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Measurement of physical-chemical properties of soils for Jawar crop

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ABSTRACT

This paper describes the measurement of on field soil properties for jawar crop. The measured properties are soil water content, resistivity, conductivity, P^H and total dissolved solids. Few more properties like texture, gravimetric water content, volumetric water content, soil melting capacity, bulk density, porosity, water holding capacity and chemical compositions were determined in laboratory, after air drying the soil samples collected from the same locations. This study has been carried out at the test location as it comes under low rain area. So this location was used to study the effect of water content on physical - chemical properties of the soil and its effect on the jawar yield. The profile probe PR2 and an indigenously developed resistance meter was used to measure the soil water content and the resistivity respectively. The experimental observations shows that the on- field soil water content for the jawar crop should be in the range of 19 to 35 percent cm^3cm^{-3}. From the resistivity measurements it is observed that as depth of the probe from the field surface increases the soil resistivity decreases.

K**eywords:** Profile probe; Resistance meter: Soil physical- chemical properties; Low rainy season area; Jawar crop field.

INTRODUCTION

There are lots of development in the agricultural such as equipments, knowledge, and number of things that affect crop productivity. Farmers involved in precision agriculture can now get more detailed information about their farming options than ever before. In addition to yield boundary and filed attribute maps, new electronic, mechanical and chemical sensors have been developed to study soil and plant properties.

The real part of complex dielectric constant is an important parameter through which the soil water content can be determined. The knowledge of the behavior of soil water is useful since it affects intensively many physical and chemical reactions of the soil as well as plant growth. This physical property plays an important role in many agronomic, ecological and hydrological investigations to understand the soils chemical, mechanical, hydrological and biological relationships. The theoretical basis for soil moisture measurement is based on the large contrast between the dielectric constant of water (80) and that of dry soil (3 to 5) [1-3]. The dependence of dielectric constant on moisture can be measured with time domain reflectometry (TDR), frequency domain reflectometry (FDR) or number of sensors available in the market [4-7].

The soil water content is the most important physical property of the soil which is used to characterize the availability of water for plants. Large range of approaches is available to measure this. The aim of these methods is either to provide fast measurement value or to provide value for continuous measurements over large periods. All approaches need calibrations for individual soils if absolute values are actually needed and they can have a restricted linearity at high or low moisture ranges. Most alternative methods describe the physical properties of a very restricted solid volume, which then becomes the representative for a large bulk volume. Several reviews of soil water content measurement have been published in the past, notably those by [8]. More recently, another review has been published by [9, 10] has provided very useful summaries of theory and practice of many of the techniques available, and the contribution of the Gardener has been revised and updated [11,12].

In the present study the author has reported proper physical - chemical properties of soils for jawar. The measurements were carried out on two different jawar fields of around one hectare area. Plots have been made on these fields of the size of 5m X 3m.The field location was at Ramling Mudgad, Taluka - Nilanga, District- Latur of Maharashtra- India. The field location is non-irrigated farming land and depends only on rain water which comes under low rain area. The jawar yield obtained from the measured fields with minimum water content was in the range of 10,000/ - to 11,000/ - Kg/ ha in 2012 when there was drought in that area. Therefore, this field location was selected to study the status of water content, its effect on physical - chemical properties of the soils and on the jawar yield. The filed jawar crop is shown in Fig. 1.

EXPERIMENTAL SECTION

2.1 Field location

The field experiment was conducted on an agronomy farm (18^0 24′ N, 76^0 36′ E and 631 m altitude) at Ramling Mudgad, District- Latur of Maharashtra- India. The color of the soils was faint black and dark black. Under average climate conditions, the area is an arid and receives 300 mm to 350 mm average precipitation that occurs in the month of July through October. March through May is the driest period for crop growth. Little precipitation occurs during the winter months of October and November. The mean annual temperature is around 28 ^{0}C. The mean annual sunshine period is around 8520 h.

2.2 Soil sampling

Soil samples were collected from 10 to 15 cm depth layer at different points on the experimental site. Around 10 to 12 soil samples were taken from each site and after removing the surface organic materials and fine roots all the samples mixed thoroughly to make one composite sample. The soil samples were then brought to laboratory in rigid containers to avoid atmospheric changes and breaking the soil aggregates. After air drying for a week, the soil sample was divided into two groups for analysis. Prior to the analysis, each soil sample was passed through a 5 mm sieve. The collected soil samples mixed thoroughly to make one composite mixture and crushed well before the analysis. The texture analysis of both the soil samples was completed with the help of mechanical sieves which is noted in Table 1.

The physical properties of soil play an important role to improve the life and quality of soil, since they are related with the water holding capacity, water conducting ability, aeration, water retention, productive capacity, structure and plant nutriments. The physical properties of the soil samples collected from the test locations were completed in laboratory which is noted in Table 2.

2.3 Soil Characterization

Soil P^H was measured in distilled water at soil: water ratio of 1:5 using a P^H meter after shaking the suspension for 30 min and equilibration for 30 min. The same suspension was used to determine the electrical conductivity (EC) after allowing them to settle for half an hour using an EC meter. Particle size distribution (soil texture) was determined using mechanical sieves. The available soil organic matter (SOM), Nitrate (N), Phosphate (P_20_5), Ammoniacal Nitrate (N), and Potassium (K) were determined in laboratory and are illustrated in Table 3.

2.4 Soil water content

A profile probe (PR2) soil moisture measurement system was used to measure the soil water content. It is based on the principle of frequency domain reflectometry (FDR) technique. Using this probe the soil water content can be measured on agronomic farm up to one meter depth as 100 mm, 200 mm, 300 mm, 400 mm, 600 mm and 1000 mm. It works by inserting the probe into the soil. When power is applied to the probe, it creates a 100 MHz frequency signal that is applied to the stainless steel rings, which transmit an electromagnetic field extending about 1000 mm into the soil. The field passes easily through the access tube wall, but less easily through the air gaps. The water content in the soil surrounding the rings dominates its permittivity. The permittivity of soil has strong influence on the applied field, resulting in stable voltage output that acts as a simple sensitive measure of soil water content.

The water content was measured on the experimental site in the month of September, when soya bean crop was two months old. Prior to the measurements plots have been made on the test locations. The water content was measured at the crop root (i.e. at 15 cm depth) with equal intervals. The measured soil water content at the experimental location one and two is given in Table 4 and 5 respectively**.** The accuracy of measurement is in between ± 0.06 cm^3cm^{-3} with generalized soil. Figure 2 and 3 shows the photograph while measuring soil water content at location one and two respectively.

2.5 Soil Resistivity

Knowledge of soil resistivity is the key factor to decide structural stability. It varies widely from field to field and changes seasonally. It depends on water content, chemical composition, soil type (sand, clay and silt), and temperature. It has a direct impact on the degree of corrosion in underground pipelines. The decrease in soil resistivity relates to an increase in rusting corrosion activity of the soil therefore the protective treatment is necessary. Soil resistivity data is also useful to make sub-surface geophysical survey. It affects the design of a grounding system. When it is possible to choose the location of the earth connection, resistivity measurement helps to qualify the soil [13-17].

To study the corrosion activity of the soil at the experimental site the resistivity was measured at the depth of 10 cm. The resistance meter works by inserting the two probes into the soil. The probes are made from copper rods and are purchased from the local market. It is tapered at one end and wired at another end. The probes are very sensitive for water content changes. The probes established an electrical contact with the earth. The meter injects constant current through the ground via. the two probes. The current flowing through the earth develops a potential difference. Measuring V and I, the resistance per cm was calculated. The resistivity was determined using the following formula given by Wenner [18].

$$\rho = 2 \Pi AR \tag{1}$$

Where ρ, A and R are the soil resistivity in Ohm- cm, horizontal spacing between the probes and the resistance measured form the meter respectively. The measured soil resistivity at the test location one and two is given in Table 6 and 7 respectively.

2.6 Soil conductivity

Soil conductivity is one of the simplest, least expensive soil measurements available to the farmers today. Conductivity refers to the electrical conductivity (EC) of a solution, or it is a measure of the electric current generated by charged ions in the solution. The electrical conductivity varies not only to the concentration of salts present, but also to the chemical composition of the nutrient solution and soil moisture. It does not differentiate among the various elements, it measures total solutes. Plants tend to take nutrients up in an ionic form, so soil conductivity of a soil solution give an idea of the nutrient content in a soil. Measurement of electrical conductivity is nothing but monitoring the changes in the nutrient solution over time [19, 20]. That will give an idea of what type of adjustments should be made to keep the solution in balance for the crop to grow and give maximum yield. The conductivity at the test locations one and two was measured with the help of hand held conductivity meter at the crop root which is noted in Table 4 and 5 respectively. From the knowledge of conductivity the total dissolved solids (TDS) was determined which is illustrated in the same Table 4 and 5.

2.7 Soil P^H

The P^H of a soil is the hydrogen ion activity. It is very important because soil solution carries it nutrients such as Potassium (K), Phosphorus (P) and Nitrogen (N) that plants need in specific amounts to grow and fight off diseases. Therefore soil P^H measurement is very essential for healthy crop. All fertilizer, fungicide and water can't save a yard which is out of soil P^H balance. Without starting with the proper soil P^H, all effort and energies will be waste. Only when the Soil P^H is right then the other variables become significant. When soil pH is in balance, plants and other forms of life have a chance to prosper and live healthy happy lives. When soil P^H is not proper, growth will slow. Plants will not be able to utilize nitrogen and other food properly. The soil P^H at the test location one and two was measured with the help of hand held pH meter at the crop root which is noted in Table 4 and 5 respectively.

RESULTS AND DISCUSSION

The soil texture, physical and chemical properties of the soil samples collected from the test location one and two is illustrated in Table 1, 2 and 3 respectively. The measured on-field parameters like volumetric water content, conductivity, P^H and TDS at test location 1 and 2 is noted in Table 4 and 5 respectively. The soil resistivity for both the depths at the location 1 and 2 is noted in Table 6 and 7 respectively.

Table 1. Soil texture

Sr. No.	Soil texture	Jawar test location 1	Jawar test location 2
1	Coarse Sand (Percentage)	27.30	04.63
2	Fine sand (Percentage)	9.26	07.18
3	Silt (Percentage)	24.49	36.06
4	Clay (Percentage)	38.95	52.13

Table 2. Soil physical properties

Sr. No.	Physical properties	Jawar test location 1	Jawar test location 2
1	Gravimetric water content (θg)	0.47 $g.g^{-1}$	0.42 $g.g^{-1}$
2	Volumetric water content(θv)	0.59 $cm^3.cm^{-3}$	0.55 $cm^3.cm^{-3}$
3	Volumetric water content (θv) by SM-150 probe	0.586 % Vol.	0.356 % Vol.
4	Soil wilting capacity	0.340 %	0.455 %
5	Water holding capacity	56.5 %	62.5%
6	Bulk density	1.27 g/cm^3	1.31 g/cm^3
7	Soil porosity	0.52	0.52
8	Air-filled porosity	0.07	0.05
9	Water at wilting point	29.3%	26.0%
10	Available water	17.7%	16.0%

Table 3. Soil chemical properties

Sr. No.	Chemical Composition	Jawar test location 1	Remark	Jawar test location 2	Remark
1	Available Organic carbon (% by wt)	Below 0.5%	Low	Below 0.5 %	Low
2	Available Nitrate (Kg/hectare as N)	4.08	low	20.41	High
3	Available phosphate (Kg/hectare as P_2O_5)	0	Low	0	Low
4	Available potassium (Kg/hectare as K)	45.36	Medium	45.36	Medium
5	Ammoniacal Nitrogen(Kg/hectare as N)	5.89	Low	5.89	Low
6	Conductivity	140 μ℧ /cm	Non-saline	100 μ℧ /cm	Non-saline
7	Total dissolved solids (TDS)	77-105 ppm	less	55 - 75 ppm	Medium
8	pH	7.9	Slightly basic	7.5	Slightly basic

The soil water content was measured at the depth of 30 cm from the field surface. The probe sensor was at 15 cm depth i.e. at the crop root. The measured soil water content was different at different locations and it was in the range of 19.71 % to 30.52 % ($cm^3cm^{-3)}$ for location one and 24.51 % to 34.79 % ($cm^3cm^{-3)}$ for location two. The variation in water content is more for filed two than that of field one. This may be due to the variation in textural composition at the two test locations.

The soil resistivity was measured on the same test locations with a resistance meter. The resistivity was different at different locations and it was found in the range of 138 to 157 K- Ohm-cm at 10 cm depth and 135 to 145 K- Ohm-cm at 20 cm depth for location one. For field two it was found in the range of 138 to 155 K- Ohm-cm at 10 cm depth and 136 to 153 K- Ohm-cm at 20 cm depth for location two. The variation in resistivity is due to, the dissimilar proportion of water content, physical and chemical composition at the test locations. The soil resistivity is higher at 10 cm depth than that of 20 cm at the two test locations because water may be percolated in the soil and less water may be available at the top of the field than that of the 20 cm depth.

The P^H of the soils was found in the range of 7.1 - 7.5 for test location one and 7.1 - 7.5 for location two. The ionic conductivity was found in the range of 412 - 447 μ℧/cm for test location one and 380 - 490 μ℧/cm for location two. From the knowledge of conductivity the total dissolved solids (TDS) was determined and it was in the range of 229 to 332 ppm for field one and 209 to 367 ppm for field two.

Table 4. Field measurements for hybrid jawar crop at test location one

	Volumetric water content measurement			Conductivity, TDS and P^H measurements		
Sr. No.	Test location	Depth of the profile Probe in cm	Percentage volumetric water content (cm^3cm^{-3})	On field ionic Conductivity (EC) (μ℧ /cm)	Total dissolved solids (ppm)	On field P^H
	A					
0		30	23.40	439	241 - 329	7.2
1		30	24.76	430	236 - 322	7.3
2		30	20.53	436	239 - 327	7.4
3		30	19.71	429	235 - 321	7.2
4		30	21.45	420	231 - 315	7.3
5		30	22.34	428	235 - 321	7.2
	B					
0		30	21.56	421	231- 315	7.1
1		30	23.74	412	226 -309	7.4
2		30	21.89	416	288 -312	7.3
3		30	22.14	423	232 -317	7.2
	C					
0		30	21.93	443	243 - 332	7.1
1		30	26.52	447	245- 332	7.4
2		30	25.69	441	242-330	7.2
3		30	29.16	428	235 - 321	7.3
4		30	27.85	438	240 - 328	7.4
5		30	25.19	423	232 - 317	7.5
	D					
0		30	28.68	418	229 - 313	7.2
1		30	29.47	430	236- 322	7.3
2		30	28.27	428	235 - 321	7.2
		30	30.52	416	288 - 312	7.4

Table 5. Field measurements for hybrid jawar crop at test location two

	Volumetric water content measurement			Conductivity, TDS and P^H measurements		
Sr. No.	Test location	Depth of the profile probe in cm	Percentage volumetric water content (cm^3cm^{-3})	On field ionic Conductivity (EC)(μ℧ /cm)	Total dissolved solids (ppm)	On field P^H
	A					
0		30	31.11	446	245- 334	7.1
1		30	29.16	390	214 - 292	7.1
2		30	25.03	423	232 - 317	7.3
3		30	24.51	447	245 - 335	7.5
4		30	26.52	439	241 - 329	7.4
5		30	27.12	489	268 - 366	7.5
	B					
0		30	26.38	405	222 - 303	7.3
1		30	28.34	431	237 - 323	7.4
2		30	26.61	419	230 - 314	7.5
3		30	27.36	467	256- 350	7.5
	C					
0		30	26.38	428	235 - 321	7.4
1		30	31.72	486	267 - 364	7.5
2		30	29.24	457	251 - 342	7.2
3		30	32.45	435	239 - 326	7.1
4		30	31.85	477	262 - 357	7.3
5		30	30.23	490	269 - 367	7.4
	D					
0		30	33.23	452	248-339	7.2
1		30	34.79	461	253 - 345	7.4
2		30	33.46	380	209 - 285	7.5
		30	32.48	432	237- 324	7.5

Table 6. Field resistivity measurements for hybrid jawar crop at test location one

	Resistivity measurement					
Sr.No.	Horizontal Spacing between the probes in cm (A)	Vertical Depth of the probes in cm (B)	Soil resistivity (ρ) (K Ohm -cm)	Horizontal Spacing between the probes in cm (A)	Vertical Depth of the probes in cm (B)	Soil resistivity (ρ) (K Ohm cm)
1	0 - 50	10	151	0 - 50	20	141
2	50-100	10	151	50-100	20	141
3	100-150	10	148	100-150	20	143
4	150-200	10	148	150-200	20	143
5	200-250	10	145	200-250	20	141
6	250-300	10	149	250-300	20	141
7	300-350	10	149	300-350	20	143
8	350-400	10	149	350-400	20	143
9	400-450	10	139	400-450	20	143
10	450-500	10	157	450-500	20	145
1	0 - 50	10	151	0 - 50	20	141
2	50-100	10	145	50-100	20	142
3	100-150	10	145	100-150	20	142
4	150-200	10	147	150-200	20	143
5	200-250	10	147	200-250	20	143
6	250-300	10	143	250-300	20	141
1	0 - 50	10	144	0 - 50	20	135
2	50-100	10	144	50-100	20	135
3	100-150	10	132	100-150	20	136
4	150-200	10	132	150-200	20	136
5	200-250	10	138	200-250	20	135
6	250-300	10	142	250-300	20	135
7	300-350	10	142	300-350	20	136
8	350-400	10	142	350-400	20	138
9	400-450	10	142	400-450	20	139
10	450-500	10	142	450-500	20	136
1	0 - 50	10	144	0 - 50	20	135
2	50-100	10	138	50-100	20	135
3	100-150	10	139	100-150	20	135
4	150-200	10	140	150-200	20	136
5	200-250	10	142	200-250	20	135
6	250-300	10	143	250-300	20	137

The soil texture was determined in laboratory after air drying the soil samples for a week. Amongst the two test locations, the location two has lower percentage of coarse sand and higher percentage of clay than that of location one.

From physical properties it is observed that the field two has higher water holding capacity than that of field one since it has higher percent of clay.

The soil chemical analysis shows that the organic carbon, available phosphate (P_2O_5), and available Nitrogen (N) are low at both the test locations. The nitrate (N) is low at location one and high at location two. The available potassium (K) is medium at both the test locations. The P^H is slightly basic and conductivity is non saline at both the locations.

Table 7. Field resistivity measurements for hybrid jawar crop at field two

	Resistivity measurement					
Sr.No.	Horizontal Spacing between the probes in cm (A)	Vertical Depth of the probes in cm (B)	Soil resistivity (ρ) (K Ohm -cm)	Horizontal Spacing between the probes in cm (A)	Vertical Depth of the probes in cm (B)	Soil resistivity (ρ) (K Ohm cm)
1	0 - 50	10	145	0 - 50	20	142
2	50-100	10	145	50-100	20	142
3	100-150	10	146	100-150	20	141
4	150-200	10	147	150-200	20	141
5	200-250	10	145	200-250	20	141
6	250-300	10	145	250-300	20	142
7	300-350	10	145	300-350	20	141
8	350-400	10	141	350-400	20	139
9	400-450	10	147	400-450	20	143
10	450-500	10	151	450-500	20	141
1	0 - 50	10	138	0 - 50	20	136
2	50-100	10	139	50-100	20	137
3	100-150	10	146	100-150	20	141
4	150-200	10	146	150-200	20	141
5	200-250	10	147	200-250	20	144
6	250-300	10	149	250-300	20	145
1	0 - 50	10	146	0 - 50	20	143
2	50-100	10	147	50-100	20	145
3	100-150	10	146	100-150	20	144
4	150-200	10	147	150-200	20	144
5	200-250	10	151	200-250	20	144
6	250-300	10	147	250-300	20	141
7	300-350	10	148	300-350	20	142
8	350-400	10	149	350-400	20	146
9	400-450	10	148	400-450	20	143
10	450-500	10	151	450-500	20	145
1	0 - 50	10	145	0 - 50	20	143
2	50-100	10	145	50-100	20	142
3	100-150	10	155	100-150	20	151
4	150-200	10	155	150-200	20	151
5	200-250	10	148	200-250	20	143
6	250-300	10	150	250-300	20	145

Fig.1. On field Jawar crop at test location

Fig. 2. On field soil water content measurement with the help of profile probe at test location one.

Fig. 3. On field soil water content measurement with the help of profile probe at test location two.

CONCLUSION

The experimental measurements presented in this paper leads to the following major conclusions for jawar crop to grow and give maximum yield:

i) The soil water content should be in the range of 19 % to 35 % (cm^3cm^{-3}).
ii) The soil resistivity should be in the range of 135 to 155 K- Ohm-cm.
iii) The soil P^H should be around neutral to slightly basic.
iv) The conductivity should be non saline and in the range of 100 – 150 μ℧ /cm.
v) The jawar crop will grow in clay as well as in sandy loam soils.
vi) The jawar crop will grow in the soils having less organic carbon.
vii) The said crop will grow in the soils having less proportion of phosphate and nitrogen.
viii) The potassium (K) required for the said crop should be in the range of medium to high.

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