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Influence of Liming on Yield of Rice and Soil Properties in Acidic Soils of High Rainfall Zone

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Abstract:** Soil acidity is an important agricultural problem while evaluating the production potential of most of the crops. A field experiment was conducted in farmers field at Gananadhasapuram village of Thovalai taluk (strongly acidic soil) and Andarkulam village of Agastheswaram taluk (moderately acidic soil) during Pishanam (Oct-Feb) and late Pishanam (Nov–Mar) season of 2017-2018 respectively, in the high rainfall zone to study the effect of different source and levels of lime on yield of rice and soil properties. Liming materials viz., dolomite and calcite were tried at different levels along with recommended fertilizers + $ZnSO_4$. The experiment was conducted in RBD. The results of the experiment revealed that significantly higher grain (7.09 and 7.40 t ha^{-1}) and straw (10.3 and 10.5 t ha^{-1}) yield of rice were recorded with the application of dolomite @ 0.75 LR (6.36 t ha^{-1}) (T_7) and @ 0.50 LR (1.6 t ha^{-1}) (T_5) respectively in the strongly and moderately acidic soils along with recommended dose of fertilizers during pishanam and late pishanam seasons. The soil pH, EC, available NPK, exchangeable Ca, Mg and DTPA extractable Zn, Cu were increased and the DTPA extractable Fe and Mn were decreased upon lime application irrespective of the sources. The economics of various treatments revealed that, the highest B:C ratio (1.86 and 2.56) was recorded with the application of dolomite @ 0.75 LR (6.36 t ha^{1}) (T_7) and @ 0.50 LR (1.6 t ha^{-1}) (T_5) along with recommended dose of fertilizers in the strongly and moderately acidic soils respectively during pishanam and late pishanam seasons. The study clearly indicated that in strongly acidic soils, the application of dolomite @ 0.75 LR (6.36 t ha^{-1}) (T_7) and in moderately acidic soils, dolomite @ 0.50 LR (1.6 t ha^{-1}) (T_5) along with recommended dose of fertilizers and $ZnSO_4$ is found to be the best for getting higher yield and higher returns per rupee invested under rice cultivation.

***Keywords:** Liming, Rice, Soil properties, Yield and B:C ratio*

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Introduction

Soil acidity is an important constraint in agriculture production. Soil acidity occurs due to build-up of acid forming elements in the soil. Soil acidity is a natural occurring process due to heavy rainfall and removal of cations like calcium, potassium and magnesium by leaching. Acidic parent materials and decomposition of organic matter also leads to formation of acidic condition in soil. Acceleration of acidification is by acid forming fertilizers usage, disturbance of soil structure, cultivation of high yielding crops (Fageria and Baligar, 2008). Higher acidity in soils leads to reduction in crop productivity. In India, acidic soils occupy about 49 million ha area, of which 26 m ha has pH below 5.5 and 23 m ha has pH between 5.6 and 6.5 (Panda, 1979). In Tamil Nadu, acidic soils occupy about 2.6 m ha area. Rice *(Oryza sativa* L.*)* is one of the important cereal crops in India contributing about 45% to the total food grain production and staple food for more than 60% of world population (Singh *et al.,* 2011). Rice crop prefers a soil with a pH from 4.0 to 8.0 with an optimum value of around 6.0. Nutrient availability in soil and the performance of rice depends on the pH value of soils. Most of the plant nutrients are highly available in neutral soil having pH 6.6 to 7.4 (Hausenbuiller, 1972). Acidic condition of the soil is one of the major limiting factor for plant growth and development (Adams, 1986). The application of lime to an acidic soil is a common practice in many counties. Lime application in acid soil is beneficial for soil health and improves the crop yields. The soils of high rainfall zone viz. Kanyakumari district are light textured, low in organic matter and strongly acidic to moderately acidic in nature in most cases. The status of available N, P, K, Ca and Mg of these soils are low. The soil has low cation exchange capacity. The maintenance and management of acidic soils are thus very important to obtain highest resource use efficiency and productivity of the crop on sustainable basis (Caires *et al.,* 2008) . Liming increases the availability of P, Ca, Mg and Mo and renders iron, and manganese insoluble and harmless and increases fertilizer effectiveness (Halim et al., 2014). Thus, the crop plants may have a better nutrition and produce a higher yield. Lime application, is a sustainable crop production technology for better soil fertility management of acidic soil. Lime serves not only as an ameliorant but also an amendment in acidic soils. In these regard, a study is highly imperative in acidic soil to optimize the source and level of liming material for sustaining the rice crop productivity. The application of lime is potential and cost effective in reducing soil acidity. The present investigation was carried out to study the amelioration capacity of dolomite and calcite in acid soil and its influence on yield and economics.

Materials and Methods

Site description

A field experiment was conducted in farmers field at Gananadhasapuram village of Thovalai taluk (strongly acidic soil) and Andarkulam village of Agastheswaram taluk (moderately acidic soil) during *Pishanam* (Oct-Feb) and *late Pishanam* (Nov–Mar) season of 2017-18 respectively, in the high rainfall zone of Tamil Nadu, to study the effect of different sources and levels of lime on soil fertility, yield and economics of rice cultivation.

Field experimental

The field experiment was conducted in the strongly acidic soils of Gananadasapuram (location I) and moderately acidic soils of Andarkulam villages (location II) during pishanam (Oct-Feb) and Late pishanam (Nov-Mar) seasons respectively in the high rainfall zone. The rice crop varieties TPS 3 and TPS 5 were used as test crops during the different seasons respectively. The physico-chemical characteristics of the soil of the experimental fields are presented in Table 1.

The experiment was laid out in a randomized block design with ten treatments replicated thrice. The treatment combinations include, treatment T_1 is absolute control, the treatment T_2 was the application of recommended dose of fertilizers with $ZnSO_4$ @ 25 kg ha^{-1}, For the treatments from T_3, T_5, T_7 and T_9, lime as dolomite at different levels based on lime requirements 0.25 LR (2.12 and 0.8 t ha^{-1}) (T_3), 0.50 LR (4.24 and 1.6 t ha^{-1}) (T_5), 0.75 LR (6.36 and 2.4 t ha^{-1}) (T_7) and 1.0 LR (8.48 and 3.2 t ha^{-1}) (T_9) respectively for pishanam and late pishanam seasons along with recommended dose of fertilizers and $ZnSO_4$ was tested. For the treatments from T_4, T_6, T_8 and T_{10}, lime as calcite at different levels based on lime requirement 0.25 LR (2.32 and 0.88 t ha^{-1}) (T_4), 0.50 LR (4.63 and 1.76 t ha^{-1}) (T6), 0.75 LR (6.95 and 2.64t ha^{-1}) (T_8) and 1.0 LR (9.25 and 3.22t ha^{-1}) (T10) during pishanam and late pishanam seasons along with recommended dose of fertilizers and $ZnSO_4$ was tested. The 0.25, 0.50, 0.75 and 1.0 LR corresponds to 25%, 50%, 75% and 100% Lime requirement of soil. The fertilizer was applied to all the plots except absolute control plot based on RDF (pishanam 150:50:50 and late pishanam 120:40:40 kg $ha^{-1}$of $N:P_2O_5:K_2O$ respectively). Lime was applied to the soil one week prior to transplanting rice seedlings and mixed thoroughly, The Ca content of calcite is 40 per cent and the Ca and Mg content of dolomite is 22 per cent, and 13 per cent respectively. The dolomite requirement was calculated based on calcium carbonate equivalent and neutralizing value. Phosphorus was applied basally as mussoorie rock phosphate. Potash was applied by broadcasting in four equal splits as muriate of potash, during basal, tillering, active tillering and panicle initiation stages. The $ZnSO_4$ was applied at the time of planting. The crop was kept free of weeding by hand weeding. It was also protected from pest and disease by adopting the need based plant protection measures.

Soil and Plant analysis

Soil samples collected at different growth stages of rice were analyzed for pH, EC (Jackson (1973), organic carbon (Walkley and Black, (1934)), available N (Subbiah and Asija, (1956)), phosphorus (Jackson, 1973), potassium (Stanford and English (1949), exchangeable Ca and Mg (Jackson, 1973) and DTPA extractable Fe, Mn, Cu and Zn (Lindsay and Norwell, (1978), Lime requirement (Shoemaker *et al.*, 1961) by using standard procedures. The data were subjected to statistical analysis as prescribed by Gomez and Gomez, (2010).

Results and Discussion

Effect of liming on yield attributes and yield

The yield contributing characters such as number of productive tillers m^{-2}, grain and straw yield were influenced significantly by the application of lime, NPK fertilizers and $ZnSO_4$ (Table 2).

In the present study, the application of lime had significantly exhibited its superiority to increase the number of productive tillers m^{-2}, grain and straw yield of rice. The highest productive tillers m^{-2} (375), grain (7.09 t ha^{-1}) and straw yield (10.3 t ha^{-1}) of rice was recorded with RDF + 25 kg $ZnSO_4$ + Dolomite @ 0.75 LR (T_7) followed by T_8 (356, 6.85 and 8.53 t ha^{-1} of productive tillers m^{-2}, grain and straw yield respectively), which received RDF + 25 kg $ZnSO_4$ + Calcite @ 0.75 LR in the pishanam season. In the late pishanam season highest productive tillers m^{-2} (395), grain (7.40 t ha^{-1}) and straw (10.5 t ha^{-1}) yield was recorded by T_5 (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.50 LR) followed by T_6 (362, 6.98 and 9.86 t ha^{-1} of productive tillers m^{-2}, grain and straw yield respectively) which received RDF + 25 kg $ZnSO_4$ + Calcite @ 0.50 LR.

The yield benefits can be ascribed to the increase in soil pH upon liming along with the associated improvement in nutrients availability, reduced Fe availability and many other attributes of soil fertility (Manoj-Kumar *et al*., 2012). Oya *et al.* (1990) observed that application of lime in acid soil significantly increased the Rhodes grass yield. Attanandana and Vacharotayan (1986) reported that liming with recommended fertilizer application resulted in the 37% additional increase of paddy yield compared to liming alone. The above results are in agreement with the findings of Osundwa et al. (2013).

Effect of liming on soil physico-chemical properties and available nutrient status

The pH and EC of the soil was slightly increased with the increase of lime application on acidic soil (Table 3 and 4). The application of lime @ 1.0 LR had significantly increased the soil pH. However, the effect of calcite on pH was slightly higher than dolomite. Increase in pH indicated the usefulness of liming material for amelioration of acid soil.

The calcium ions present in the liming materials can be readily adsorbed to soil particle and organic matter. However, the carbonates in turn react with hydrogen ions in solution (which act to keep the pH low), thus causing an increase in soil pH (Buni, 2015), increased soluble salts in the soil due to application of liming. Similarly, the soil EC was more in treatment which received RDF + 25 kg $ZnSO_4$ + calcite @ 1.0 LR. This is in line with finding of Anila (2014).

Further, the liming treatments significantly increased the available N, P, K, Ex.Ca, Ex.Mg, DTPA-Zn and Cu contents of soil and decreased available DTPA-Fe and DTPA-Mn contents of the soil (Table 3 and 4).

Macro nutrients

The available macro nutrient was significantly influenced by liming and fertilizers application. The higher soil available like nitrogen (238 and 218 kg ha^{-1}), phosphorus (11.8 and 11.9 kg ha^{-1}), potassium (163 and 220 kg ha^{-1}) after harvest was recorded in T_7 (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.75 LR) respectively in strongly and moderately acidic soil. This was followed by T_5 (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.50 LR) The higher soil exchangeable calcium (5.80 and 6.40 c mol (p^+) kg^{-1}) was recorded in treatment T_{10} (RDF + 25 kg $ZnSO_4$ + calcite @ 1.0 LR) compared to all other treatments, in both soil acidity situations respectively. The

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higher exchangeable magnesium (4.40 and 5.20 c mol (p^+) kg^{-1}) contents was observed in treatment T_9 (RDF + 25 kg $ZnSO_4$ + dolomite @ 1.0 LR) than all other treatments, in strongly and moderately acidic soils respectively.

Increase in soil available nitrogen due to lime application could be due to enhanced microbial activities in the soils owing to increased soil pH, the rate of decomposition of organic matter and accelerated the process of mineralization of nitrogen (Ranjit *et al.*, 2010). Liming increased P availability by changing the rate of organic P mineralization due to altered rates of microbial activity as well as increase in the utilization of soil phosphate by plants through amelioration of Fe toxicity (Haynes, 1982). Bishnoi *et al.* (1988) reported that the increase of available K status of acid soils by liming can be explained on the basis, that K released from non exchangeable fraction to available pool get accelerated when acid soils are limed. Patil and Ananthanarayana, (1989) reported that increase in exchangeable calcium was in direct proportion with increase in lime level. This is due to increase in charge density and greater affinity for higher valent ions. The calcium being divalent cation and its higher solution concentration due to liming increased its concentration in the exchange complex. Liming increased the base saturation index and reduced Al saturation and increases the magnesium concentration in soil solution. Application of lime increased magnesium adequately. Similar observation was reported by Viswanatha shetty *et al.* (2012).

Micronutrients

The available micronutrient was significantly influenced by liming and fertilizers application. The higher available DTPA-Zn (1.58 and 1.67 mg kg^{-1}) and DTPA-Cu (2.18 and 2.27 mg kg^{-1}) was recorded in treatment T_7 (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.75 LR in strongly acidic soil) and T_5 (RDF + 25 kg $ZnSO_4$ + dolomite @ 0.50 LR in moderately acidic soil) respectively, compared to all other treatments. The lower available DTPA-Fe (135 and 93 mg kg^{-1}) and DTPA-Mn (8.9 and 7.3 mg kg^{-1}) was recorded in treatment T_9 (RDF + 25 kg $ZnSO_4$ + dolomite @ 1.0 LR) in the strongly and moderately acidic soils respectively, compared to all other treatments. Jackson (1973) reported that with decrease in iron and manganese, there is increase in zinc content due to antagonistic relationship between iron and zinc. The conversion of Fe^{2+} to Fe^{3+} and Mn^{2+} to Mn^{3+} has led to lower availability upon liming.

Base saturation

The application of different sources and levels of lime application based on lime requirement of soil increased base saturation percentage (Table 3 and 4). The BSP increased from 30.8 to 82.2 in strongly acidic and from 36.4 to 80.9 in moderately acidic soil at the time of harvest. The highest BSP of 82.2 strongly acidic and 80.9 moderately acidic soil was recorded with the application of dolomite (1.0 LR) + RDF and $ZnSO_4$ @ 25 kg ha^{-1} (T_9) This was followed by the application of calcite (1.0 LR) + RDF and $ZnSO_4$ @ 25 kg ha^{-1} (T_{10}) with the BSP of 81.8 and 80.1 respectively in the strongly and moderately acidic soils. The increased concentration of Ca and Mg in the exchange sites and reduced concentration of H and Al lead to high base concentration upon liming. Similar trend was reported by Viswanath shetty et al. (2012).

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Economic analysis

Higher crop productivity with lesser cost of cultivation could result in better economic parameters like net returns and B:C ratio. The identified treatment should be economically viable so that farmers can sustain their higher income.

The B:C ratio was worked out for the different treatments in terms of soil management and fertilizers application in acidic soil (Table 2).

The maximum and economic yield with B:C ratio of 1.86 was recorded with application of dolomite @ 0.75 LR along with RDF and $ZnSO_4$ (T_7) in the strongly acidic soil (pH 5.1), (pishanam season). In case of late pishanam season rice cultivated in moderately acidic soil (pH 5.9), (late pishanam season) the maximum and economic yield with B:C ratio of 2.56 was recorded with the application of dolomite @ 0.50 LR along with RDF and $ZnSO_4$. The high economic return could be realized if lime is applied in acidic soil was also reported by Kumar (2015).

Conclusion

From this study, it can be concluded that application of dolomite @ 0.75 LR (6.36 t ha^{-1}) (T7) and @ 0.50 LR (1.6 t ha^{-1}) (T5) along with recommended dose of fertilizers and ZnSO4, could be considered as a better option for achieving higher productivity and profitability besides improving the physico-chemical characteristics of strongly and moderately acidic soils, respectively in the high rainfall zone.

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Table1. Characteristics of initial soil

Parameters	Pishanam season	Late pishanam season
I. Physical properties		
Textural class	Sandy clay loam	Sandy clay
Bulk density (Mg m^{-3})	1.39	1.31
Particle density (Mg m^{-3})	2.17	2.19
Water holding capacity (%)	35.2	36.7
II. Physico - chemical properties		
pH	5.1	5.9
EC (dS m^{-1})	0.02	0.04
CEC (c mol (p^+) kg^{-1})	12.5	14.2
III. Chemical properties		
Organic carbon (%)	4.5	4.7
Available N (kg ha^{-1})	210.0	238.0
Available P (kg ha^{-1})	8.4	9.7
Available K (kg ha^{-1})	107.0	197.0
Exchangeable Ca (c mol (p^+) kg^{-1})	2.3	2.9
Exchangeable Mg (c mol (p^+) kg^{-1})	3.4	2.4
Available Zn (mg kg^{-1})	1.02	1.07
Available Cu (mg kg^{-1})	1.78	1.95
Available Fe (mg kg^{-1})	296	258
Available Mn (mg kg^{-1})	15.2	12.7

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Table2. Effect of liming on yield attributes, yield and B:C ratio

Treatments	Pishanam season (strongly acidic soil)				Late pishanam season (moderately acidic soil)			
	No. of Productive tillers m^{-2}	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	B:C ratio	No. of Productive tillers m^{-2}	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	B:C ratio
T_1 - Control	280	2.46	4.24	1.10	284	2.64	14.58	1.18
T_2 - RDF + $ZnSO_4$ @ 25 kg ha^{-1}	318	4.59	7.79	1.76	335	4.18	8.46	1.67
T_3 - T_2 + Dolomite (0.25 LR)	332	5.25	8.03	1.74	348	5.05	8.60	1.88
T_4 - T_2 + Calcite (0.25 LR)	323	4.97	8.02	1.24	344	4.48	8.53	1.47
T_5 - T_2 + Dolomite (0.50 LR)	352	6.33	8.11	1.83	395	7.40	10.5	2.56
T_6 - T_2 + Calcite (0.50 LR)	337	5.66	8.10	1.03	362	6.98	9.86	1.90
T_7 - T_2 + Dolomite (0.75 LR)	375	7.09	10.3	1.86	358	6.59	9.73	2.18
T_8 - T_2 + Calcite (0.75 LR)	356	6.85	8.53	0.98	353	5.38	9.00	1.30
T_9 - T_2 + Dolomite (1.0 LR)	304	4.39	7.06	1.06	331	4.07	7.86	1.32
T_{10} - T_2 + Calcite (1.0 LR)	295	3.85	6.45	0.47	326	3.61	6.80	0.78
SEd	11.2	0.19	0.07	-	6.92	0.11	0.73	-
CD (0.05 %)	23.5	0.4	0.2	-	14.5	0.2	1.5	-

LR-Lime Requirement, RDF- Recommended Dose of Fertilizer, $ZnSO_4$- Zinc Sulphate

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Table3. Effect of liming on soil properties in strongly acidic soil (pishanam season)

Treatments	pH	EC	Avail.N	Avail.P	Avail.K	Ex.Ca	Ex.Mg	DTPA-Zn	DTPA-Cu	DTPA-Fe	DTPA-Mn	%BS
		(dS m^{-1})	⟵ (kg ha^{-1}) ⟶			(c mol (p^+) kg^{-1})		⟵ (mg kg^{-1}) ⟶				
T_1 - Control	4.98	0.03	102	6.20	71	2.10	1.70	0.90	1.76	345	15.2	30.8
T_2 - RDF + $ZnSO_4$ @ 25 kg ha^{-1}	4.73	0.03	198	9.60	109	2.20	1.80	1.11	1.90	259	14.0	32.9
T_3 - T_2 + dolomite (0.25 LR)	5.25	0.05	206	10.8	147	3.20	3.00	1.28	1.99	159	10.7	51.6
T_4 - T_2 + calcite (0.25 LR)	5.46	0.05	204	10.4	142	3.60	2.60	1.26	1.97	162	13.5	51.2
T_5 - T_2 + dolomite (0.50 LR)	5.22	0.05	217	11.5	151	3.50	3.30	1.36	2.11	155	11.9	58.5
T_6 - T_2 + calcite (0.50 LR)	5.36	0.04	218	10.6	148	3.90	2.90	1.32	2.08	157	12.7	57.7
T_7 - T_2 + dolomite (0.75 LR)	5.92	0.07	238	11.8	163	3.70	3.80	1.58	2.18	147	10.4	66.2
T_8 - T_2 + calcite (0.75 LR)	6.00	0.08	224	11.6	158	4.90	3.20	1.44	2.15	151	11.2	65.8
T_9 - T_2 + dolomite (1.0 LR)	6.66	0.11	187	9.50	103	4.40	4.40	1.15	1.85	135	8.90	82.2
T_{10} - T_2 + calcite (1.0 LR)	6.64	0.12	148	8.90	95	5.80	3.60	1.12	1.82	142	9.70	81.8
SEd	0.07	0.0002	3.1	0.2	3	0.08	0.06	0.03	0.04	3.6	0.29	-
CD (0.05 %)	0.2	0.004	6	0.4	6	0.2	0.13	0.07	0.09	8	0.6	-

LR-Lime Requirement, RDF- Recommended Dose of Fertilizer, $ZnSO_4$- Zinc Sulphate

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Table4. Effect of liming on soil properties in moderately acidic soil (late pishanam season)

Treatments	**pH**	**EC**	**Avail.N**	**Avail.P**	**Avail.K**	**Ex.Ca**	**Ex.Mg**	**DTPA-Zn**	**DTPA-Cu**	**DTPA-Fe**	**DTPA-Mn**	**%BS**
		(dS m^{-1})	← **(kg ha^{-1})** →			**(c mol (p^+) kg^{-1})**		← **(mg kg^{-1})** →				
T_1 - Control	5.48	0.05	128	6.40	151	2.60	2.40	1.04	1.93	264	13.5	36.4
T_2 - RDF + $ZnSO_4$ @ 25 kg ha^{-1}	5.30	0.06	194	10.3	199	3.20	2.90	1.20	2.06	195	12.3	44.4
T_3 - T_2 + dolomite (0.25 LR)	5.49	0.11	196	10.9	202	4.00	4.20	1.37	2.15	123	9.00	59.8
T_4 - T_2 + calcite (0.25 LR)	5.67	0.12	195	10.6	200	4.80	3.60	1.35	2.13	125	11.8	61.1
T_5 - T_2 + dolomite (0.50 LR)	5.97	0.13	218	11.9	220	4.30	4.60	1.67	2.27	117	10.3	67.1
T_6 - T_2 + calcite (0.50 LR)	5.86	0.13	217	11.6	218	5.20	3.70	1.53	2.24	120	11.0	65.9
T_7 - T_2 + dolomite (0.75 LR)	6.03	0.14	216	11.3	216	4.90	4.90	1.45	2.34	108	8.80	75.9
T_8 - T_2 + calcite (0.75 LR)	6.09	0.15	214	11.0	211	5.80	3.70	1.41	2.31	112	9.50	72.4
T_9 - T_2 + dolomite (1.0 LR)	6.36	0.15	193	10.0	197	5.30	5.20	1.24	2.01	93	7.30	80.9
T_{10} - T_2 + calcite (1.0 LR)	6.82	0.16	160	9.10	194	6.40	4.00	1.21	1.98	104	8.00	80.1
SEd	0.12	0.004	4.8	0.2	4.4	0.07	0.11	0.02	0.04	2.1	0.22	-
CD (0.05 %)	0.3	0.01	10	0.5	9	0.2	0.2	0.04	0.09	5	0.5	-

LR-Lime Requirement, RDF- Recommended Dose of Fertilizer, $ZnSO_4$- Zinc Sulphate