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## **DEVELOPMENT AND EVALUATION OF A TRACTOR OPERATED pH MONITORING SYSTEM**

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**Abstract:** South-western and central part of Punjab is dominated by calcareous soil includes desert soil, sandy loam to clayey and also have grey and red desert soil, calsisol soil, regosol soil and alluvial soil making alkalinity and salinity problematic as the power of hydrogen (pH) value of soil varies from 7.8 to 8.5 in this zone. Reduction-oxidation potential or 'Redox' is a measure of the electrical state of soil indicating the chemical condition of several substances and measure soil nutrient availability significant for plant growth. It varies with the relative acidity of the soil, and for purpose of comparison, Redox is expressed in milli volts (mV). pH monitoring system need to be developed which will help in mechanization of field operation by providing real time and online values of soil pH and mV, thus helping the researchers and farmers to start precision farming in the area. To achieve this, a tractor operated pH monitoring system was developed and evaluated in the field to measure the soil pH and mV along with geo-referenced locations. On an average soil pH of selected field was measured 6.55 with coefficient of variation (CV) 7.0%. Average soil mV was 40.71 having coefficient of variation (CV) 56.1. The model developed between pH and mV showed that there was a good co-relation between soil pH and mV having  $R^2=0.89$  indicating that soil pH was basically the reduction oxidation potential of soil.

**Key words:** *ph monitoring system, ph meter, GPS, bund former, soil mV*

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## INTRODUCTION

Punjab is produced about two-third of the food grains produced annually in India due to its fertile soil. Climatic differences result in varieties of soil which helps to cultivate a wide range of crops and vegetation in Punjab. The soil in Eastern Punjab is loamy to clayey and in South-western and central part of Punjab the area is dominated by calcareous soil includes desert soil, sandy loam to clayey and sierozem soil and also have grey and red desert soil, calsisol soil, regosol soil and alluvial soil making alkalinity and salinity problematic for this place. The alluvial soil of this zone can be widely described as arid and brown soil or tropical arid brown soil. The electrical conductivity of soil measured by tractor mounted soil sensor varied from 8.5 to 9.6  $\text{mS}\cdot\text{m}^{-1}$  having coefficient of variance 26.8% at soil moisture content of 26% (wb) [1]. The Power of hydrogen (pH) value in this zone ranges from 7.8 to 8.5 [2]. Power of hydrogen (pH) measures the activity of the (solvated) hydrogen ion concentration and is often written as pH. Pure water has a pH very close to 7 at 25°C. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Soil pH determined by using different methods and devices such as concentration cell with transference, a glass electrode and a pH meter, or using indicators. Specialty meters and probes are available for use in special applications, harsh environments, etc.

A study was conducted to determine Cd, Ni, Zn, Cu, Mn, Cr, Al and Se contents in spring wheat, potatoes and carrots (Cd, Ni and Zn) and estimate their correlations with certain soil factors (surface and subsurface soil pH and organic matter content) governing the plant availability of these elements. Concentrations of Zn, Mn, Ni (grain) and Cd (straw) in spring wheat (n=43); Cd, Ni, Zn, Mn, Cu and Al in potatoes (n=69); and Cd, Ni and Zn in carrots (n=36) showed significant negative correlations with surface soil pH (0–25 cm). The Se content of potatoes and Cr content of spring wheat straw were positively correlated with soil pH [5].

Reduction Oxidation Potential (ORP) or Redox is the activity or strength of oxidizers and reducers in relation to their concentration. Oxidizers (chlorine, bromine) accept electrons; reducers (sodium sulfite, hydrogen sulfide) lose electrons. Like acidity and alkalinity, the increase of one is at the expense of the other. Reduction-oxidation potential is a measure of the electrical state of soil indicating the chemical condition of several substances significant for plant growth. ORP is simply a measure of the availability of soil nutrients, particularly nitrogen. It varies with the relative acidity of the soil, and for purposes of comparison it is useful to express the 'Redox' in milli volts (mV).

It was reported that Hand held Ion Selective Electrodes (ISE) were commercially available for testing pH, sodium (Na), potassium (K), and nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ) [6] and [7] used a pH meter to measure the soil pH and correlated pH values to find the growth and soil nutrients of *Cunninghamia lanceolata* plantation, evergreen coniferous broadleaf mixed plantation and evergreen broadleaf mixed plantation.

The methods used by different scientist to measure soil pH and mV in laboratory is expensive and labour intensive as the pH measuring devices and equipments are not installed on the machines. Due to which, the soil samples are collected and bring in Laboratory manually to calculate the soil pH. Hence, there is a need to develop a machine with pH meter installed on it which will help in mechanization of field operation by providing real time and online values of pH and mV of soil, thus, helping

the researchers and farmers to start precision farming in the area. As a consequence, cost expenditure on human labour could be saved. It will indicate the protective measures to be taken so that the pH of soil can be neutralized to the permissible limits conducive for the plant growth. To achieve the goal, a tractor operated pH monitoring system was developed and evaluated in the field to measure the soil pH and mV.

## MATERIAL AND METHODS

The basic requirements for the development of soil pH monitoring system were Bund maker/Furrow maker, pH meter with data logger and GPSS (Global Positioning Satellite System) for the measurement of different parameters such as soil pH, temperature, latitude, longitude and milli volts in the field.

*Selection of the equipment/instrument.* A single furrow forming tractor operated bund maker for mounting of pH meter was selected due to safely fitting of probe on it and also had enough space for placing the pH meter and Global Positioning Satellite (GPS) system. The bund maker consists of mild steel angle iron frame, hitch system, and two blades used for bunds making for efficient use of irrigation water. Moreover, the depth of soil dugged by bund maker was up to 30 cm operated by 35 HP tractor. The blades and blades angle are adjustable along the frame to vary bund width and bund height. The Field scout pH 110 meter make, Spectrum Technologies, Inc., U.S.A was selected to mount over the bund maker. Garmin 76csx GPS system was selected due to its compatibility with field scout ph 110 meter.

*pH meter.* A special type of pH meter is required for the monitoring system so that instantaneous and real time data can be recorded. The Field scout pH 110 meter was selected to mount over the bund maker. The integrated data logger allows the user to easily collect field data with the pH meter. The logger can be used with or without GPS/DGPS. After a set of data collection, it is transferred to a PC using the Data Acquisition Software. Tab. 1 shows the technical specifications of the pH meter. The selected pH meter was very sturdy to work in severe environmental conditions of the field and suitable to work for all types of soil.

Table 1. Specifications of pH meter

Measurement Capacity	- 4,096 data points without GPS - 1,488 data points with GPS
Operating Environment	- Weather Resistant
Power	- 4 x AAA batteries - Provides 40 hours of logging
Software Requirements	- Windows 95 or higher - Field Scout Software v. 3.4 or higher (included)

*Development of pH monitoring system.* For the development of monitoring system, a platform made up of galvanized iron sheet was fitted in between the frame of Bund Maker. Two metallic boxes of galvanized iron were mounted on the platform for supporting the pH meter and GPS system. Fig. 1 shows the line diagram of designed platform and real view of platform fitted on the bund maker.

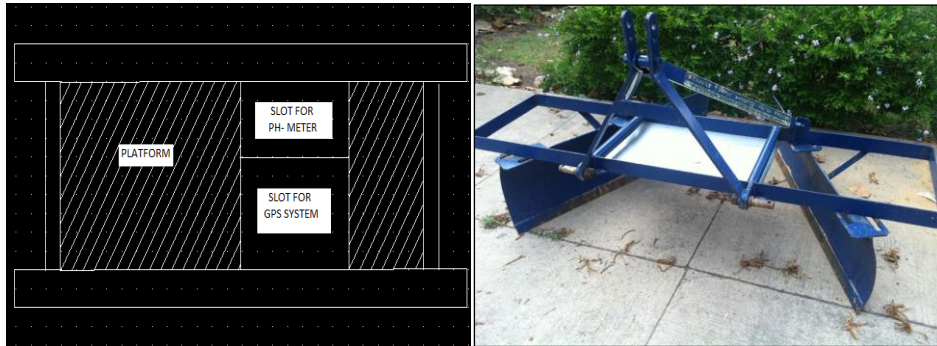


Figure 1. Line diagram of designed platform and real view platform fitting on bund maker

Fig. 2 shows the front view of the implement on which pH meter is mounted and the probe is mounted on the disc vertically.

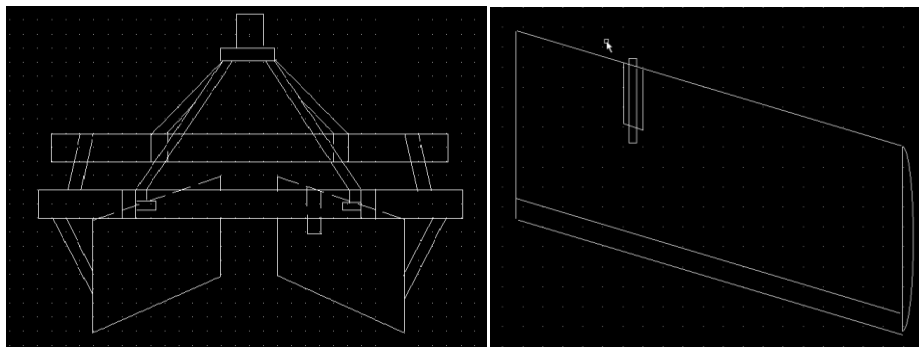


Figure 2. Front view of bund maker with probe fitted vertically

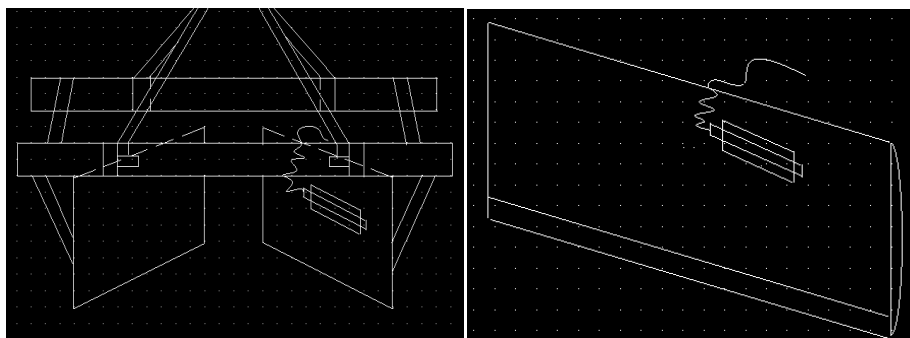


Figure 3. Front view of Bund maker with probe fitted horizontally

A slot type arrangement was made to fix the probe of pH meter on one blade of the bund maker. Initially, the slot of probe was fixed onto the blade of bund maker vertically, but this arrangement was not suitable due to soil impact on the probe. This

huge soil force could have easily damaged the delicate probe and its electrode. It was visualized that mounting of the probe horizontally instead of vertically may receive lesser impact. So keeping in view the probe was fitted horizontally on the blade of the bund maker. The horizontal mounting of the probe with the bund maker is shown in Fig. 3.

Fig. 4 shows the fitting of the pH meter probe on the bund former blade and final design of monitoring system after placing the pH meter and GPS in their respective boxes and Fig. 5 shows the operational view of bund former in the field.



Figure 4. Probe fitting on the bund maker and final design of monitoring system



Figure 5. Operational view of bund maker in the field

*Experimental Planning.* The field experiments were conducted at the departmental farm. The soil type was sandy loam. The bund maker was operated by using 35 HP tractor. The data of soil pH, Temperature, mV along with latitude and longitude of different points were recorded in the field. The data was repeated after every 5 seconds. The mapping of soil pH and milli volt data was done by using ARC GIS.

*Calibration of pH sensor.* There was need to calibrate the pH sensor as per local conditions. Therefore, to calibrate the pH sensor for its optimum settings, that was calibrated in Soil Testing Laboratory, Dept. of Soil Sciences, PAU Ludhiana. Three

buffer solutions of having pH 4.0, 7.0 and 10.0 were selected for the calibration purpose. The data recorded during the calibration of the pH sensor is mentioned in Tab. 2.

Table 2. Data during the calibration of pH sensor

<i>pH of buffer solution (standard)</i>	<i>Before calibration (pH sensor)</i>	<i>After calibration (pH sensor)</i>
4.00	4.12	4.00
7.00	7.19	6.99
10.00	9.87	10.02

To recheck the calibration of soil sensor, the sample of soil was also tested through the conventional method. The average value of soil pH measured with conventional method was 6.56, while average value of soil pH measured with pH sensor was found to be 6.44. both values were comparable and therefore soil pH sensor results were quite accurate and comparable with conventional pH measurement results.

*Field Evaluation of Monitoring System.* For determining the efficacy of the implement, experiments were conducted in the field located near Punjab Remote Sensing centre, PAU campus. The bund maker/former was operated in the field and formed bunds/furrows and soil started rising. When the probe touched the rising soil, the meter's LCD immediately started to indicate soil pH value. When this value was stabilized, the meter locked on that value and got stored in data logger. If the readings are not being geo-referenced, the green LED will briefly flash off and then back on. If the readings are being geo-referenced and a GPS signal is found, the green LED will turn off for a slightly longer time, then glow steadily. If the readings are being geo-referenced but no GPS signal is found, the LED will flash 3 times, then glow steadily. In this case, the pH reading will be recorded without latitude/longitude values. When the GPS is not connected with the meter, then the data logger records the set of readings and then it can transferred to computer or printer with the help of DAS (Data Acquisition Software). The DAS software is designed for pH 110 to allow you a convenient means of capturing data for future analysis using other software program such as LOTUS 123, EXCEL or DBASE in Windows©. It gives off the sets of readings in a excel sheet.

## RESULTS AND DISCUSSION

The developed monitoring system was used to measure the soil pH and Reduction Oxidation potential (mV) of soil with the reference provided through global positioning system (GPS). The geo referenced data of soil pH and mV measured during the evaluation of developed system are discussed below.

*Measurement of Soil pH.* Soil pH data along with its latitude and longitude are presented in Tab. 2. The table indicates that there is variability in the pH for the small field of about half acre. The maximum pH measured by using pH monitoring system was 7.24 at point having location (N30°54.627' and E75°48.688') and minimum value of pH was observed to be 5.66 at point having location (N30°54.593' and E75°48.681'). On an average soil pH was measured 6.55 with variation of soil pH having coefficient of variation (CV) 7.00. It was also observed that soil temperature was not varying

significantly as the temperature varies from 30-32°C. The soil pH map generated by using ARC GIS software is shown in Figure 6. The map was generated by using different zones of soil pH like 5.66-6.24, 6.24-6.56, 6.56-6.78 and 6.78-7.24.

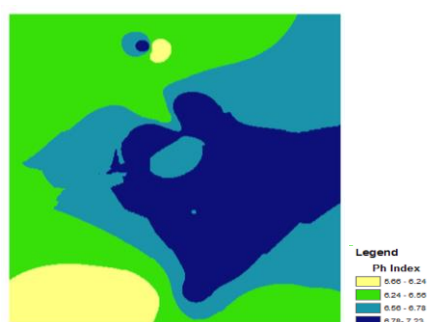


Figure 6. Soil pH map

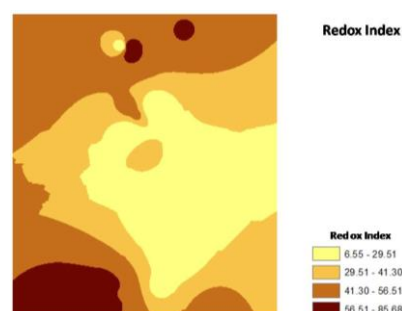


Figure 7. Soil mV map

Table 3. Soil pH and soil mV evaluation results in the field

Reading	Latitude (N)	Longitude (E)	Soil pH	Soil mV
1	30°54.629'	75°48.696'	6.51	58.9
2	30°54.626'	75°48.689'	6.07	68.1
3	30°54.631'	75°48.688'	6.49	44.6
4	30°54.625'	75°48.684'	6.48	44.3
5	30°54.625'	75°48.677'	6.37	51.9
6	30°54.624'	75°48.674'	6.34	52.2
7	30°54.593'	75°48.681'	5.66	85.7
8	30°54.595'	75°48.686'	5.82	74.4
9	30°54.595'	75°48.688'	6.16	54.9
10	30°54.592'	75°48.699'	6.35	49.0
11	30°54.593'	75°48.700'	6.37	48.7
12	30°54.592'	75°48.702'	6.44	43.6
13	30°54.595'	75°48.707'	6.52	40.5
14	30°54.598'	75°48.708'	6.66	34.1
15	30°54.627'	75°48.689'	5.84	74.1
16	30°54.619'	75°48.689'	6.28	50.6
17	30°54.618'	75°48.690'	6.44	45.9
18	30°54.613'	75°48.691'	6.60	37.1
19	30°54.606'	75°48.693'	6.77	28.5
20	30°54.596'	75°48.693'	6.90	23.3
21	30°54.600'	75°48.695'	7.17	10.8
22	30°54.605'	75°48.694'	7.18	9.0
23	30°54.608'	75°48.696'	7.22	7.4
24	30°54.616'	75°48.689'	7.22	7.3
25	30°54.619'	75°48.692'	7.22	7.3
26	30°54.627'	75°48.688'	7.24	7.2

*Measurement of Soil mV.* Soil mV data along with its latitude and longitude are presented in Tab. 3. The table indicates that there is variability in the mV for the small

field of about half acre. The maximum mV measured by using pH monitoring system was 85.7 at point having location (N30°54.593' and E75°48.681') and minimum value of pH was observed to be 7.3 at point having location (N30°54.619' and E75°48.692'). On an average soil mV was measured 40.71 with variation of soil pH having coefficient of variation (CV) 56.1. It was also observed that soil temperature was not varying significantly. The soil pH map generated by using ARC GIS software is shown in Figure 7. The map was generated by using different zones of soil pH like 6.55-29.51, 29.51-41.30, 41.30-56.51 and 56.51-85.68.

*Relationship between pH and mV.* The relation between pH value and mV value measured in the field is shown in the Fig. 8. The data measured in the field shows that pH and mV have direct relation between them. They are inversely proportional to each other. It means that as the there is increment in the value of pH, there is decrement in the value of mV. The co-relation model was developed between soil ph and mV data i.e. mentioned below:

$$mV = -2.8309 * pH + 78.929$$

The model developed between pH and mV shows that there was a good co-relation between soil pH and mV having  $R^2 = 0.89$ . It indicates that soil pH is basically the reduction oxidation potential of the soil.

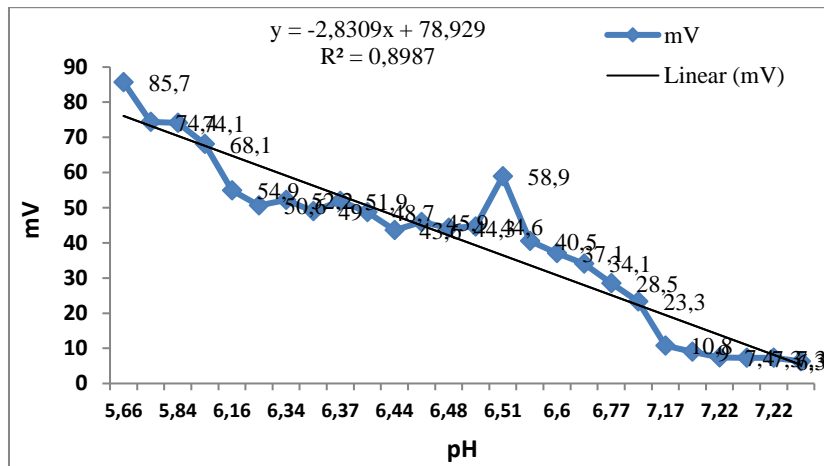


Figure 8. Co-relation model developed between pH and mV

## CONCLUSIONS

The conventional method i.e. Laboratory method of soil pH measurement is very laborious and time consuming. Therefore, it is a basic need to develop a system which can measure the real time data of soil pH and soil mV directly in the field. Hence, the tractor operated pH monitoring system was developed by mounting pH meter and GPS on bund former. The pH monitoring system measured pH and mV of soil along with the



geo referenced locations of the points. Following conclusions were drawn on the basis of the study conducted.

- The developed pH monitoring system was capable to measure and store the soil pH and milli volt (mV) data in the system along with the geo referenced locations.
- Average soil pH of selected field was 6.55 with coefficient of variation (CV) 7.0%.
- Average value of soil mV was measured to be 40.71 with coefficient of variation (CV) 55.9%.
- The model developed between pH and mV shows that there was a good correlation between soil pH and mV having  $R^2=0.89$ . It indicates that soil pH is basically the reduction oxidation potential of the soil.
- The pH and mV data of soil up to 30 cm depth was measured by using the developed system as compared to 15 cm soil depth used in the conventional method

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**RAZVOJ I ISPITIVANJE TRAKTORSKOG pH MONITORING SISTEMA****Amritpal Singh<sup>1</sup>, Lokesh Rampal<sup>1</sup>, Vishal Bector<sup>2</sup>, Manjeet Singh<sup>2</sup>,  
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**Sažetak:** Jugo-zapadnim i centralnim delom Punjaba dominiraju krečnjačka i pustinska zemljišta, peskovita ilovača, a takođe i crvena pustinska zemljišta, kalcifikovana zemljišta i aluvijalni nanosi koji dovode do problematične alkalnosti i saliniteta, jer pH vrednost zemljišta varira od 7,8 do 8,5 u ovoj zoni. Redoks potencijal je mera električnog stanja zemljišta koji ukazuje na hemijsku stanje više supstanci i merenje hranljivih materija iz tla značajnih za rast biljaka. Ona varira sa relativnim kiselosti zemljišta. Radi poređenja, Redoks potencijal se izražava u mili voltima (mV). pH monitoring system treba da se razvije da bi omogućio pri radu na terenu u realnom vremenu merenje vrednosti pH zemljišta i mV i tako pomogao istraživačima i poljoprivrednicima da počnu sa primenom precizne poljoprivrede. Da bi se to postiglo, razvijen je sistem monitoringa pH i mV na traktoru na georeferenciranim lokacijama. Na zemljištu sa prosečnom pH odabranih oblasti je izmerena vrednost od 6,55, sa koeficijentom varijacije (CV) 7,0%. Prosečni mV je bio 40.71, sa koeficijentom varijacije (CV) 56.1. Model koji je razvijen između pH i mV pokazao je značajnu korelaciju pH zemljišta i mV sa  $R^2 = 0.89$ .

**Ključne reči:** *ph monitoring sistem, ph metar, GPS, zagrač, zemljišni napon*

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