Water Management Mediated Chemical Kinetics of Soils Influencing Rice Growth

Prasanta Kumar Patra

Dept. of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, P.O.-KrishiViswavidyalaya, Mohanpur Nadia, West Bengal (741 252), India

Corresponding Author

Prasanta Kumar Patra
e-mail: drpatrapk@yahoo.co.in

Article History

Article ID: IJEP109
Received in 12th July, 2016
Received in revised form 7th August, 2016
Accepted in final form 15th August, 2016

Abstract

The present field investigation was carried out to study the effect of water management mediated chemical kinetics of soil influencing Rice growth. Rice, the staple food of nearly half of the world population, is the most important crop of India occupying 23.3% of gross cropped area contributing 43% of total food grain production and 46% of total cereal production, continues to play vital role in the national food grain supply. Despite phenomenal increase in food grain production from 5l MT in 1950-51 to 264.38 Mt in 2013-2014. The System of Rice Intensification (SRI) formulated on certain core principles from soil chemistry and biology, rice physiology and genetics and the principles of sustainability with the possibility of adjusting the exact technical components based on the prevailing biophysical and socioeconomic realities of an area, is a niche –production method. Apart from “soil fertility management” through integrated use of organic and inorganic sources of plant nutrients, the system also results in saving significant amount of irrigation water in rice production. “Irrigation Water Management” is practiced in such a way that the soil is kept well drained rather than continuously flooded and saturated during the vegetative growth period. Water regime influences rice growth and yield by influencing different soil chemical and physic-chemical parameters which in turn influences the soil microbial community and their functions and thus turnover of nutrients. The effect is very much soil specific and no generalization can be made.

Keywords: Water management, chemical kinetics, soil health, Rice

1. Introduction

Rice, the staple food of nearly half of the world population, is the most important crop of India occupying 23.3% of gross cropped area contributing 43% of total food grain production and 46% of total cereal production, continues to play vital role in the national food grain supply. Despite phenomenal increase in food grain production from 5l MT in 1950-51 to 264.38 Mt in 2013-2014, the intensification of rice production systems on irrigated lands has started exhibiting its carrying capacity as reflected by downward compound growth rate in area production and productivity of rice in green revolution belt since 1990due to its serious negative social and environmental externalities such as (1) Decline in soil fertility and overall deterioration of soil health, (2) depletion of water tables, (3) aggravation of air pollution, and (4) resistance of weeds to certain herbicides. Whether farmers can continue to sustain yield increases faster than the rise in demand from population growth through meticulous management of basic agricultural resource - soil, water and biological inputs remains one of the key issues.Technologies that lower costs, improve and sustain soil health, are favourable to the environment, save resources such as water and nutrients; save on use of insecticide and other pesticides and improve returns are currently in high demand. The System of Rice Intensification (SRI)formulated on certain core principles from soil chemistry and biology, rice physiology and genetics and the principles of sustainability with the possibility of adjusting the exact technical components based on the prevailing biophysical and socioeconomic realities of an area, is a niche –production method.This system calls for research and adaptation of the system to specific conditions of an area rather than trying to impose practices relevant to one location on the other injudiciously. Apart from “soil fertility management”through integrated use of organic and inorganic sources of plant nutrients, the system also results in saving significant amount of irrigation water in rice production. “Irrigation Water Management” is practiced in such a way that the soil is kept well drained rather than continuously flooded and saturated during the vegetative growth period. Two possibilities are suggested (1) application-of a small quantity of water daily but leaving the field dry for several short periods to the point of surface cracking during tillering and (2) flood and dry the field for alternating periods known as Alternate Wetting and Drying.

Apart from about 50% water savings, the yield advantages reported from on-farm and on-station experiments conducted in Africa, Asia and Latin America, range from 19 to 270% with yield levels as high as 15 to 20 t ha^{-1}. But, the results of these studies do not always converge and it is difficult to compare the results from one experiment with another. Hence, there is a need for documenting the results of such experiments under diverse soil conditions. The present paper aims at studying the effect of water management on changes in chemical and physico-chemical properties of different soils in relation to rice yield.

2. Methodology

A series of experiments were conducted in the green house in 16l glazed porcelain pots with bulk soil samples collected from different location of the Philippines (Table 1), atthe International Rice Research Institute (IRRI),to study the chemical kinetics and rice (cv. IR-54) growth and yield in different types of soils (Table 1). With twelve kg soil, each of the pots were fitted with two bright platinum electrodes and a tensiometer for in-situ measurement of Eh and soil moisture tension and were flooded with demineralised water. After 2 weeks of flooding, N, P and K at 100, 50 and 75 mg kg^{-1} soil respectively, were added to each pot and mixed thoroughly. Along with continuously flooded water regime (CF), a saturated water regime (CS) and alternately flooded and dried water regimes were imposed in triplicate plots in a Randomized Complete Block Design (Gomez and Gomez, 1984). While the pots with CF were maintained at 3-5 cm standing water, the pots of drying treatment were drained

Table 1: Some Important Characteristics Of The Soils Used In The Experiments

Characteristics	Values in Different Soils											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
pH (1:1) (Water)	6.4	4.8	6.6	4.5	7.5	4.8	6.5	6.3	5.7	5.8	7.5	6.1
Organic carbon (%)	2.00	2.20	1.65	2.47	0.90	3.49	0.86	0.71	1.18	0.51	0.86	1.77
Total N (%)	0.17	0.24	0.14	0.24	0.08	0.26	0.06	0.08	0.12	0.05	0.08	0.13
Total S (%)	0.09	0.07	0.10	0.08	0.05	0.10	0.029	0.034	0.039	0.038	0.039	0.040
Available												
N (mg.kg^{-1})	152	283	55.7	150	30.1	166.	49.0	65.1	88.0	20.9	13.6	71.6
P (Olsen) (mg.kg^{-1})	5.5	2.1	30.9	2.9	7.9	2.9	0.9	4.3	1.7	0.9	5.7	6.3
S (mg.kg^{-1})	33.7	39.4	4.1	67.6	2.3	42.1	0.7	5.3	4.9	1.3	1.5	10.9
Zn (mg.kg^{-1})	0.52	2.64	0.36	3.32	0.12	3.06	0.28	0.88	0.70	0.44	0.10	0.28
Cu (mg.kg^{-1})	0.10	3.60	0.06	5.80	0.08	3.40	0.14	0.40	1.04	1.18	0.06	0.08
Exchangeable												
K (c mol kg^{-1})	2.3	0.38	1.80	0.25	0.30	0.23	0.15	0.22	0.29	0.12	0.26	0.10
Ca (c mol kg^{-1})	21.7	12.5	17.7	13.2	37.9	8.30	1.08	11.0	3.95	5.63	34.9	3.69
Mg (c mol kg^{-1})	15.8	6.2	12.6	6.10	6.93	2.60	12.1	3.42	7.27	1.92	4.93	20.5
Active												
Fe (%)	1.93	6.71	2.90	4.60	1.30	3.88	3.77	1.67	0.57	0.67	1.15	5.08
Mn (%)	0.12	0.04	0.19	0.03	0.06	0.09	0.06	0.38	0.01	0.10	0.06	0.06
Water soluble Si (mg.kg^{-1})	230	100	219	110	82.7	73.4	126	90.9	65.2	50.1	92.0	149
CEC [c Mole (P+) Kg^{-1}]	60.0	41.4	47.0	44.6	45.5	46.6	18.2	21.8	16.2	10.7	44.9	36.4
Mechanical Analysis												
Clay (%)	53	63	29	71	31	58	16	22	15	15	32	31
Silt (%)	33	35	50	26	51	35	22	16	44	51	53	31
Sand (%)	14	2	21	3	16	7	62	62	41	34	15	38
Textural Class	Clay	Clay	Silty Clay Loam	Clay	Clay	Clay	Sandy Loam	Sandy Clay Loam	Loam	Silty Loam	Clay	Clay

Soil : (1) Maahas_1; (2) Luisiana-1; (3) Maahas-2; (4) Luisiana-2; (5) San Manuel; (6) Luisiana-3; (7) Bancal; (8) San Ildefonso; (9) Cabangan; (10); Kalikid; (11) Pao; (12) San Agustin to dry at 0.3 bar tension after which again saturated with calculated amount of drainage and / or demineralised water. To get the saturated water regime, sufficient water was added to the pots to just saturate the soil without any standing water and the loss due to evapo-transpiration was replenished by adding water 4 times a day. Two plants were harvested at 8 weeks after transplanting (WAT) and the remaining 2 plants were grown to maturity and grain and straw yields were recorded. Statistical significance of treatment effects on different characteristics of soil solution was inferred from least significant difference (CD p=0.05) test using analysis of variance. Using a PC, with the help of SPSS software (SPSS 7.5, 1997), all variables measured at different sampling dates and different plant growth and yield parameters were statistically analyzed following methods meant for randomized complete block design (RCBD). Duncan's multiple range test (DMRT) at 5% was followed to compare the treatment means.

3. Results

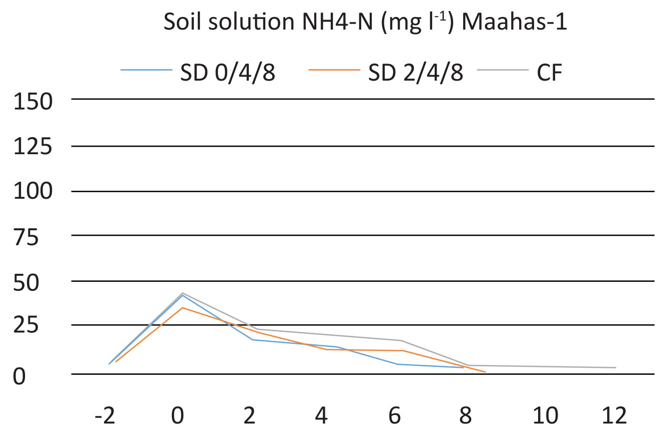
Significant changes in the chemical kinetics of soils influencing rice growth and yield under different water management practices were observed (Table 2).

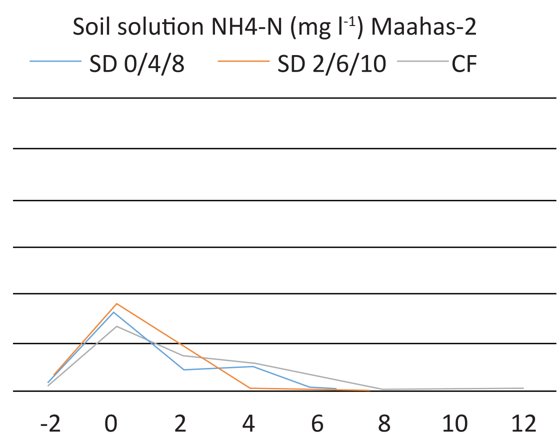
While the pH of acidic soils increased due to flooding, it decreased in alkaline soils. Saturated water regime (CS), maintaineda trend of pH similar to flooded water regime (CF) but soil drying reversed soil solution pH towards its initial value and on reflooding again changed but did not regain values as in CF. Soil solution Eh values (mV) decreased due to flooding in CF and increased in dried and reflooded water regime. Saturated water regime (CS) maintained higher Eh values of soil solution compared to their CF counterpart in all soils resulting in oxidation of nutrients.Soil solution EC values were comparatively lower under CS and dried and reflooded water regimes than in CF. Reflooding of dried soils tended to increase the soil solution EC but could not reach to the level in CF.Soil solution concentration of NH_4-N, P, K, Ca, Mg, Fe, Mn and Si under CS as well as in alternately dried and reflooded water regime maintained comparatively lower values than under CF (Figure 1-5).

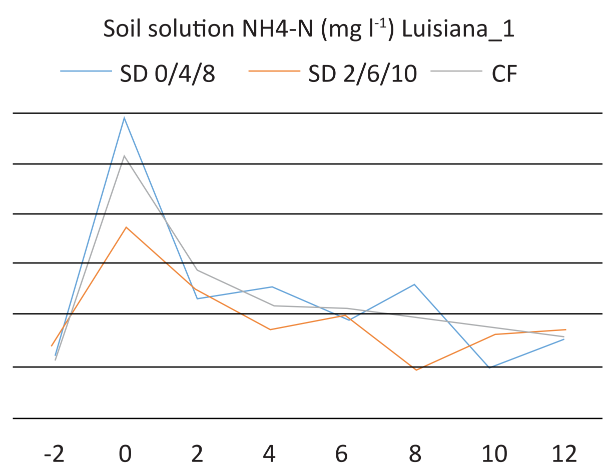
Table 2: Shoot, grain and straw yield of rice under different water management practices in three soils

	San Manuel	Luisiana-1	Maahas-2
Shoot Weight (g pot^{-1})			
CF	19.8	17.9	3.7
SD2-4/6-8	17.4	15.1	18.5
SD4-6/8-10	21.8	15.2	3.2
SD 6-8	17.8	16.2	4.0
Grain Weight (g pot^{-1})			
CF	35.40	64.70	1.60
SD2-4/6-8	30.70 (-13.3)	50.30 (-22.3)	36.40 (2175.0)
SD4-6/8-10	38.20 (7.9)	51.60 (-20.2)	25.0 (1462.5)
SD 6-8	44.60 (26.0)	59.50 (-8.0)	21.30 (1231.2)
Straw Weight (g pot^{-1})			
CF	28.9	52.5	7.1
SD2-4/6-8	20.9	41.0	31.5
SD4-6/8-10	24.5	51.3	21.9
SD 6-8	32.8	53.3	23.4

Figures in the parenthesis are % change from CF







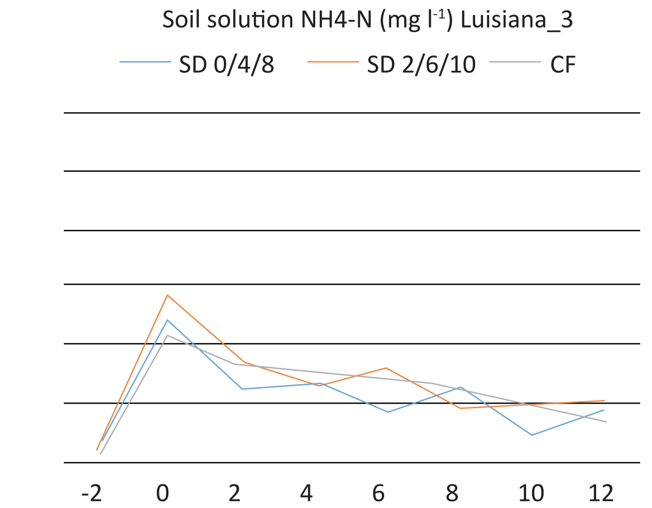


Figure 1: Soil solution NH4-N (mg.l^{-1}) under different water management practices

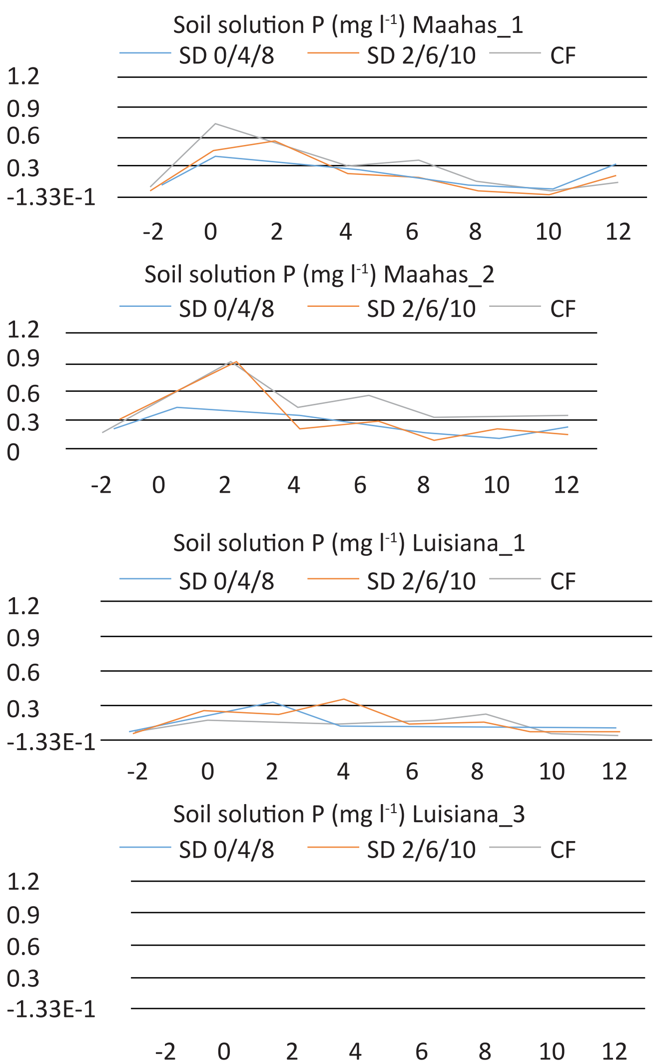


Figure 2: Soil solution phosphorus (mg.l-1) under different water management practices

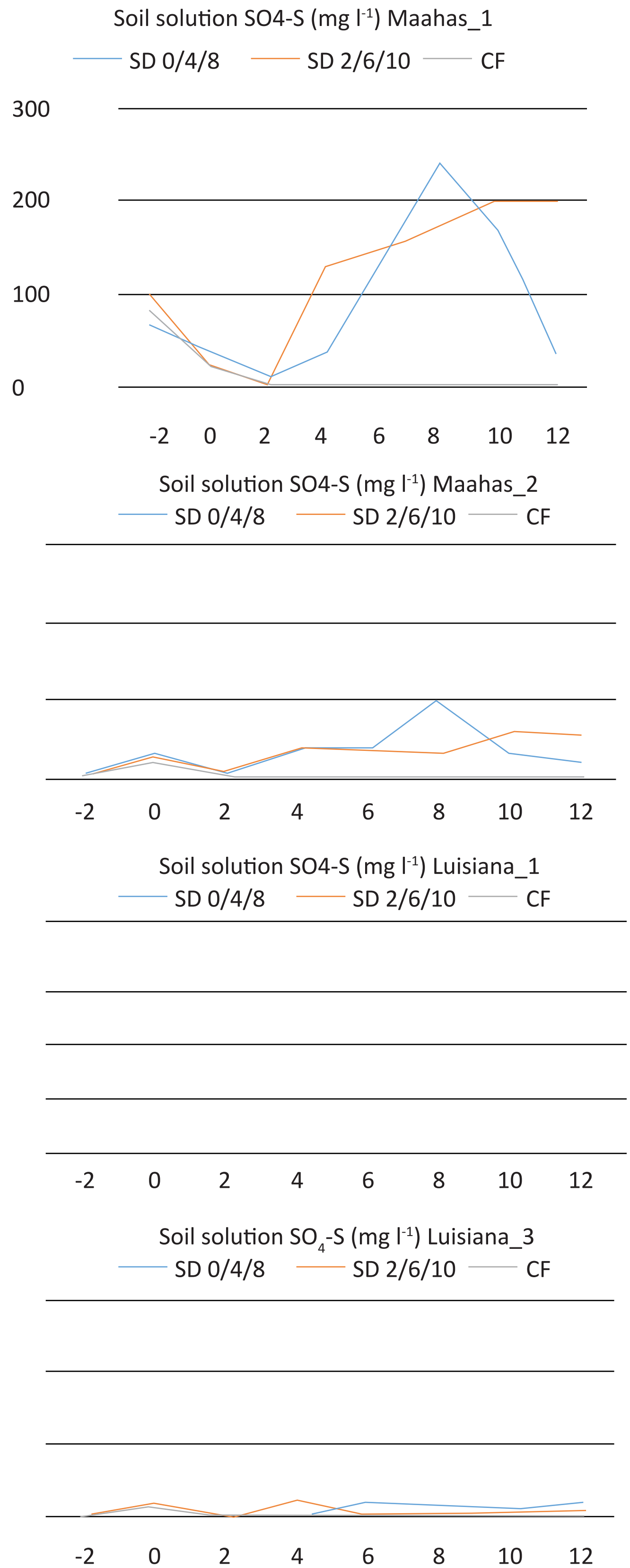


Figure 3: Soil solution SO_4-S (mg l^{-1}) under different water management practices

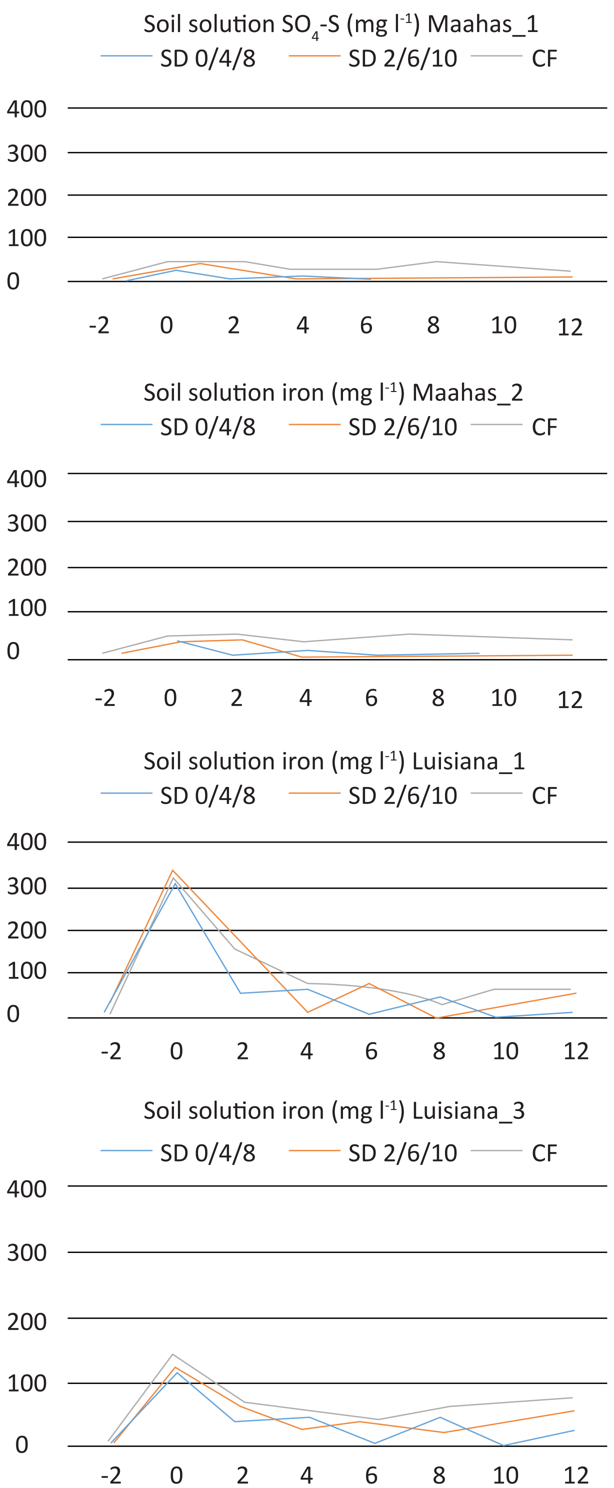


Figure 4: Soil solution Iron (mg l^{-1}) under different water management practices

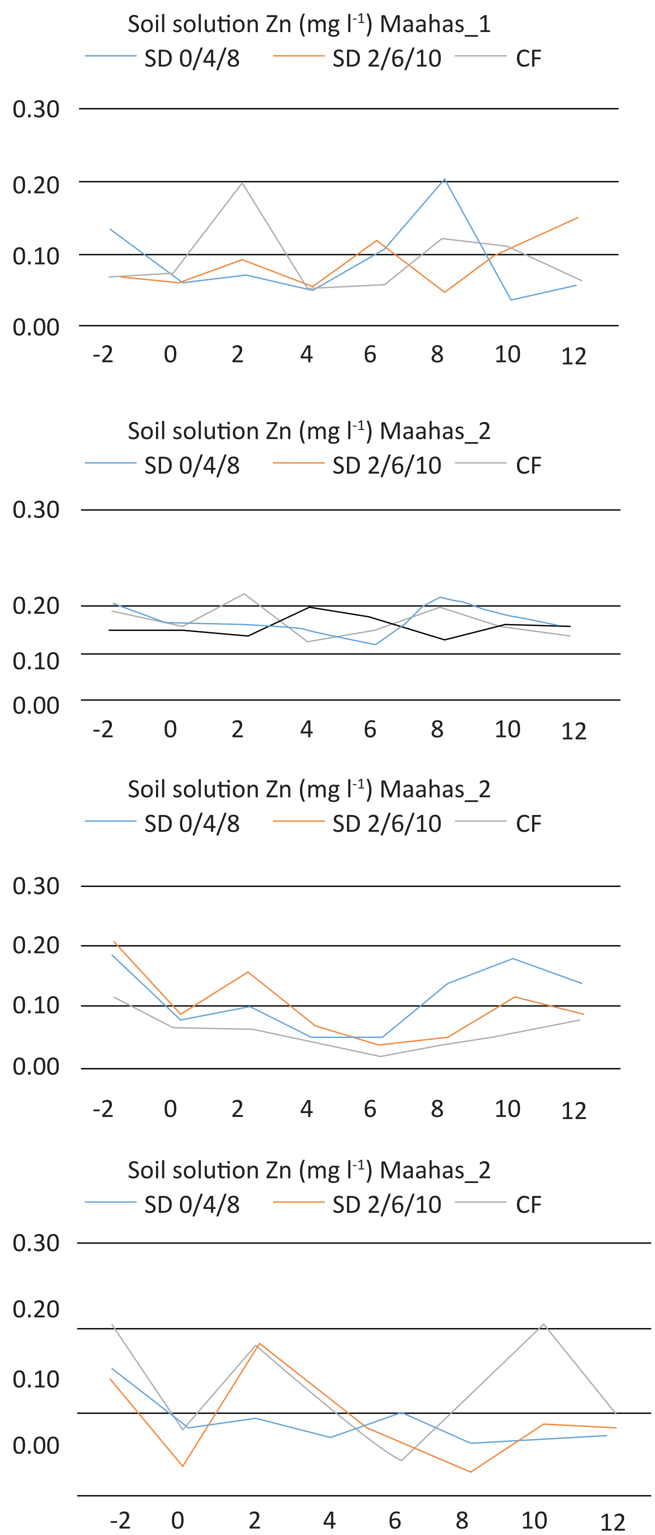


Figure 5: Soil solution Zinc (mg l^{-1}) under different water management practices

Soil solution concentration of SO_4-S and Zn under CF water regime was the lowest while keeping the soil saturated (CS) improved the SO_4-S and Zn content of the soil solution (Figure 3, 5). Alternate wetting and drying, particularly in S deficient soils (Soil Nos. 3,6,7, 8, 9, 10, 11, 12) improved the SO_4-S content and in Zn deficient soils (Soil No. 5, 11) improved the Zn content. This helped rice plants to overcome sulphur and /or Zn deficiency prevalent under CF water regime.

4. Plant Growth Parameters

Water regime influenced plant growth through its effect on soil chemical and physico-chemical and nutritional parameters. While under normal and neutral soils best rice growth was observed under CF water regime (Soil No. 1) (Table 3). Decreasing water supply under CS water regime resulted in 19.3% reduction in grain yield and alternate drying and reflooding either during tillering or reproductive phase, further reduced grain yield ranging from 51.2% to 62.2% compared to CF water regime. In the sulphur deficient soils (Soil No. 3, 6, 7, 8, 9, 10, 11, 12) soil drying during tillering stage resulted in higher grain yield compared to the CF water regime (Table 4) because of improvement in S availability in soil as evident from soil solution kinetics data. In Fe toxic soil (Soil No. 2) CS water regime produced 35% more grain yield compared to CF water regime by alleviating Fe toxicity and drying the soil to field capacity and keeping for 2 weeks resulted in 77.8% increase in grain yield. Similarly in Zn deficient soils (Soil No. 5, 11) also soil drying resulted in improved crop growth and grain yield probably by alleviating Zn deficiency in these soils.

Table 3: Influence of water regimes on grain yield (g. pot^{-1}) and changes in grain yield (%) of rice on 4 soils

Treatments	Maahas-1		Maahas-2		Luisiana-1		Luisiana-3	
	Grain Yield	% Change	Grain Yield	% Change	Grain Yield	% Change	Grain Yield	% Change
CF	69.4	-	64.3	-	24.5	-	30.3	-
SD 0-4	14.9	-78.5	21.6	-66.4	35.5	+44.9	18.4	-39.3
SD 4-8	32.1	-53.7	51.8	-19.4	43.2	+76.3	13.6	-55.1
SD 6-10	45.8	-34.0	50.4	-21.6	23.5	-4.1	20.3	-33.0
SD 0/4/8	37.6	-45.8	26.5	-58.8	34.1	+39.2	16.4	-45.9
SD 2/6/10	29.6	-57.3	35.2	-45.2	32.7	+33.5	24.0	-20.8
Mean	38.2	-53.9	41.6	-42.3	32.3	+38.0	20.5	-38.8

Table 4: Influence Of Sulphur Application And Five Water Management Practices On Plant Height, Tiller And Panicle Number, Shoot, Grain And Straw Yields Of Rice (Var. IR 54) (Average Of 6 Soils From Sl No. 7-12)

Treatments	PHH	TN	PN	Dry weight (g. pot^{-1})		
				Grain	CF	Straw
CF	97.9	4.2	4.1	9.7		15.8
CF+ S	96.4	5.1	5.1	13.7	41.2	17.6
CS	99.4	3.7	3.7	10.3	6.2	14.7
SD 2-4	103.7	3.7	3.6	11.1	14.4	13.3
SD 4-6	99.6	4.6	4.6	13.0	34.0	16.3
SD 8-10	102.3	4.6	4.6	12.6	29.9	16.7
CD (p=0.05)	3.4	0.4	0.4	1.5		1.7

PHH: Plant Height at Harvest (cm); TN: Tiller Number (hill-1); PN: Panicle Number (hill-1); CF: % Change from CF

5. Conclusion

Water regime influences rice growth and yield by influencing different soil chemical and physic-chemical parameters which in turn influences the soil microbial community and their functions and thus turnover of nutrients. The effect is very much soil specific and no generalization can be made. This is probably the reason why the results of different studies under diverse soil and climatic conditions do not always converge and the results from one experiment cannot be compared with another. But our results points out to the fact that under suboptimal soil conditions with deficiency of S and Zn and toxicity of iron, the system of rice intensification (SRI) using less water could be used for yield advantage.