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Soil pH as a Master Variable of Agricultural Productivity in Burdwan-I C.D. Block, Barddhaman, West Bengal

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Abstract

Soil pH is considered as master variable as it controls physical, chemical and biological properties of soil. Acidification, a natural process, is accelerated in agricultural system. To maintain productivity of crop, desired pH level is 6 to 7 in soil. For that reason, liming is an inevitable practice in acid soil. In this study, 208 soil samples of surface layer (0-15cm) have been collected from arable land along with detail interaction with the cultivator regarding cropping pattern, application of fertilizer, liming, productivity of crops and management of soil. Soil pH_{H2O} has been tested along with pH_{KCl}, buffer capacity (BC), total acidity (TA), and requirement of lime. Soil pH_{H2O} has been found out as factor of pH_{KCl}, BC, TA and also liming. Average pH_{H2O} is decreased with intensification of cropping pattern. There is pH_{H2O} 6.36 in single cropped land but it is 6.004 in triple cropped land. Again, in aman-boro-potato cropping pattern, pH_{H2O} is 5.66 where 404.77 kg ha^{-1} yr^{-1} nitrogen is added as fertilizer. As lime is not applied in the agricultural land, 4 to 10 ton ha^{-1} $CaCO_3$ is required for achieving desire pH_{H2O} of 6.0 to 6.8. Nitrogen holding capacity is depended on soil pH_{H2O} (r= -0.11) in the block again soil pH_{H2O} is decreased with increasing amount of N fertilizer addition (r = -0.10) in the soil. Consequently, productivity of paddy and til (sesame) is influenced with soil pH_{H2O} and pH_{H2O} is the first component of the agro-pedological system. In this study, soil pH_{H2O} has become the principal variable which determines lime requirement, total acidity and nitrogen content in soil.

Introduction

Soil pH, one of the most important properties of soil in perspective of agro-ecological system, is controlled by clay minerals, organic matter and oxides of Al, Fe, Ca and Na (Thomas, 2006). However, it controls other properties of soil (Brady and Weil, 1999). Root growth and nutrient uptake are hampered in case of low soil pH due to soluble form of Al^{3+} (Rangel, 2003). Although pH values are not adequate to determine lime requirement, pH of soil indicates the chemical reactions (Thomas, 2006) and through liming, soil pH can be increased to ameliorate acidity of soil (Rangel, 2003). Not only chemical properties, but also physical (flocculation or deflocculation) and biological (mineralization or immobilization) properties of soil are determined through pH (Bolan and Kandaswamy, 2005). Thomas (2006) has described major categories of pH and their significance. The pH range 4 to 5, due to presence of trivalent exchangeable aluminum, indicates problem of root growth and pH 5.5 shows reaction of hydroxy-Al [Al(OH)] with H^+, formed by nitrogen fertilizer or lime. But, pH 6 to 7 indicates Ca^+ as exchangeable cation, free of trivalent exchangeable aluminum, non-exchangeable hydroxy-Al and optimum soil conditions for crop growth with lowest negative consequences. Availability of nutrients (nitrogen, phosphate), base saturation (Ca, Mg, K and Na) and toxicity of soil (Al^{+3}, Fe^{+2}) are determined by soil pH (Chesworth, 2008).

Decline in soil pH in agro-pedological systems may be sufficient to cause moderate to severe Al^{+3} and Mn^{+2} toxicity, which affects the long-term economic viability of farming systems and degradation of soil resource (Rangel, 2003). Maintaining 'healthy' soil pH 6 to 7 through application of lime provides satisfactory growing condition by reducing Al^{+3}, increasing calcium (Wolf and Snyder, 2003). But as the required amount is high, the carrying of lime into the field is a problem (Rangle, 2003). So, a soil acidification model can be used to calculate the amount of lime required for maintaining the soil pH at the desired level (Rangel, 2003; de Kelin et al., 2010). In this research work, soil pH has been studied as a principal property of the soil and influential factor for productivity of crops.

Objectives

The objectives of this research work is to investigate relationship between soil pH_{H2O} and other chemical properties of soil such as pH_{KCl}, buffer capacity, total acidity, lime requirement and nitrogen content and to analyze the influence of soil pH_{H2O} on productivity of crops.

Study Area

The area of the block is 250.54 km^2 in which 206.95 km^2 is used for agriculture. Population density of the block is 718 person/ km^2 (Census, 2011). *Aman-boro* paddy is cultivated in 87% agricultural land. Cropping intensity of the block is 205. Agricultural density is 59 cultivators /km^2 whereas physiological density is 1067 person/km^2. The latitudinal and longitudinal extension of the block is from 23° 12′4″N to 23º 22′48″N and from 87° 47′8″E to 88° 4′24″E respectively.

Materials and Methods

Soils

The study has been done on the basis of primary data. For collecting of soil samples, the block has been divided into grids of one sq km. On the basis of grid, 208 soil samples have been collected along with detail interview with the cultivators about their techniques of cultivation and the soil management practices.

Soil Testing

The collected soil samples have been dried in air and pH_{H2O} has been tested with distilled water at soil-water ratio of 1:2.5 by glass electrode pH meter. Another pH has been measured with 1N KCl at soil-KCl solution ratio of 1:2.5. To measure the charge of clay surface, $\Delta pH = pH_{H2O} — pH_{KCl}$ has been calculated. Buffer capacity has been measured with 0.01 N NaOH and expressed as $\beta = db/d(pH)$, where '*db*' is the amount of added base causes *d*(pH) change in pH. Total acidity has been measured by 1N NaOAC solution, adjusted to pH 8.2. Lime requirement has been tested by the method of Schoemaker et al. (1961). Total nitrogen (TN) has been measured as per the method of Subbiah and Asija, 1956.

Statistical Analysis

To analyze the data, linear regression, curvilinear regression and multiple regression have been computed in MS Excel, 2007 and Statistica 10.0. Correlation values have been tested its significance in (N - 2) degrees of freedom (208 - 2 = 206). Principal component has been analyzed in Past 3.0. Thematic maps have been prepared using Map Info 7.0. The equations of regression analysis are:

$$Yc = a+bx \quad \ldots\ldots\ldots\ldots (1)$$

$$Yc = a + bx_1 + cx_2 \quad \ldots\ldots\ldots (2)$$

$$Yc = a+bx_1 + cx_2 + dx_3 \ldots\ldots\ldots (3)$$

Results and Discussions

Soil pH_{H2O}

In the block, the range of pH_{H2O} of soil is 4.51 to 8.25. The pH_{H2O} of soil is highly related with buffer capacity (0.38) and organic carbon (-0.1183) in soil. The lowest pH_{H2O} value (4.51) has been found in southern part due to low buffer capacity. The highest value of pH_{H2O} (8.25) has been observed in north-eastern part because of high buffer capacity and deposition of alluvium through flood water. In north-western part, acidic soil (<5.5) has been found for low buffering capacity of soil whereas slightly alkaline soil (7.5-8.5) has been noticed in south-western part due to higher buffering capacity (Fig. 1).

Spatial Distribution of Soil pH_{H2O}

In the block, 9.88% of the agricultural land is characterized of acidic soil whereas 62.25% land belongs to slightly acidic condition. Neutral soil pH is found in 27.63% land while only 0.38% land is tending to become alkaline (Table -1).

Soil pH_{H2O} in Different Cropping Pattern

The soil pH_{H2O} is highly variable with the pattern of crops. In the single cropped land, the average pH_{H2O} value is 6.36 because lowest amount of nitrogen (N) fertilizer (76.5 kg ha^{-1} yr^{-1}) is added. In the double cropped paddy field, it is 6.19 where 176.38 kg ha^{-1} yr^{-1} N is added. The pH_{H2O} in triple cropped land is 6.004 where 325.66 kg ha^{-1} yr^{-1} N is added (Fig.2). Hence, with the increase of intensity of cultivation, the pH_{H2O} value in the soil decreases because of mismanagement of soil without use of lime and organic manure.

In the study area, there is a relation between nitrogen addition and declining of pH_{H2O}. In single crop cultivation, *aman,* soil pH_{H2O} is 6.36 where nitrogen is added 76.5 kg ha^{-1} yr^{-1}. In double cropped cultivated land, *aman-boro*, soil pH_{H2O} is 6.19 while addition of N is 176.38 kg ha^{-1} yr^{-1}. Again, in *aman*-potato cultivation, soil pH_{H2O} is 6.13due to 313.5 kg ha^{-1} yr^{-1} N-addition (1.7 times than *aman-boro*). In the land of *aman-boro*-potato cultivation, soil pH_{H2O} is lowest (5.66) where highest N (404.77 kg ha^{-1} yr^{-1}) is added (Fig.3). Hence, with the increase of application of N-fertilizer, soil pH_{H2O} is decreasing. Because through nitrification, NH_3 volatilisation and NH^{4+} assimilation process, 2 mole, one mole and one mole H^+ per mole N is added in the soil. In NO_3^- assimilation and de-nitrification process, one mole H^+ each per mole is consumed (de Klein, 2010; Helyar and Porter, 1989).

In the different combination of crop and application of N, the pH_{H2O} is varied considerably. In *aman* cultivation where 76.5 kg N ha^{-1} yr^{-1} is applied, average pH_{H2O} is 6.36 and where applied N is highest in cultivation of *aman-boro*-potato (404.77 kg ha^{-1} yr^{-1}), pH_{H2O} is lowest (5.66).

In potato cultivation, application of N (222.27 kg ha^{-1} yr^{-1}) is more than twice than paddy cultivation (85.56 kg ha^{-1} yr^{-1} in *aman* and 119.54 kg ha^{-1} yr^{-1} in *boro*). For this reason, the pH_{H2O} in soil of potato field is lower (6.13) than *aman-boro* land (6.19). In spite of relatively low application of N in cultivation of *aman-boro-til*, pH is low (5.98) than other combination of crops. Soil pH is highest (7.33) in combination of *aman*-mustard - *til* (Fig.*4*).

Factors of Soil pH_{H2O}

Soil pH_{H2O} is highly dependent on other properties of soil, like buffering capacity, organic carbon, clay and application of N in soil. The values of correlation of pH_{H2O} with buffering capacity, organic carbon, clay and application of N are 0.38, -0.12, -0.02 and 0.02 respectively. Correlation value of pH with BC and OC is signified at 99.99 and 95% confidence level. The multiple regression equation is:

$$Y_{pH} = 5.6397+0.38x\ BC-0.122x\ OC+0.027x\ Clay+0.018x\ N\text{-}addition$$

$$r = 0.40 \quad p =< 0.0001 \ldots (4)$$

The correlation value between OC and pH_{H2O} is -0.12, signified at 95% level (Fig.5) because the accumulation of soil organic matter results in soil acidification because its constituent excess cations (or organic anions) are not released to neutralise the acidifying effect of their uptake by the herbage' and production of humic acid from humus (de Kelin et al., 2010).

Again, with the use of nitrogen as fertilizer, the pH_{H2O} is increased up to 220 kg ha^{-1} yr^{-1} and decreased thereafter. The yearly application of 220 kg ha^{-1} yr^{-1} N has been shown the highest pH_{H2O} in soil (6.20). The correlation between N-addition and pH_{H2O} is 0.10, signified at 90 per cent level (Fig. 6).

Soil pH_{KCl}

The charge of clay surface is determine by calculating pH from pH_{KCl}. If pH is > 0, that represents negatively charged clay surface while pH lower than 0 represent positively charged clay surface. Soil pH values measured in 1 mole l^{-1} KCl salt solutions are generally lower than the pH obtained using water, because the cations in these salts tend to displace H^+ and Al^{3+} from soil materials to soil solution (Bolan and Kandaswamy, 2005). Adsorbed H^+ ions is replaced by K^+ ions as K^+ is placed in top of electrochemical series:

H-soil + KCl K-soil + Hcl

(Biswas and Mukherjee, 1994)

In this block, the all soil samples have been found negatively charged clay. The range of pH_{KCl} is 3.45 to 7.33 (Fig. 7). The pH_{KCl} is dependent on pH_{H2O}. With the lowering of pH_{H2O} and higher concentration of adsorbed H^+, the release and replace of H^+ in KCl solution is greater in weak electrolytic solution of soil and the value of pH is higher in acidic state of soil. The correlation between pH_{H2O} and pH_{KCl} is 0.9262 which is significant in 99.999 per cent confidence limit (Fig. 8). The correlation between pH_{H2O} and ΔpH is 0.2121 which is also significant in 99% confidence limit (Fig. No.9). The equations are

$$Y\ pH_{KCl} = 1.778 - 1.097x pH_{H2O} \quad r = 0.92 \ldots (5)$$

$$Y\ pH = 1.778 - 0.097x pH_{H2O} \quad r = 0.21 \ldots (6)$$

Total Acidity

Total acidity of soil, called also hydrolytic acidity or titratable acidity, is present in pH range 5.5 to 7.0 as hydroxyl Al-polymers associated with clay minerals, aluminosilicates, weak acid groups on humus and organically formed Al (Sarkar and Halder, 2005; Curtin et al., 1984; Hoyt, 1977). Total acidity (extractable acidity), is the amount of acidity released from soil by sodium acetate (NaOAC) solution buffered at pH 8.2, which includes all the acidity from salt-replaceable (or exchangeable) and residual (or non-exchangeable) sources (Soil Survey Staff, 1999; SSSA, 2008). Salt-replaceable acidity consists primarily of hydrogen and aluminum ions that are held in soil colloids (Dai and Richter, 2000; Sarkar and Halder, 2005).

However, salt-replaceable acidity is more important because of potential Al phyto-toxicity problems insusceptible plants (Seybold, 2009). The buffered pH of 8.2 represents the pH that can be attained when a soil is treated with excess ground limestone (Bradfield, 1941). Total acidity is important because soils with similar pH values can have vastly different quantities of acidity that will require different quantities of agricultural lime (Bloom et al., 2005). More importantly, the acidity associated with salt-replaceable aluminium and hydrogen, weak-acid groups of organic matter, and hydrolyzable sesquioxides associated with clay minerals or organic matter will be neutralized (Thomas and Hargrove, 1984).

Spatial Distribution of the Total Acidity

In the study area, 0.51% land has been observed total acidity of 0 - 0.3 meq/100g soil which generally contains pH_{H2O} > 6.6. 16.4% agricultural land (33 soil samples) has been characterized with total acidity 0.3 - 0.6 meq/100g soil at pH_{H2O} range 6.3 - 6.6. In the middle and eastern part of the block, 33.53% agricultural land has been noticed total acidity 0.6 - 0.9 meq/100g soil. In southern part of the block, 22.46% land has been characterized with total acidity of 0.9 - 1.2 meq/100g for generally under 5.6-6.0 pH_{H2O} range. In western and eastern part of the block, 9.34 and 1.04 per cent of land has contained observed total acidity of 1.2 - 1.5 and 1.5-1.8 meq/100g soil respectively due to pH_{H2O} <5.6 (Fig. 10; Table - 2).

The correlation values of total acidity with pH_{H2O}, OC and clay are -0.76, 0.10 and 0.13 which are signified at 99.9%, 90% and 95% significance level. The equation of multiple regression is:

$Y_{TA} = 4.1888-0.76 \times pH_{H2O}+0.263 \times OC+0.0003 \times clay$

$r = 0.77 \quad p=< 0.0001$

From the regression of pH_{H2O} and TA, the equation is:

$Y_{TA} = 4.339 - 0.568 \times pH_{H2O}$

$r = -0.76$…(7) (Fig. 11)

Buffering Capacity

Spatial Distribution of Buffering Capacity

There is a relation between pH_{H2O} and buffer capacity in soil. Soil buffer capacity 0-3 ml/unit has been observed in 2.64% land mostly where the pH_{H2O} is low. 56.21% land has been characterized of 3-6 ml buffer capacity from northern, middle and eastern part of the block. 34.14% of land has shown buffer capacity of 6-9 ml/unit where the 6 - 6.5 pH_{H2O} range has been noticed. Buffer capacity 9 - 12 ml/unit pH has been observed in 6.25% land (Fig. 12; Table-3).

The correlation between pH_{H2O} and buffer capacity is 0.39 which is signified at 99.9% confidence level (Fig. 13). Higher buffer capacity has been found in higher pH_{H2O}. This can be deduced that higher pH_{H2O} is a result of higher buffer capacity of soil (Fig. 1 and 12).

Lime Requirement in Arable Soil

Agricultural lime is a soil amendment containing calcium carbonate, magnesium carbonate, and other materials, which are used to neutralize soil acidity and to furnish calcium and magnesium for plant growth (Daji, 1996; Foth, 1990). The amount of lime required is the quantity needed to change the initial soil pH to the optimum soil pH (Chesworth, 2008).

Sarkar and Halder (2003) has mentioned pH 6.5-7.5 as ideal for plant growth and liming as a efficient management practice in acid soil and soil environment for higher yield and sustainable agriculture. Higher pH of buffer solution requires low amount of lime to increase the pH_{H2O} at desire level (pH_{H2O} 6.0, 6.4, 6.8). Lime is not require in the soil where pH_{H2O} is above 6.0 (Chesworth, 2008; Sarkar and Halder, 2003).

Spatial Distribution of Requirement of Lime in Arable Land

In the block, 53.78% land, lime is not require as pH_{H2O} is higher than 6.0. In 11.42% agricultural land, the tested pH of buffer solution is 6.25-6.35 where 6.56, 7.78 and 8.9 ton/ha lime is required to raise soil pH_{H2O} at 6.0, 6.4 and 6.8 respectively. In 23.22% agricultural land, the pH of buffer solution is 6.35-6.45 where 5.59, 6.56 and 7.53 ton/ha lime is required to increase the pH_{H2O} at 6.0, 6.4 and 6.8 respectively.

The pH of buffer solution of 6.45-6.55 has been found in 7.83% agricultural land where 4.37, 5.35, 6.05 ton/ha lime is required to increase the pH_{H2O} at 6.0, 6.4 and 6.8 respectively (Fig. 14). In the block, pH of buffer solution, 6.25-6.35 has been found in northern, western and eastern part where pH_{H2O} is 5.0-5.3. The pH of buffer capacity 6.35-6.45 has been observed in middle and south-eastern part of the block at pH range of 5.3 - 5.6 (Table - 4).

Factors of Lime Requirement in Arable Soil

The correlation between pH_{H2O} and lime requirement is 0.8288, significant at 99.9% confidence level which shows that low lime requirement in the soil of higher pH_{H2O} (Fig. 15). The equation is:

$Y_{lime} = 4.686 + 0.304 \times pH_{H2O} \quad r=0.83$…… (8)

The correlation between total acidity and lime requirement is 0.38, signified at 99% confidence level (Fig. 16). As H^+ and Al^{3+} concentration increase in acid soil, more lime is required to replace H^+ and Al^{3+} and to form Ca-clay. With the lowering of total acidity and higher pH_{H2O}, lime requirement decreases. The equation is: $Y_{Lime} = 6.592 - 0.153 \times TA \quad r=0.38$….. (9)

Importance of Soil pH5.6.1 Nitrogen Content in Soil

The correlation between pH_{H2O} and nitrogen content in soil is 0.1178. In the curvilinear relation, between these variables, at pH 6.18, the nitrogen content is lowest (181.96 kg/ha). With the increase and decrease of pH_{H2O} from 6.18, the nitrogen content in soil increase (Fig. 17). The equation is:

$Y_{TN}=811.8 - 203.7pH_{H2O}+ 16.47pH_{H2O}^2 \quad r = 0.11$...... (10)

Agricultural ProductivityProduction of *Aman*

The correlation between production of the *aman* and soil pH_{H2O} is 0.0836 which is not satisfactorily significant (Fig. 18). But, in the, curvilinear relation, pH_{H2O} 6.56 has been obtained the highest production. The equation is

$Y_{Aman}=27.25+10.36pH_{H2O}-0.789pH_{H2O}^2 \quad r = 0.08$.....(11)

Production of *Boro*

The correlation between production of the *boro* and soil pH_{H2O} is 0.1048 which is signified at 90 per cent confidence level. In this relation, pH_{H2O} 6.18 has been shown the highest production of *boro* (70.49Q/ha) (Fig. .19).

$Y_{Boro}=14.59+ 18.10 \times pH_{H2O} -1.46 \times pH_{H2O}^2 \quad r = 0.10$.....(12)

Production of Potato

The correlation between soil pH_{H2O} and the production of potato is 0.27 which is not satisfactorily signified relation (Fig. 20). Though in this study, the lowest production (326.51Q/ha) has been found at 6.05, as the production of potato is depend on physical properties specially bulk density or compaction rather than chemical properties (Foth, 1990).

Production of Sesame (*Til*)

The correlation between soil pH_{H2O} and production of *til* is 0.59 which is signified at 98 per cent confidence level (Fig. 21). The production of *til* is affected with lowering of soil pH_{H2O}.

The equation is:

$Y_{til} = 10.17 - 3.021x\ pH_{H2O}$ r = 0.59............(13)

Factor(s) of Production of Crops

In the agro-pedological system of the block, pH_{H2O} is the determining component for production of paddy. The eigen value is 2.15 in pH_{H2O} and 43.04% of variance has been analyzed in pH_{H2O}. Other variables are positively correlated with pH_{H2O} except total nitrogen. The second component of the system is total nitrogen content in soil which has obtained eigen value of 1.048 and 20.96% of variance has been analyzed in second component. All other variable are negatively correlated with this component. The third component of the system is nitrogen addition in the soil which has obtained eigen value of 1.025 and 20.5% of variance has been explained (Table - 5 & 6). pH_{H2O} and pH_{KCl} are positively correlated with nitrogen addition while TN and BC have shown negative correlation with these variables. Hence, soil pH_{H2O} can be treated as a master variable of soil for controlling of other chemical properties of the soil, like pH_{KCl}, total acidity, buffer capacity, nitrogen content, lime requirement and productivity of crops.

Conclusion

From this study, it has been found out that pH_{H2O} is the principal variable of the agro-pedological system. It is directly related with production of crop, like paddy and sesame. Other chemical properties like pH KCl, total acidity, buffer capacity, lime requirement and nitrogen content in soil are controlled with pH_{H2O}. Paddy cultivation is highly affected with lowering of soil pH_{H2O} and as liming in agricultural land is not practice, soil acidification or lowering of soil pH_{H2O} hampers the production of crops. As soil pH_{H2O} lowers with intensification of cropping practice and amount of nitrogen addition in soil, proper management and required amount of lime are to be practiced to maintain the soil pH_{H2O}. Presently, different amount of $CaCO_3$ is required to ameliorate the toxicity of soil. To measure the rate of soil acidification and yearly requirement of $CaCO_3$ to maintain soil pH_{H2O}, further research is required. In present context, practice of organic agriculture with sufficient amount of lime and monitoring of soil can sustain the soil health and its productivity.

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References

1. Biswas, T.D. & Mukherjee, S.K. (1994). Textbook of Soil Science, Tata McGraw-Hill Pub. Co. Ltd, New Delhi, pp-144.
2. Bloom, P. R., Skyliberg, U. L. and Sumner, M.E. (2005). Soil acidity. in: Chemical Processes in Soils. SSSA Book Series 8. M. A. Tabaiabai. And D. L. Sparks (eds.). SSSA. Madison. WI. pp. 411-460. *In* Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science, Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
3. Bolan, N.S. and Kandaswamy, K. (2005). pH, *in* Hillel, D., Rosenzweig, C., Powlson, D., Scow, K., Singer, M. & Sparks, D. (2004). Encyclopedia of Soils in the Environment, Academic Press, NY.
4. Bradfleld, R. (1941). Calcium in the soil: I. Physico-chemical relations. J. SoilSci. Soc. Am. Proc. 6:8-15. *In* Seybold, C.A., Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science, Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
5. Brady, N.C. and Weil, R.B. (1999). The Nature and Properties of Soils, Prentice Hall: Upper Saddle River, NJ, *In* Bolan, N.S. and Kandaswamy, K. (2005). pH, *in* Hillel, D., Rosenzweig, C., Powlson, D., Scow, K., Singer, M. & Sparks, D. (2004). Encyclopedia of Soils in the Environment, Academic Press, New York.
6. Chesworth, W. (2008). Encyclopedia of Soil Science, Springer, Netherlands.
7. Curtin, D., Rostad, H. P. W., and Huang, P.M. (1984). Soil acidity in relation to soil properties and lime requirement. Can. J. Soil Set. 64:545 554. *In* Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
8. Dai, K. H. and Richter, D. D. (2000). A re-examination of' exchangeable acidity as extracted by potassium chloride and potassium fluoride. Commun. Soil Sci. Plant Anal. 31:115 -139. *In* Seybold, C.A., Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
9. Daji, J.A., Kadam, J.R. & Patil, N.D. (1996). A Text Book of Soil Science, Media Promoters and Publishers pvt. Ltd., Bombay .
10. de Klein, C.A.M., Monaghan, R.M. & Sinclair, A.G. (2010). Soil Acidification: a Provisional Model for New Zealand Pastoral Systems, Taylor & Francis, London, Retrieved on 27 March 2014, 06:23p.m.
11. Foth, H.D. (1990). Fundamentals of Soil Science, John Wiley & Sons, New York, pp-42-53.
12. Helyar, K. R. & Porter, W. M. (1989). Soil Acidification, its Measurement and the Processes Involved. In: Robson, A. D. ed. Soil Acidity and

Plant Growt
13. Hoyt. P. Bh. Marrickville, Academic Press. Pp. 61-101.. (1977). Effects of organic matter content on exchangeable Al and pH-dependent acidity of very acid soils. Can. J. Soil Sci. 57:221 222. *In* Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
14. Rengel, Z. (2003). Handbook of Soil Acidity Marcel Dekker, Inc. New York.
15. Sarkar, D. & Halder, A. (2005). Physical and Chemical Methods in Soil Analysis Fundamental Concepts and Analytical Chemistry and Instrumental Techniques, New Age International (P) Ltd. Publishers, New Delhi.
16. Seybold, C.A., Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
17. Shoemaker, H.E., McLean, E.O. and Pratt, P.F. (1961). Buffer Methods for Determining Lime Requirement of Soils with Appreciable Amounts of Extractable Aluminium. Proc. Soil Sci. Soc. Am. 25: 274-277 in Sarkar, D. & Halder, A. (2005). Physical and Chemical Methods in Soil Analysis Fundamental Concepts and Analytical Chemistry and Instrumental Techniques, New Age International (P) Ltd. Publishers, New Delhi.
18. Soil Survey Staff. (1999). Soil Taxonomy: A Basic System of Soil Classification for Making and interpreting Soil Surveys. 2nd Ed. Agric. Handb. 436. U.S. Gov. Print. Office, Washington, DC. In Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
19. SSSA. (2008). Glossary of Soil Science Terms. Soil Science Society of America, Madison, WI. In Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
20. Subbiah, B.V. and Asija, G.L. (1956). A Rapid Procedure for the Determination of Available Nitrogen in Soils. Curr. Sci. **25**: 259-260 *in* Sarkar, D. & Halder, A. (2005). Physical and Chemical Methods in Soil Analysis Fundamental Concepts and Analytical Chemistry and Instrumental Techniques, New Age International (P) Ltd. Publishers, New Delhi.
21. Thomas, G.W. (2006) pH *in* Lal, R. (2006). Encyclopedia of Soil Science, Taylor & Francis.
22. Thomas, G. W. and Hargrove, W.L. (1984). The chemistry of soil acidity. *In* Adams, F. (1984). Soil Acidity and Liming. Agronomy Monograph no. 12. 2nd Ed. (ed.). ASA-CSSA-SSSA, Madison. Wi. pp. 3-49. *In* Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.
23. Wolf, B. & Snyder, G.H. (2003). Sustainable Soils The Place of Organic Matter in Sustaining Soils and Their Productivity, Food Products Press, New York.181975044.

Table – 1: Spatial Distribution of Soil pH_{H2O} Categories, Burdwan-I C.D. Block, 2014

Soil pH	Fertility Class	% of Land
Below 5.5	Acidic	9.88
5.5 - 6.5	Slightly Acidic	62.25
6.5 - 7.5	Neutral	27.63
7.5 - 8.5	Tending to become Alkaline	0.38

Source: Computed by the authors

Table – 2: Spatial Distribution of Total Acidity of Soil, Burdwan-I C.D. Block, 2014

Total Acidity (meq/100g Soil)	% of Land
0 - 0.3	0.519
0.3 - 0.6	16.400
0.6 - 0.9	33.530
0.9 - 1.2	22.460
1.2 - 1.5	9.340
1.5 - 1.8	1.040

Source: Computed by the authors

Table – 3: Spatial Distribution of Buffer Capacity of Soil, Burdwan - I C.D. Block, 2014

Buffer Capacity (ml/unit pH)	% of Land
0 - 3	2.64
3 - 6	56.21
6 - 9	34.14
9 - 12	6.25
12 - 15	0.39
15 - 18	0.05

Source: Computed by the authors

Table – 4: pH of Buffer Suspension for Lime Requirement

pH of Buffer Suspension	pH of Buffer Suspension	% of Land	Requirement of Lime (tons/ha of pure CaCO3)		
			pH 6.0	pH 6.4	pH 6.8
6.05-6.15	6.1	0.86	8.51	10.21	11.66
6.15-6.25	6.2	2.38	7.53	8.99	10.21
6.25-6.35	6.3	11.42	6.56	7.78	8.99
6.35-6.45	6.4	23.22	5.59	6.56	7.53
6.45-6.55	6.5	7.83	4.37	5.35	6.05
6.55-6.65	6.6	0.39	3.4	4.13	4.61
pH_{H2O}>6.0		53.78			

Source: Computed by the authors

Table – 5: Components of Agro-pedological System (after PCA)

Components	Eigen value	% variance
pH_{H2O}	2.15227	43.045
Total Nitrogen	1.04821	20.964
N-Addition	1.02516	20.503
pH BC	0.70920	14.184
pH KCl	0.06515	1.303

Source: Computed by the authors

Table – 6: Factor Loadings of Components

Variables	Factor Loading				
	PC 1	PC2	PC3	PC4	PC5
pH_{H2O}	**0.9561**	0.1448	0.1209	-0.1287	-0.1800
pH_{KCl}	0.9249	0.1416	0.2235	-0.2093	**0.1700**
pH BC	0.5788	-0.4664	-0.4664	**0.6578**	0.0230
Total Nitrogen	-0.2117	**0.7999**	0.4397	0.3740	0.0003
N-Addition	0.0549	-0.5755	**0.7414**	0.2761	-0.0070

Source: Computed by the authors

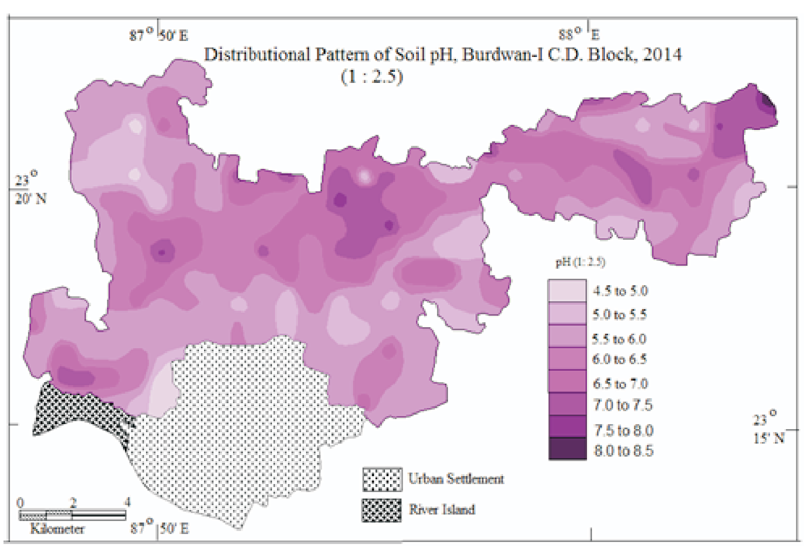

Fig. 1: Spatial Distribution of Soil pH_{H2O}, Burdwan - I C.D. Block, 2014

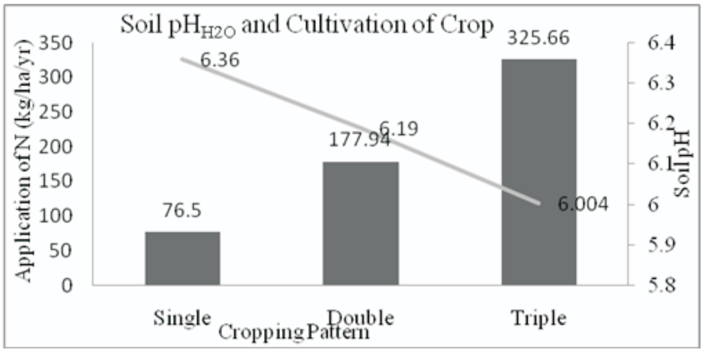

Fig. 2: Soil pH_{H2O} and Intensity of Cropping

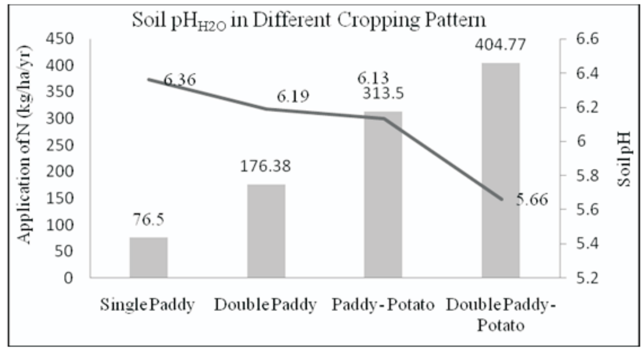

Fig. 3: Soil pH_{H2O} in different Cropping Patterns

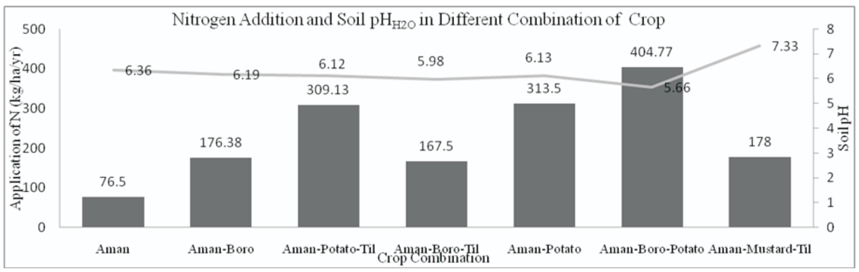

Fig. 4: Nitrogen Addition and Soil pH_{H2O} in different Combinations of Crops

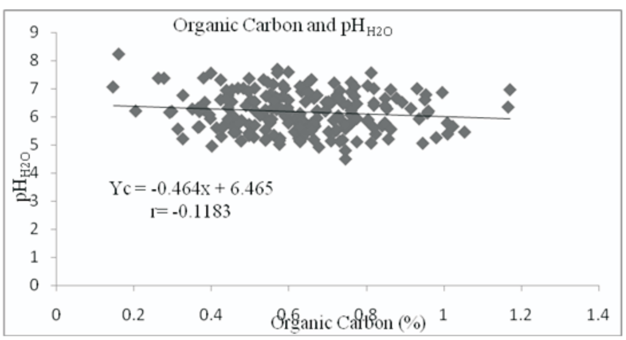

Fig. 5: Organic Carbon and Soil pH_{H2O}

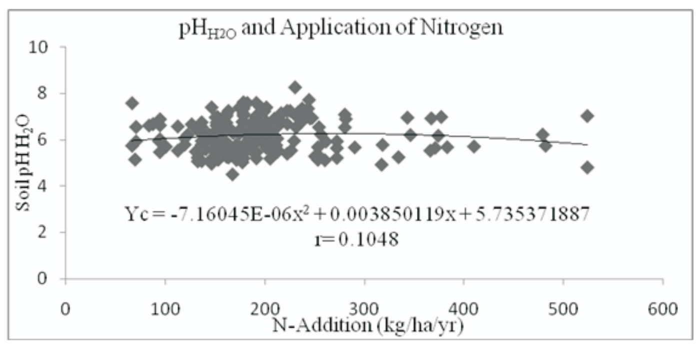

Fig. 6: Nitrogen Addition and Soil pH_{H2O}

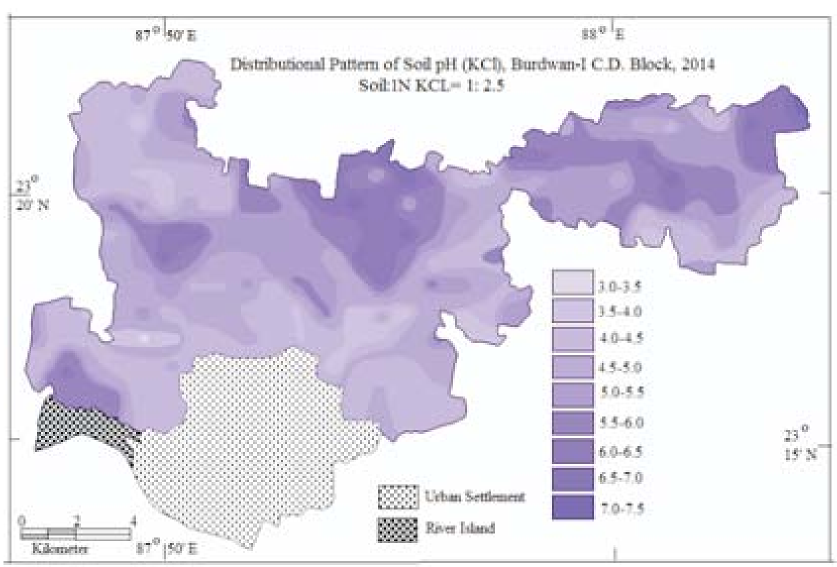

Fig. 7: Spatial Pattern of Soil pH_{KCl}, Burdwan - I C.D. Block, 2014

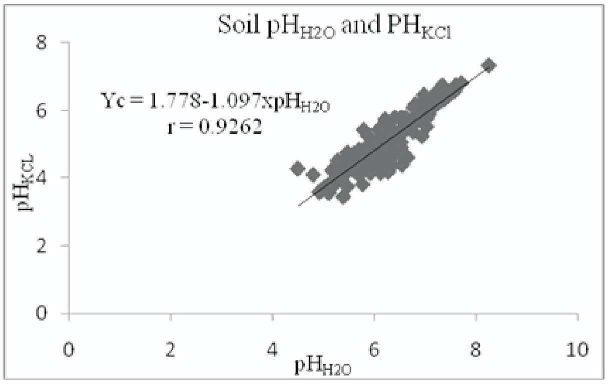

Fig. 8: Soil pH$_{H2O}$ and Soil pH$_{KCl}$

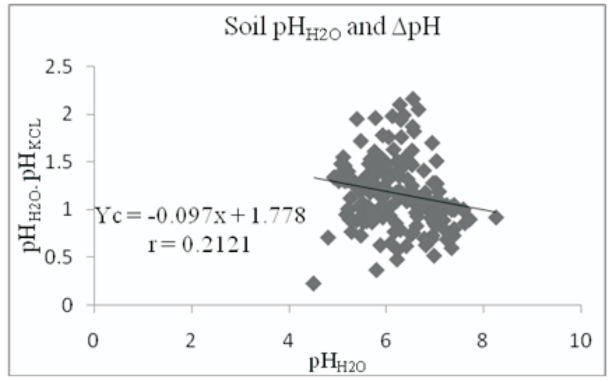

Fig. 9: Soil pH$_{H2O}$ and ΔpH

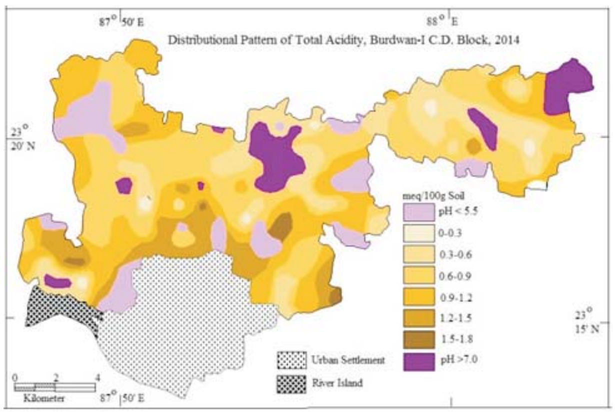

Fig. 10: Spatial Pattern of Soil Total Acidity, Burdwan - I C.D. Block, 2014

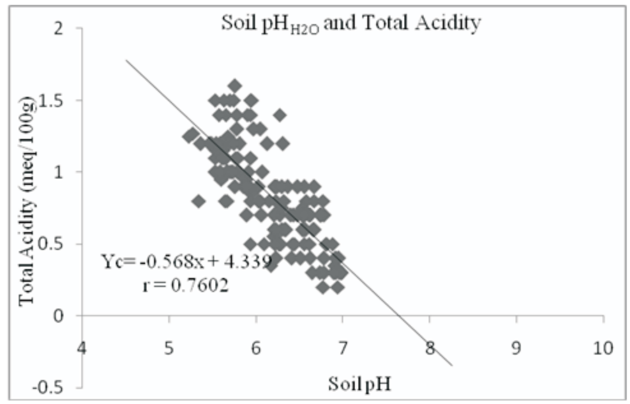

Fig. 11: Soil pH$_{H2O}$ and Total Acidity

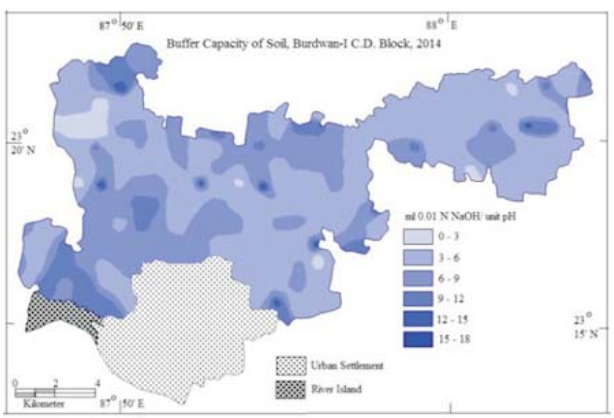

Fig. 12: Spatial Pattern of Soil Buffer Capacity, Burdwan - I C.D. Block, 2014

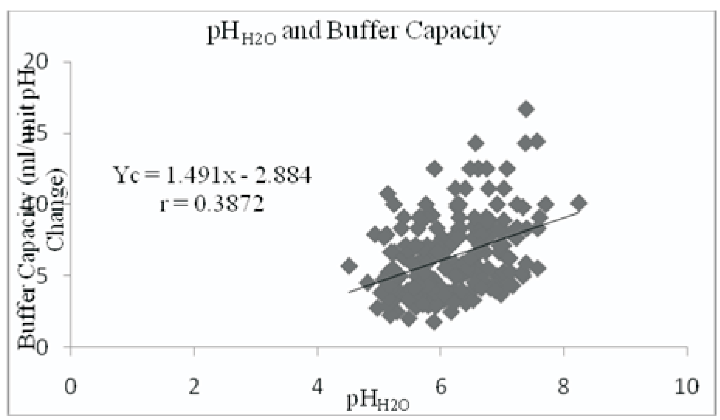

Fig. 13: Soil pH$_{H2O}$ and Buffer Capacity

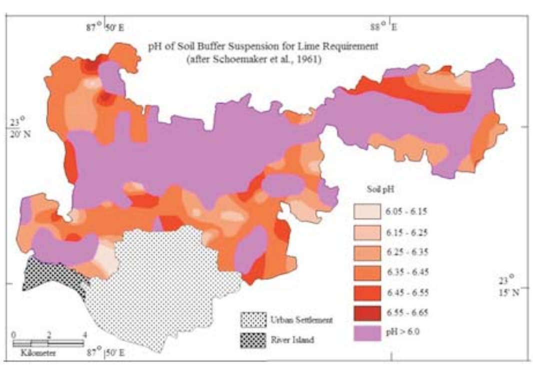

Fig. 14: Spatial Pattern of pH of Buffer Suspension of Lime Requirement, Burdwan - I C.D. Block, 2014

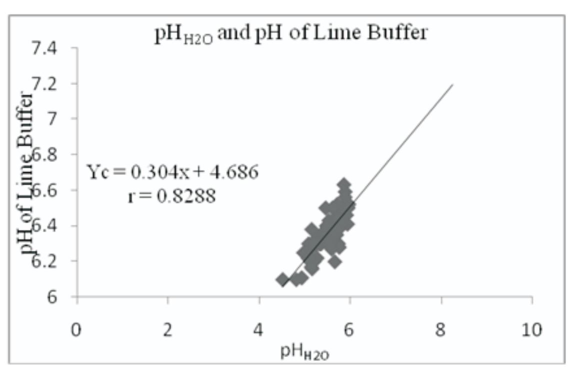

Fig. 15: Soil pH$_{H2O}$ and Lime Buffer

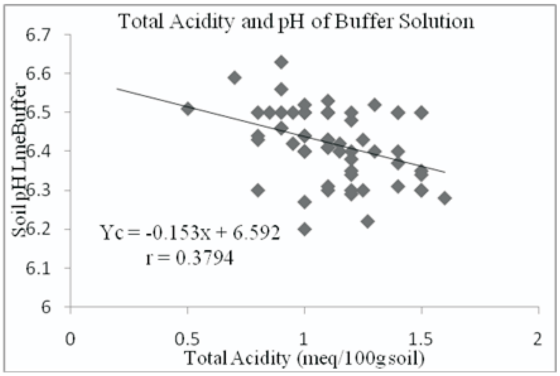

Fig. 16: Total Acidity and Soil pH of Buffer Solution

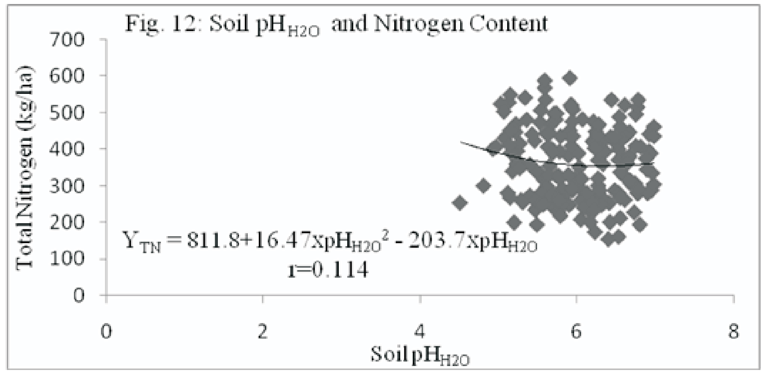

Fig. 17: Soil pH_{H2O} and Nitrogen Content

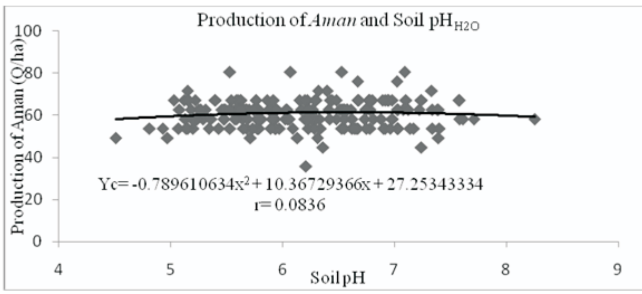

Fig. 18: Soil pH_{H2O} and Aman Production

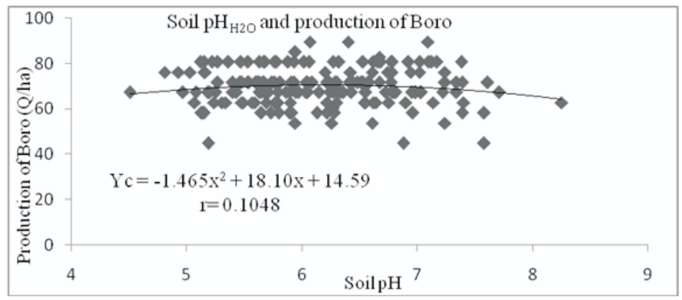

Fig. 19: Soil pH_{H2O} and Boro Production

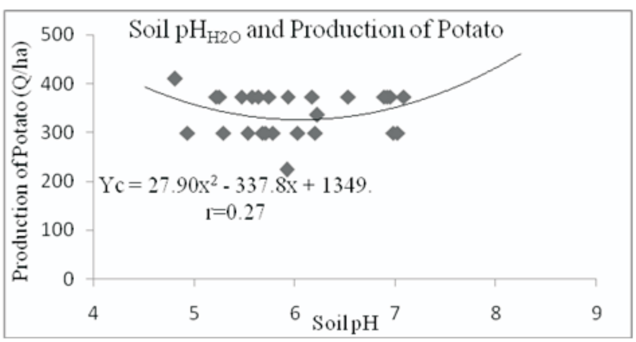

Fig. 20: Soil pH_{H2O} and Potato Production

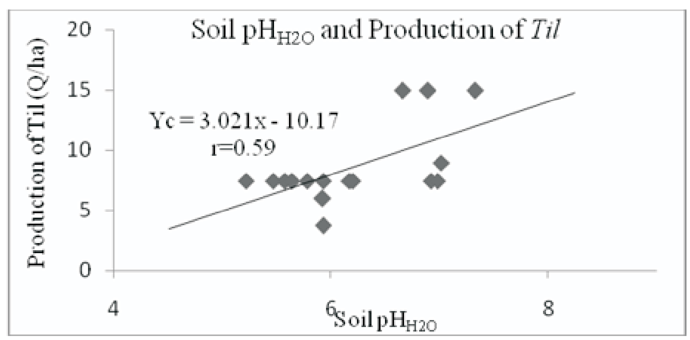

Fig. 21: Soil pH_{H2O} and Til Production

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