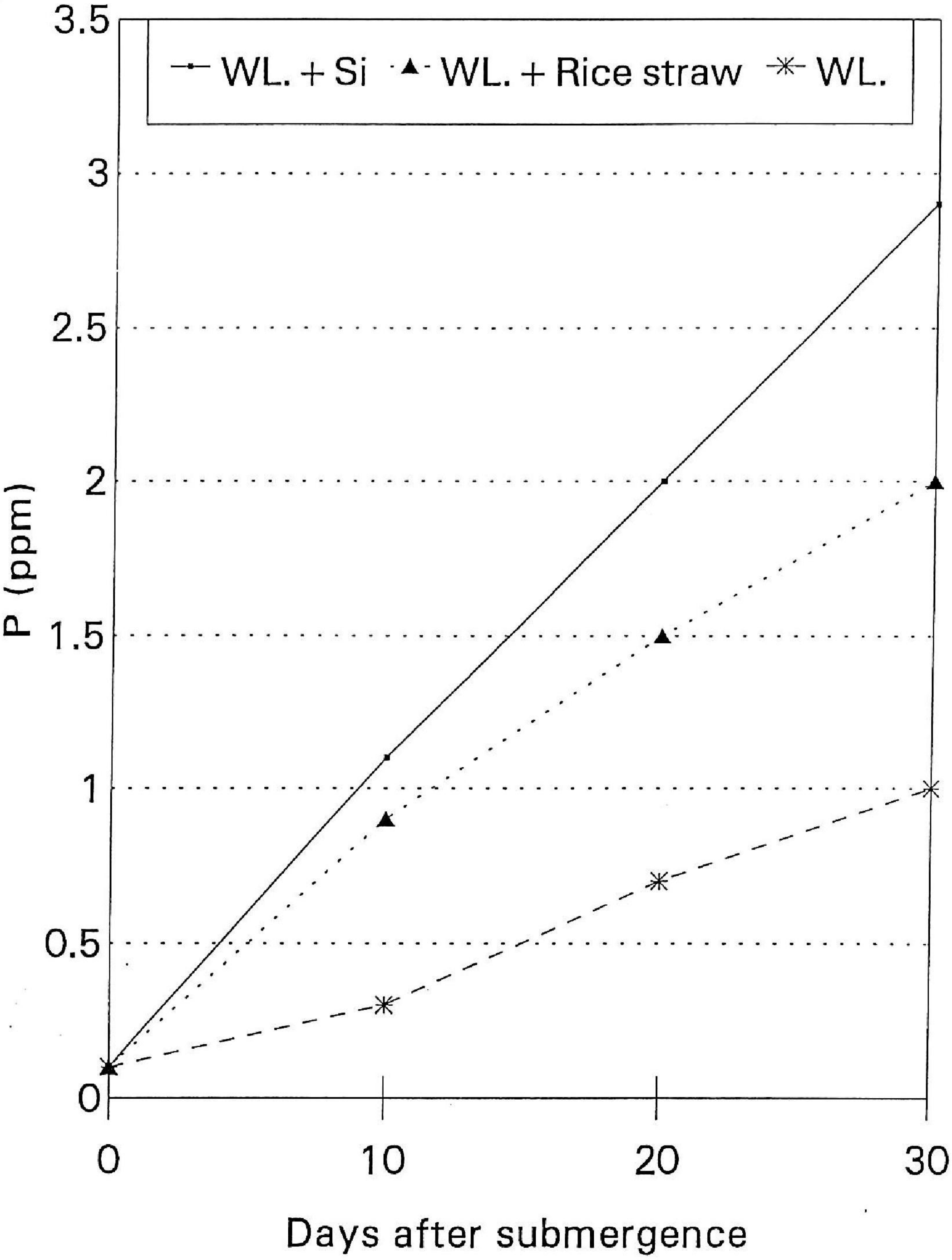
Effect on P availability

Data presented in Table (1) and illustrated in Fig. (2) show that I concentration in the percolation solution of Sakha clay loam soil increase from 0.1 ppm to 1.0 ppm by submerging the soil under incubation at 30 °C± 2: for 30 days. Results obtained in this experiment are in good agreement with those obtained by Suduan, (2003) and (Synder and Nathan, 2002). In this respect, Ponnamperuma, (1972), reported that when a soil is submerged, the oxygen supply is cut off and reduction set in. A striking consequence of reduction is the increase in the concentration of water soluble P. The increase in concentration of water soluble P in submerged soil is markedly affected by soil properties.

The changes in soil Eh and pH with flooding play an important role in releasing nutrient to the growing plants. Continuous flooding resulted in higher uptake of P in the rice plants than non-flooding and this suggest that the P is the main factor determining the growth of rice plants, and this was strong controlled by soil water regimes. The increases in P absorption by rice plants is expected from increases in solubility of native and applied P and increased rate of diffusion of P to absorbing roots in the continuously flooded conditions (Siam *et al*., 2016 and Willett, 1991).

The pH of the studied soil is about 8.0, and this may increase the solubility of P which is a consequence of the decrease in pH of this soil on flooding for' the solubility of hydroxyapatite increases as pH decreased. This increase in solubility of P is associated with decrease in Eh as reported by Lee *et al*. (2011) and Knowles *et al*. (2012) who reported that the increase in solubility of P in noncalcareous soils is associated with decrease in Eh or an increase in Fe (11).

Data presented in Table (1) and illustrated in Fig. (2) reveal that addition of rice straw to submerged clay loam soil increased the P concentration in the percolation solution from 0.1 ppm (at 0 time) to 2.0 ppm after 30 days from submergence. All the obtained P values by straw treatment were higher than those obtained by submergence alone. In submerged soils, the decomposition of organic matter is almost entirely the work of facultative and obligated anaerobes. Since anaerobic bacteria operate at a much lower energy level than aerobic organisms, both decomposition and assimilation are much slower in submerged soils than in aerobic soils (Venterea *et al*. 2005)



Si=1000 mg sodium meta silicate/kg soil. WL. = waterlogging alone

Fig. 2: Influence of waterlogging, rice straw and sodium meta silicate addition to Sakha clay loam soil on the availability of phosphorus.

The main end product in submerged soils are CO2, Hydrogen, methane, ammonia, amines, mercaptans, hydrogen sulfide, and partially humified residues. One to three tons of CO2 are produced in the plow layer of 1 hectare of a soil during the first few weeks of submergence (Siam *et al*. 2015;

Sudhalakhsmi *et al*., 2007). The obtained results in this study are confirmed by Holah, (1989) who stated that organic manure considerably increased the availability of P and when 2% organic matter was added to the soils, reduction of waterlogged soils and change in soil pH values were faster. These results agreement with those obtained by Siam *et al*. (2016) ; Lee *et al.* (1995) who stated that uptake of P by rice was increased by application of organic matter and by increasing nitrogen rate.

The addition of sodium meta silicate to submerged Sakha clay loam soil increased available P in the percolation solution from 0.1 ppm (at 0 time) to 2.9 ppm after 30 days from submergence date (Table 1 and Fig. 2). The effect of sodium meta silicate on increasing P availability may be attributed to 1) partial saturation of sorption sites by silicate ions, thus decreasing P sorption which results in greater P solubility (Mosalem *et al.,* 1992), and 2) Inactivation of Fe and Al by formation of insoluble compounds with P, but Si competition reduces this formation making more P availability Sharawat, (2005). In addition to stimulating desorption of phosphate anions from soluble phosphates of calcium, aluminum, iron and magnesium, silica fertilizers also have a good adsorption capacity and decrease P leaching by 40-70% (Matichenkov and Bocharnikova, 2001). It is is argued that Si promotes growth by improving the imbalances of nutrients, especially P. In contrast Ma *et al*. (2001) reported that Si decreases P uptake in rice, tomato, cucumber, soybean, and strawberry. Also Abou-Baker *et al*. (2011) Indicated that $MgSiO_4$ gave the highest values of p%.

Conclusion

- Addition of sodium meat silicate as a positive effect on the availability of Si soluble in the percolation solution of Sakha soil compared with submergence alone or submergence + rice straw treatments.
- Results in this study also reveal that all available P in the percolation solution of Sakha soil was higher in sodium meta silicate + submergence treatment than in rice straw + submergence and submergence alone treatments.

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