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Silicon Release Characteristics of Graded Levels of Fly Ash with Silicate Solubilizing Bacteria and Farm Yard Manure in Soil Under Submergence

S. K. PEDDA GHOUSE PEERA[1*], P. BALASUBRAMANIAM[1], P. P. MAHENDRAN[2]

ABSTRACT

An incubation experiment was conducted to study the release characteristics of silicon from native soil and applied sources *viz*, Fly Ash (FA), Silicate Solubilizing Bacteria (SSB) and Farm Yard Manure (FYM). The soil for incubation study collected from Eastern block of Agricultural Engineering College and Research Institute which is low status of plant available silicon. The treatments consist of graded levels of FA *viz.*, 0, 12.5, 25, 37.5 and 50 g/kg of soil with and without SSB and FYM. Six sets of plastic containers consist of 40 numbers in each set to accommodate 20 treatments with 2 replications under Factorial Completely Randomized Design for 15, 30, 45, 60 75 and 90 days duration of incubation. The calculated quantity of FA, SSB and FYM was applied to each container containing 10 g of soil and mixed thoroughly. Extracted plant available Si by using 1N NaOAc (pH 4.0) and estimated calorimetrically at 15 days interval i.e 15, 30, 45, 60 75 and 90 days duration of incubation. The results revealed that among different treatments, addition of SSB + FYM resulted a consistent increase of N NaOAc (pH 4.0) extractable Si from 144.7 mg per kg to 272.2 mg per kg during 15^{th} to 60^{th} days after incubation, thereafter a slight decline in N NaOAc (pH 4.0) extractable Si was observed up to 90 days. Among the different treatments the application of SSB +FYM recorded the highest N NaOAc (pH 4.0) extractable Si of 272.2 mg per kg at 60^{th} day followed by FYM (258.0 mg per kg) on 75^{th} day of incubation. The control recorded the least N NaOAc extractable Si throughout the incubation period. Imposition of graded levels of fly ash and their interaction with various sources viz., SSB, FYM and SSB+FYM have shown significant variations in the N NaOAc (pH 4.0) extractable Si throughout the incubation period. Imposition of fly ash @50 g kg^{-1} of soil with SSB + FYM depicted more release at 15,30,45,60 and 75 days after incubation which was on par with addition of fly ash @25 g kg^{-1} of soil at 90 days after incubation.

Key words: fly ash, release of silicon, silicate solubilizing bacteria, farm yard manure

INTRODUCTION

Silicon depletion can occur in traditional rice soils from the continuous monoculture of high yielding varieties with intensive cultural practice especially if farmers are not replacing the Si removed by rice (Miyake, 1993). The amount of Si available to plants in soil is very small and varies with different soils. However, concentration of Si in the solution increases after flooding as well as with organic matter of the soil. (Ponnamperuma, 1984). Addition of silicate sources to the soil not only increased the available Si but also interacted with native soil and applied sources enhanced the solubility (Subramanian and Gopalswamy,1990). Several sources of Si have been used as Si nutrition for rice. Among them, coal combusted fly ash, which has been used to a limited extent as Si source since it contains 56.2 per cent of total Si in the form of polymerized silicic acids that are difficult to solubilize. The release of Si from fly ash is higher than opal; these facts suggest that the availability

[1]Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur-621712, Tamil Nadu
[2]Agricultural College and Research Institute, Madurai, Tamil Nadu, India.
*Corresponding author's Email: ghouse.agri@gmail.com

of Si in the soil applied with fly ash is increased (Raghupathy, 1993). However, the addition of silicate solubilizing bacteria on the availability of Si under submerged conditions are not yet been studied in detail. Addition of silicate sources to the soil not only increased the available Si but also interacted with native soil and applied sources and enhanced the solubility and decreases the fixation of added phosphorus in soil (Subramanian and Gopalswamy, 1990).

Several sources of Si have been used as Si nutrition for rice. Among them fly ash, which has been used to a limited extent. Hence, the use of fly ash as a source of Si in submerged rice soil under field condition is needs to be investigated in detail. Therefore the present investigation was undertaken to study the release pattern of N NaOAc extractable Si which is considered as an available to rice.

MATERIALS AND METHODS

An incubation experiment was conducted by using sandy loam soil to study the effect of graded levels of fly ash with and without SSB and FYM on the release of Si under submerged condition. The experiment was set in the laboratory at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu. The treatments include *viz.* Control, SSB @ 1 mg $kg^{-1}$of soil, FYM @ 258 mg Kg^{-1} and SSB + FYM with graded Levels of fly ash *viz*. 0, 12.5, 25.0,37.5 and 50.0 mg $kg^{-1}$of soil replicated twice in Factorial Completely Randomized Design. The soil used for the incubation contained the medium available N, P and high available K and available Si was 70 mg per kg. The soil was slight acidic to neutral in reaction without excess soluble salts. The fly ash used in incubation was alkaline in soil reaction with low salts, containing 216 ppm of available Si. The FA applied to each container containing 10 g of soil and mixed thoroughly. The calculated quantity of SSB culture is thoroughly mixed with 2 kg of soil (i.e. 2 mg of SSB culture with 2 kg of soil) and 10 g of this soil is transferred to the each polythene containers meant for SSB treatment. Calculated quantity of FYM is added to each container for the respective treatment receives FYM. The container used for the study was made up of polythene with a capacity of 50 ml. Totally 240 number were used for entire experiment. After imposing treatments, the final volume of water for submergence was maintained 10 ml uniformly in each of the all the containers. Each set of 50 samples were analysed for N NaOAc extractable Si (Imaizumi, and Yoshida, 1958) at 15 days interval ie 15, 30, 45, 60, 75 and 90 days after incubation.

RESULTS AND DISCUSSION

Release of N NaOAc extractable Si

The Si availability was assessed on release in soil during the incubation under submerged condition by the addition of graded levels of fly ash with FYM & SSB. The significant differences in N NaOAc extractable Si was observed by the addition of different sources viz., SSB, FYM and SSB + FYM and the mean N NaOAc extractable Si ranged from 144.7 mg per kg to 272.2 mg per kg. Among the different treatments, addition of SSB + FYM released the highest mean N NaOAc extractable Si of 144.7,179.2,229.7,272.2, 258.0 and 226.0 mg per kg at 15, 30, 45, 60, 75 and 90 days after incubation respectively. This clearly indicates that the Si availability was increased up to 60 days after incubation thereafter a declining trend was observed. In control the least mean N NaOAc extractable Si of 73.8 mg per kg was recorded at 15^{th} days after incubation and an increasing trend was observed due to submergence up to 60 days by recording 125.1 mg per kg there after declined. In the case of SSB and FYM addition alone, a consistent increase of N NaOAc extractable Si was observed from 15^{th} to 60^{th} days after incubation thereafter a constant level of N NaOAc extractable Si was observed up to 90 days. Among the different sources the application of SSB + FYM recorded the highest N NaOAc extractable Si followed by FYM .The control recorded the least N NaOAc extractable Si throughout the incubation period. Application of graded levels of fly ash and their interaction with various sources viz., SSB, FYM and SSB + FYM had significant effect on increase in release of N NaOAc (pH 4.0) extractable Si throughout the incubation period (Fig 1 and Table 1a,1b). Among treatments imposition of fly ash 50.0 mg kg^{-1} with SSB + FYM registered higher release, however addition of 12.5 mg kg^{-1} with SSB + FYM revealed the consistent, progressive increase in release of N NaOAc (pH 4.0) extractable Si throughout the incubation period.

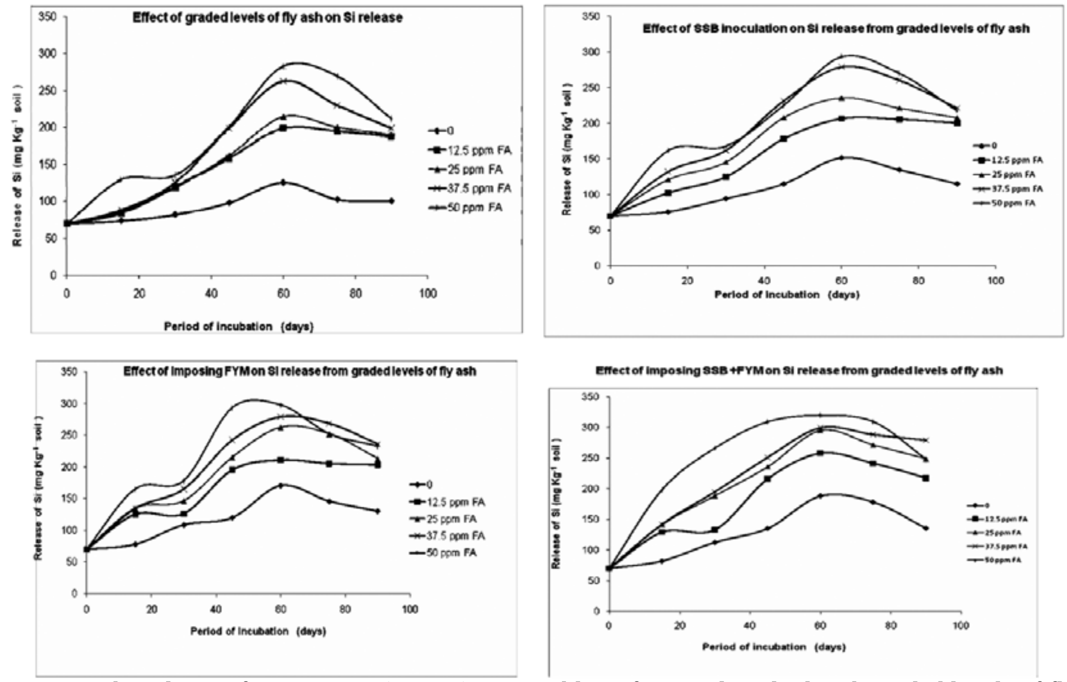

Fig.1: Depicting the release of 1N NaOAc (pH 4.0) extractable Si from soil applied with graded levels of fly ash during the incubation

Table1a: Effect of Graded Levels of Fly ash with and without SSB, FYM on release of N Na O Ac- (pH 4.0) extractable Si* (mg kg^{-1}) in soil at different periods of incubation

Source	15th day						30th day						45th day					
Treatments	Levels of Fly Ash (g Kg $^{-1}$)						Levels of Fly Ash (g Kg $^{-1}$)						Levels of Fly Ash (g Kg $^{-1}$)					
	0	12.5	25.0	37.5	50.0	Mean	0	12.5	25.0	37.5	50.0	Mean	0	12.5	25.0	37.5	50.0	Mean
Control	73.8	84.1	86.1	88.2	129.1	92.3	82.0	119.0	120.1	125.1	135.3	116.3	98.0	158.0	162.0	198.8	201.0	163.6
SSB	75.85	102.5	121	132.2	162.0	118.7	94.3	125.1	145.6	162.2	168.1	139.0	115.0	178.5	208.1	231.6	225.5	191.7
FYM	77.9	125.1	134.8	134.3	165.0	131.8	108.6	126.2	146.5	165.2	178.3	145.0	119.7	195.0	215.2	242.4	293.1	213.1
SSB+ FYM	82.0	129.2	141.4	142.0	198.8	144.7	112.7	133.2	188.6	194.8	266.5	179.2	135.3	216.6	236.0	251.1	309.5	229.7
Mean	77.4	110.2	120.7	137.3	163.7	121.8	99.42	125.8	150.2	161.8	187.0	144.8	117.1	187.0	205.3	231.0	257.3	199.5
		SE d		CD (P=0.05)				SE d		CD (P=0.05)				SE d		CD (P=0.05)		
Factor (F)		2.0		4.2				2.9		6.1				3.2		6.7		
Level (L)		2.3		4.7				3.3		6.8				3.6		7.5		
FL		4.5		9.4				6.5		13.7				7.2		15.0		

*Mean of two replications

Table 1b: Effect of Graded Levels of Fly ash with and without SSB, FYM on release of N Na O Ac- (pH 4.0) extractable Si* Si (mg kg^{-1}) in soil at different periods of incubation

Source	60th day						75th day						90th day					
Treatments	Levels of Fly Ash (g Kg $^{-1}$)						Levels of Fly Ash (g Kg $^{-1}$)						Levels of Fly Ash (g Kg $^{-1}$)					
	0	12.5	25.0	37.5	50.0	Mean	0	12.5	25.0	37.5	50.0	Mean	0	12.5	25.0	37.5	50.0	Mean
Control	125.1	198.8	215.2	262.4	283.0	216.9	102.5	195.0	201.0	229.5	269.5	102.5	100.5	187.5	190.5	199.0	212.0	178.0
SSB	151.7	207.0	235.8	279.3	293.7	233.5	135.0	206.0	221.5	260.5	270.5	218.7	115.0	201.0	208.0	221.5	218.0	192.7
FYM	170.2	210.5	262.4	279.4	297.3	243.9	145.5	205.0	252.0	268.5	252	224.6	130.0	203.0	213.0	236.0	232.5	203.0
SSB+ FYM	188.6	258.3	295.2	299.2	320.0	272.2	178.5	242.0	271.5	288.0	309.5	258.0	135.5	218.0	249.0	279.0	248.0	226.0
Mean	158.8	218.6	252.1	280.1	298.4	241.6	140.3	212.0	236.5	261.6	275.3	225.1	120.2	202.3	215.1	233.8	227.6	199.8
		SE d		CD (P=0.05)				SE d		CD (P=0.05)				SE d		CD (P=0.05)		
Factor (F)		3.8		7.9				3.6		7.6				3.0		6.2		
Level (L)		4.2		8.8				4.1		8.5				3.4		7.0		
FL		8.5		17.7				8.1		17.0				6.7		14.0		

*Mean of two replications

Addition of SSB and FYM ranked best followed by FYM and SSB on the availability of Si. It was obvious that addition of Coal combusted fly ash increased the Si concentration due to its higher Si content. Similar observation has been reported by Lee (2006) and Yeledhalli (2007). The addition of SSB favouring the release of Si was also observed in the present investigation. Similar results obtained by (Balasubramaniam, 2003) which might be due to that microorganisms play a vital role in solubilization of silicates in nature. The primary and secondary silicate minerals can be attacked through products of microbial metabolism (Muntz, 1890 and Theil, 1927). Further Si in soil due to the SSB inoculation might have solubilised. It was obviously evident from the earlier reports of Muralikannan (1996) and Anthoniraj (1998) who clarified that SSB inoculation augmented Si content in soil solution. Similarly FYM addition alone significantly enhanced the N NaOAc extractable Si in soil might be attributed to the decomposition of FYM in soil resulting in production of organic acids, which contributed H^+ to the soil and promoted silicate hydrolysis on one hand and on the other hand can complex with cation component of silicate mineral as they are potent complex forming agents (Avakayan *et al.*, 1986), citric, oxalic, keto acid and hydroxy carboxylic acids, usually form complexes with cations in fly ash which is ferroalumionosilicate, promote the removal and retention of Si in this soil in dissolved state. Duff and Webley (1959) reported dissolution of silicates due to complexing of 2- keto glutonate with cationic components, as those complexes are more stable than silicates. The rate of FYM mineralization is positively correlated with dissolution of Si from soil. In addition, on decomposition of FYM in soil it was possible to increase the humic acid and fulvic acid content in soil. As these high molecular weight organic acids were capable of dissolving Si from feldspar, biotite and muscovite (Tan, 1980). Schnitzer and Kodama (1976) reported that Si was released on dissolution of mica by fulvic acid. Hence, the above mechanism might have contributed increased N NaOAc- Si in soil due to FYM addition.

In the present study the increase of Si in soil was not only due to FYM alone, but also release from soil due to SSB addition. Hence it can be concluded that the amount of Si available in soil originated from two sources *viz.*, from Si contained in the FYM and from the soil minerals due to SSB and FYM decomposition. The similar observations were also claimed earlier by Chandramani (2009). The initial increase of available Si may be due to the possible action of CO_2 on alumino silicates. The subsequent stabilization and decrease with passage of time could be related to the recombination of Si with alumino silicates. This view is in good agreement with earlier findings of Ponnamperuma (1972), Rao and Venkateswaralu (1974), Nayar (1982a) and Subramanian and Gopalswamy (1991a) . In interaction progressive and maximum release of Si observed in imposition of 50.0g Kg^{-1} fly ash soil with SSB + FYM up to 75 days which may be due to dissolution of fly ash matrix and solubilization of trace minerals polymerization of excessively released monosilicic acid and blocking of silica surfaces by reactions of Fe and Al (Kruger and Surridge, 2006 and Korndorfer, 2009). The consistent increase throughout the incubation period was observed on application of 12.5 g kg^{-1} of fly ash with SSB and FYM. The control recorded the least N NaOAc (pH 4.0) extractable Si throughout the incubation period which may due to lower silicate release from both kaolinite and montmorillonite clays in the intermediate soil pH range (Beckwith and Reeve, 1964).

CONCLUSION

1. The availability of Si was enhanced by the imposition of different treatments. The maximum available Si was noticed due to addition of SSB + FYM.
2. Magnitude of Si release was higher due to imposition of SSB than FYM. The availability of Si in soil increased from 15^{th} to 60^{th} days after incubation (DAI) irrespective of treatments thereafter, slight decrease was noticed.
3. The availability of Si was increased by the addition of fly ash in graded levels over control. The highest available Si was observed due to application of fly ash @ 50g kg^{-1} of soil. However, the constant and progressive release of Si throughout the incubation period was observed due to application of fly ash @ 12.5g kg^{-1} irrespective of treatments.

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