Soil and water test based advisories in agriculture

K.M.Sellamuthu, R.Santhi, S.Maragatham, P.Malathi and R. Natesan

Department of Soil Science and Agricultural Chemistry

Directorate of Natural Resource Management

Tamil Nadu Agricultural University

Coimbatore - 641 003

Soil is the prime source of nutrients for crops and it provides support for plant growth in many ways. Soil is a precious natural resource and hence maintenance of soil health is important for sustaining its productivity over long run. Knowledge about soil health and its maintenance is critical to sustaining crop productivity. Due the crop intensification and high yielding varieties grown, it has reported that a net negative balance of 8-10 mt of NPK per annum in India. About 40 to 50 per cent of the foodgrain production in India can be attributed to fertiliser use and the fertiliser consumption in India has increased significantly over years. The escalation in fertiliser prices has severed a setback to the concept of balanced fertilization. Blanket recommendation of fertilisers lead to over or under use of fertilisers ultimately deterioration of soil health. Hence, soil and water testing is essential for sustaining soil health and to improve nutrient use efficiency.

A. Soil test based advisories

The health of soils can be assessed by the quality and stand of the crops grown on them. A scientific assessment is possible through detailed physical, chemical and biological analysis of the soils. Essential plant nutrients such as N, P, K, Ca, Mg and S are called macronutrients, while Fe, Zn, Cu, Mo, Mn and B are called micronutrients. It is necessary to assess the capacity of a soil to supply nutrients in order to supply the remaining amounts of needed plant nutrients. Soils may have large amounts of nutrient reserves but all or a part of these reserves may not be of any use to crops because they

may not be in plant-available form. For the purpose of estimation or analysis of plant-available soil nutrients, such methods are to be used that have been tested/verified for the correlation of nutrients extracted and their plant availability.

Soil properties expected to be analysed:

Soil sample should represent the whole field. Soils properties vary from place to place. In view of this, efforts should be made to take the samples in such a way that they are fully representative of the field.

Soil have to be analysed for physical properties viz., soil texture, bulk density, physico-chemical properties viz., Soil reaction (pH) and Electrical conductivity (EC), Chemical Properties viz., Organic carbon, Available nitrogen, Available phosphorus, Available potassium, Exchangeable calcium and magnesium, available sulphur and micronutrients and their ratings are given in Table 1 & 2.

Table 1. Ratings for physico chemical properties

Optimum BD for plant growth (Mg m^{-3})	Texture	pH	Electrical Conductivity (dSm^{-1})
<1.60	SCL -Sandy Clay Loam	3.0-5.6 - Strongly acid	<2.0 - Very low
<1.40	CL-Clay Loam	5.6-6.2 -Moderately acid	2-4 - Low
<1.40	SL-Sandy Loam	6.2-6.7 -Slightly acid	4-8 - Moderate
<1.40	SC-Sandy clay	6.7-7.3- Neutral	8-16 - High
<1.40	S- Sand	7.3-7.9-Slightly alkaline	> 16 -Very high
<1.10	SC-Sandy clay	7.9-8.5-Moderately alkaline	
<1.10		>8.5 -Strongly alkaline	

Table 2 Ratings for soil fertility properties

A. Ratings for Soil Available Nutrients as followed in Tamil Nadu

S.No	Nutrients	Low	Medium	High
1.	Organic Carbon (%)	<0.5	0.5-0.75	>0.75
2.	Available N (Kg ha^{-1})	<280	280-450	>450
3.	Available P (Kg ha^{-1})			
	Olsen P	< 11	11-22	>22
	Bray P	<24.2	24.2-49.7	>49.7
4.	Available K (Kg ha^{-1})	< 118	118-280	>280

B. Critical Limits for Available Micronutrients as followed in Tamil Nadu

S.No	Elements	Deficient	Moderate	Sufficient
1.	$CaCl_2$ S (mg kg^{-1})	<10	10-15	>15
2.	DTPA Fe (mg kg^{-1})	<3.7	3.7-8.0	>8.0
3.	DTPA Mn (mg kg^{-1})	<2	2-4	>4
4.	DTPA Zn (mg kg^{-1})	<1.2	1.2-1.8	>1.8
5.	DTPA Cu (mg kg^{-1})	<1.2	1.2-1.8	>1.8
6.	Hot Water Soluble Boron (mg kg^{-1})	<0.46	0.46-1.0	>1.0

Soil test based fertilizer prescription for crops

Soil test based fertilizer prescription necessitates to avoid over use or under use of fertilizers for crop requirement. If soil test values or not available, recommended dose of fertilizer as per the Crop Production Guide by TNAU, Coimbatore & Department of Agriculture and 12.5 tonnes of FYM per hectare along with biofertiliser is recommended.

Soil Test Crop Response Based IPNS (STCR - IPNS) for various crops

General or blanket fertiliser recommendations are not based on soil fertility and may lead either to under or over usage of fertilisers. Therefore, an appropriate approach could be the recommendations emanating from Soil Test Crop Response Correlation (STCR) studies which are based on Inductive cum Targeted yield model (Ramamoorthy *et al*., 1967). It provides a scientific basis for balanced fertilisation and balance between applied nutrients and soil available nutrients (Ramamoorthy and Velayutham, 2011). Integrated Plant Nutrition System (IPNS) is a concept which aims at the maintenance or adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible sources of plant nutrients in an integrated manner. Adopting this concept, research work has been carried out in the All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation (AICRP-STCR) over the past four decades for various crops and cropping sequences, preferably under Integrated Plant Nutrition System (IPNS) during the last two decades.

In Tamil Nadu, under the AICRP-STCR, STCR-IPNS recommendations have been developed for desired yield targets of 27 crops on sixteen soil series. In addition, STCR-IPNS recommendations have been developed for rainfed cotton and maize and for emerging technologies *viz.*, SRI, drip fertigation *etc.* Santhi *et al*. (2012) documented soil test based fertiliser prescriptions developed under IPNS for various crops on various soil types in different agro-climatic zones of Tamil Nadu. Few such prescriptions for rice under SRI, rainfed maize and glory lily are furnished in Table 3. Accomplishing all these recommendations, a computer software 'DSSIFER' (Decision Support System for Integrated Fertiliser Recommendation) has been developed to generate crop, site and situation specific balanced fertiliser prescriptions for desired yield targets of various crops in Tamil Nadu and has been updated as DSSIFER 2010 (Santhi *et al.*, 2010). DSSIFER can be used as a smart tool for promoting STCR-IPNS which results in enhanced fertiliser use efficiency and crop productivity.

Table 3. Soil test crop response based fertiliser recommendations under IPNS

i. Rice (SRI)

Soil : Noyyal series (Typic Haplustalf) FN = 4.33 T - 0.53 SN - 0.68 ON

Season : Kharif FP_2O_5 = 2.08 T - 3.18 SP - 0.70 OP

Target : 80 q ha^{-1} FK_2O = 2.78 T - 0.30 SK - 0.63 OK

Initial soil tests (kg ha^{-1})			NPK (kg ha^{-1}) + GM @ 6.25 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}			NPK (kg ha^{-1}) + FYM @12.5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}		
SN	SP	SK	N	P_2O_5	K_20	FN	FP_2O_5	FK_2O
200	18	300	187	86	99	185	87	100**
220	20	350	177	80	84	175	81	95
240	22	400	166	74	69	164	75	80
260	24	450	156	67	54	154	68	65
280	26	500	145	61	39	143	62	50

**Maximum dose

Table 4. Fertilizer recommendation for secondary and micro nutrients

Nutrie	Crops	Recommendation (as basal)
Zinc	Wetland / Semidry / Rainfed rice	25 kg $ZnSO_4$ ha^{-1}
	Maize / Sorghum / Finger Millet/ Cumbu	
	Oil seeds and Pulses	
	Cotton, Turmeric, Tomato	50 kg $ZnSO_4$ ha^{-1}

	Sugarcane	37.5 kg $ZnSO_4$/ha
Iron	Semidry / Rainfed rice, Maize and Sorghum	50 kg $FeSO_4$ +12.5 t FYM ha^{-1}
	Sugarcane, Turmeric	100 kg $FeSO_4$ +12.5 t FYM ha^{-1}
Cu	Wetland rice - Cauvery delta	5 kg $CuSO_4$ combined with 0.2 % foliar spray thrice
	Cauliflower	10 kg $CuSO_4$ + 12.5 t FYM ha^{-1}
Mn	Sesame	5 kg $MnSO_4$ ha^{-1}
	Cumbu and Soybean	0.2% $MnSO_4$ foliar spray
B	Groundnut, Sunflower, Maize	10 kg Borax ha^{-1}
	Cauliflower	20 kg Borax + 12.5 t FYM ha^{-1}
	Tomato	10 kg Borax + 12.5 t FYM ha^{-1}
	Cereals (Rice, Maize, Sorghum) and Onion	30 kg S ha^{-1}
S	Oil seeds, Pulses and Potato	40 kg S ha^{-1}
	Cotton	55 kg S / ha along with 2 % Mg SO_4 and 1% urea as foliar spray

	Tapioca	20 kg S ha^{-1}
Fe and Zn	Jasmine	25 g $FeSO_4$ and 4.0 g $ZnSO_4$ / plant
Zn and B	Sunflower , Groundnut	25 kg $ZnSO_4$ + 10 kg Borax ha^{-1}
N and B	Sunflower	Blending of B @ 0.2 % (as urea basis) with N @ 40 kg ha^{-1}
N and B	Groundnut	Blending of B @ 0.2 % (as urea basis) with N @ 30 kg ha^{-1}
Ca and S	Rice	500 kg gypsum ha^{-1}
Ca and S	Groundnut	400 kg gypsum ha^{-1}
Multi nutrient	Grapes	0.2 % $ZnSO_4$+ 0.1 % boric acid +1 % urea twice during blooming and ten days after first spray
	Banana	0.5 % $ZnSO_4$ + 0.2 % $FeSO_4$ + 0.2 % $CuSO_4$ + 0.1 %

		boric acid at 3, 5 and 7 months after planting

Decision Support tools in advisory service

Decision making becomes complicated when several factors are to be considered while generating and advocating optimum nutrient management practices. Under such circumstances, decision support systems are handy tools for natural resource management for agricultural production.

The DSSIFER (Decision Support System for Integrated Fertiliser Recommendation) software, which is a computer based decision support system, developed in Visual Basic 6.0 as a "Stand Alone" version utilises the crop and location specific fertiliser prescriptions evolved through Soil Test Crop Response based Integrated Plant Nutrition System (STCR-IPNS) developed by the ICAR-AICRP-STCR, Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore and Mitscherlich-Bray percentage sufficiency recommendations developed by the Soil Testing Wing of the State Department of Agriculture, Tamil Nadu to generate crop and location specific balanced fertiliser prescriptions.

The fertilizer prescription is based on soil fertility and yield target for various crops pertaining to different agro-climatic zones of Tamil Nadu. So, it can very well be used in Soil Testing Laboratories run by various organization. It is being used in Soil Testing and Technology Advisory Centre (SOTAC), Department of Soil Science and Agricultural Chemistry of TNAU, KVKs, Agriclinic cum Mini Soil Testing Laboratories at each block level, Soil Testing Laboratories of PACBs, NGOs, private entrepreneurs, scientists, research scholars, progressive farmers *etc.* for prescribing fertiliser doses and soil and water quality management technologies.

Benefits

- Increase in crop yield (on an average upto 30%)
- Increase in Fertilizer Use Efficiency
- Correction of inherent soil nutrient deficiencies
- Maintenance of soil fertility
- Least adverse effect on environment by minimizing nutrient losses, maintaining soil productivity and sustaining high yield even under varying soil, climate and agro-climatic conditions.

B. Irrigation water quality testing and advisory

Water is a vital resource for agriculture like land, and it is a finite resource that has to be shared amongst a growing population. It has been estimated that in Asia per capita water availability has fallen by around 80 per cent during last five decades. Given that much of Asia's crop production is dependent on irrigation. This decline in water availability has potentially severe implications for food severity. This is exacerbated by growing demand for water from urban and industrial sectors that compete with demand for water from agricultural sector.

Irrigation water always contains some soluble salts irrespective of its source. The suitability of waters for a specific purpose depends on the types and amounts of dissolved salts. Some of the dissolved salts or other constituents may be useful for crops. However, the quality or suitability of waters for irrigation purposes is assessed in terms of the presence of undesirable constituents, and only in limited situations is irrigation water assessed as a source of plant nutrients. Some of the dissolved ions, such as NO3, are useful for crops.

Parameters for water quality assessment

Water quality is determined according to the purpose for which it will be used. The continuous use of irrigation water of varying quality in terms of its higher salt content (Saline), high EC and SAR (Saline-sodic) (or) high RSC affect the physical and chemical properties of soil over a long period of time. Ultimately the soils become unfit for any agricultural operation. Hence, it is essential to assess the quality of irrigation water before using them.

The important characteristics of irrigation water that have been used in determining its quality are: (1) Salinity hazard (2) Sodicity hazard (3) Carbonate hazard (4) Permeability hazard (5) Concentration of Boron and other specific ion toxicity.

1) Salinity hazard

Accumulation of soluble salts in the soil is directly related to the salt content of the irrigation water (Table 5) . A salinity problem due to irrigation water occurs if the total quality of salts is high enough that the salts accumulate in the crop root zone.

The effect of salt on crop growth is largely of an osmotic nature, restricting the availability of soil water to plants. The concentration of soluble salts in irrigation water can be determined in terms of electrical conductivity and is expressed as dS m^{-1} at 25°C. For solutions of very low EC, units can be μS cm^{-1}. The total salt concentration can also be measured as TDS (Total Dissolved Salts) by the following equation:

$$TDS\ (ppm) = EC\ in\ dsm^{-1} \times 640.$$

Table 5. Classification of irrigation water based on Electrical conductivity

EC dS m^{-1}	Salinity Class	Remarks
< 0.25	Low	Safe with no likelihood of any salinity problem developing
0.25-0.75	Medium	Need moderate leaching.
0.75-2.25	High	Not to be used on soils with inadequate drainage. Crop with moderate salt tolerance to be grown
2.25-5.0	Very High	Not to be used on soils with inadequate drainage. Crop with high salt tolerance to be grown

Richards (1954)

1) Sodicity hazard

Irrigation waters containing higher proportion and sodium to other cations lead to the problem of sodicity. The sodicity hazard of irrigation water is usually evaluated by sodium Adsorption ratio (SAR). Sodium Adsorption Ratio (SAR): It is expressed as the relative proportion of sodium to other cations viz., Ca and Mg in water and is calculated by using the following formula, where the concentration of ions is expressed in me L^{-1}

$$SAR = Na^{+} / \ ((Ca^{++} + Mg^{++}) / 2)^{1/2}$$

Irrigation water is under low sodicity class (SAR < 20) can be used for crops which are semi-tolerant to tolerant (Table 6). Moderate sodic waters can be used only for tolerant crops.

2) Carbonate hazard

Carbonates and bicarbonate ions are important because they are having the tendency to precipitate Ca and Mg in soil solution (Table 6). The effect of bicarbonate and carbonate ions on water quality is expressed in terms of Residual sodium carbonate (RSC) concept, where the concentration of ions is expressed in me L^{-1}.

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

Table 6. Classification of irrigation water based on SAR

Class	Classification	Remarks
Water suitability		
< 10	Safe	
10 - 20	Moderate	
>20	Unsafe	
Crop Suitability		
< 5	Non-sodic	All soils and crops
5-10	Normal water	All soils and crops except sodium sensitive crops
10-20	Low sodic water	Semi – tolerant to tolerant crops
20-30	Medium sodic water	Tolerant crops
30-40	High sodic water	Not suitable
> 40	Very high sodic water	Not suitable

Ayers and Westcot (1976)

Table 7. Classification of irrigation water based on RSC (me L^{-1})

Class	Classification	Remarks
Water suitability		
< 1.25	Safe	
1.25 - 2.50	Moderate	

>2.50		Unsafe	
Crop Suitability			
A_0	-ve	Non alkaline water	For all soils and crops
A_1	0	Normal water	For all soils and crops (even crops sensitive to carbonate and bicarbonate)
A_2	0-0.25	Low alkalinity	Semi – tolerant to tolerant crops
A_3	2.5-5.00	Medium alkalinity	Tolerant crops with little management
A_4	5.0-10.0	High alkalinity	Can be used in soils with good drainage
A_5	> 10.0	Very high alkalinity	Not suitable

(Ayers and Westcot, 1976)

Irrigation water containing high concentration of carbonate and bicarbonate ions, have a tendency to precipitate Ca, and to lesser extent Mg, in the form of carbonates as solution becomes more concentrated. This leads to an increase in SAR of soil solution and consequently to an increase in ESP of the soil.

1) Permeability hazard

Permeability hazard occurs when the rate of water infiltration into and through the soil is reduced by the effect of specific salts. High sodium in irrigation water results in severe soil permeability problem. Permeability in also affected by to carbonate and bicarbonate content in irrigation water. Permeability Index can be calculated by using the following formula, where the ionic concentrations are expressed in me L^{-1}.

Permeability Index (PI) = Na (HCO_3) / (Ca + Mg + Na) x 100

2) Specific ion toxicity

Ground waters having toxic ions such as B, Cl, F, No_3, Se etc. also become problematic for irrigating crops and have consequence of entering human food chain (Table 8). Apart from boron and fluorine, there are some trace elements present in irrigation waters may also cause toxic effect. The permissible maximum concentrations of these toxicants in irrigation waters are based on the limitations of soils for crop production (Table 9).

Specification	Degree of problem		
	No problem	Increasing problem	Severe problem
Sodium (adj-SAR)	<3	3.0-9.0	>9.0
Chloride (mg L^{-1})	< 4	4.0-10.0	>10.0
Boron (mg L^{-1})	< 0.75	0.75-2.0	>2.0

NO_3 – N (mg L^{-1})	< 5.0	5.0-30.0	>30.0
HCO_3-N (mg L^{-1})	< 1.5	1.5-8.5	>8.5
Fluoride (mg L^{-1})	< 1.0	1.0-15.0	>15.0

Somani (1991)

Table 9. Permissible concentration of trace elements in irrigation waters (ppm)

Element	**For waters used continuously on all soils (mg l^{-1}) / ppm**	**For use upto 20 years on fine textured soils of pH 6.0 to 8.5 (mg l^{-1})**
Aluminium	5.0	20.0
Arsenic	0.1	2.0
Beryllium	0.1	0.5
Boron	0.75	2.0
Cadmium	0.1	0.05
Chromium	0.10	1.0
Cobalt	0.25	5.0
Copper	0.20	5.0
Fluorine	1.00	15.0
Iron	5.00	20.0
Lead	2.50	10.0
Lithium	5.00	2.5
Manganese	0.20	10.0
Molybdenum	0.01	0.05
Nickel	0.20	2.0
Selenium	0.02	0.02
Vanadium	0.10	1.0
Zinc	2.00	10.0

(Ayers and Westcot, 1976)

Management of poor quality water

Irrigation is essential for good crop production, where large area fall under arid and semi-arid regions and when rainfall is seasonal and erratic. Due to scarcity of fresh water for irrigation in theses areas, the under ground water becomes major source of irrigation which are commonly saline/ sodic. It necessitates the use of poor quality water for irrigation. However, poor quality irrigation water can be utilized by adopting proper management.

Irrigation management

Conjunctive use of good quality water: Wherever feasible, the saline or sodic waters can be applied to the land in conjunction with good quality water (rain water/ canal water and river water) to reduce the harmful effect of poor quality water. The cyclic / alternate use of poor quality water (or) blending methods can be employed. Good drainage must be provided to get lower water table thereby salt accumulation in upper surface (or) near root zone can be avoided. Poor quality irrigation water is not suitable for sprinkler irrigation. However drip irrigation is a potential means of utilizing poor quality water. As it wets the soil surface around the crop continuously there is hardly little chance for accumulation of salt on the surface.

For high SAR water the dilution can be decided by a dilution factor with the quality of water available for dilution

$$\text{Dilution factor} = \frac{(\text{SAR of problem water})^2}{(\text{SAR of desired water})^2}$$

Crop Management

Salt tolerant crops are to be grown to the soils affected by salinity and sodicity. Crops such as wheat, barley, cowpea etc totally fail to grow under highly saline conditions. Oilseed crops, which require less water can tolerate high EC levels where as most of the pulses, are very sensitive to salts (Table 10).

Pre soaking of seeds with the 0.1 per cent NaCl 0.5 per cent KH_2PO_4 will improve salt tolerance of crops. Germination of seeds decreases with increasing salinity. Seeds have to be placed in the area where the salt concentration is less. With furrow irrigation the salts tend to concentrate mainly in the centre of the ridge between furrows and in a thin layer along the top of the ridge. The salt concentration is less on the slope of the ridge and the bottom of the ridge. Seeds have to be placed on the slope of the ridge several centimeters below the crown of the ridge. By this method satisfactory germination is possible even when the EC of soil is 30 – 40 dS m^{-1}.

Crops suitable to the dominant ion composition in irrigation may be selected for cultivation.

Following are the crops preferring a dominant ion for luxuriant growth

Magnesium loving crops ($MgCl_2$ $MgCO_3$ – rich water)	:	Banana, Sugarcane, Chillies, Tapioca, Cotton, Vegetables (except tomato) and flowering crops
Chloride loving crops (Na, Ca, Mg rich water)	:	Coconut, Chillies, Brinjal, Sunflower and Jasmine

Calcium loving crops (Chloride rich water)	:	Cotton, Millets and Curry leaf
Bicarbonate loving crops	:	Millets, Rice Chillies, Sugarcane, Cotton, Sunflower and Fruit crops (except Mango, Citrus and Grapes)

Table 10. Relative tolerance of crop plants to salt

Tolerant	**Moderately tolerant**	**Sensitive**
Field crops		
Finger millet	Rice	Black gram
Sugar beet	Wheat	Green gram
Cotton	Sunflower	Bengal gram
	Groundnut	
	Sorghum	
	Castor	
	Soybean	
	Sesame	
Vegetables		
Asparagus	Brinjal	Carrot
Spinach	Cabbage	Radish
Amaranthus	Onion	Coriander
	Potato	Mint
	Chillies Garlic	Cumin
Forage crops		
Bermuda grass	Rye grass	Red clover

Rhodes grass	Sudan grass	Meadow foxtail
Birds root	Alfalfa	
Barley (Hay)	Wheat	
Fruits		
Date palm	Pomegranate	Pear
	Guava	Apple
	Grape	Orange
	Fig	Peach
	Ber	Mango

Use of chemical amendments

Gypsum and iron pyrites are the chemical amendments used frequently to reclaim the soil, which is affected by salts. Gypsum application is necessary for reducing damage due to excessive sodium in irrigation water. The soil solution at the root zone must not contain more than 70 percent of sodium out of total cations.

For saline water the gypsum requirement can be calculated as follows:

Gypsum requirement (lb acre ft^{-1}) = {[(Na X 0.43) – (Ca + Mg)] + [(CO_3 HCO_3 X 0.7] + 0.7} X 234

For sodic water, gypsum requirement can be calculated based on residual sodium carbonate as 1 me of RSC = 1 me of $CaSO_4$

Nutrient management

Organic matter addition has distinct impact in improving soil when using saline / sodic water. Liberal application of farmyard manure or compost will be much beneficial. Use of nitrate and sulphate rich fertilizers is suitable to reduce chloride accumulation in plants. Use of ammonium and chloride rich fertilizers will help to counteract effect of excess sulphate. Applying superphosphate is essential with high magnesium water irrigation. Further, with this water, sulphate rich fertilizers must be avoided and liberal use of potassium fertilizer is necessary to overcome Mg-K antagonism. Alkali soils have acute deficiency of zinc. Hence, basal dressing of $ZnSO_4$ is necessary particularly to rice.

Generally saline, and alkaline soils irrigated with poor quality waters are low in their fertility status, especially with reference to nitrogen and sometimes to phosphorus. Green manuring of *Sesbania* before rice is beneficial. Alternatively, pressmud, water hyacinth Farmyard manure or any other potential source of nutrients may be utilized to supplement fertilizer N in alkali soil for sustainable crop production with simultaneous improvement in soil, which may be increased upto 50% of recommended dose. Use of organics also brings down the soil pH and ESP.

Soil Management

Deep ploughing with disc plough helps to turn down salts accumulated on surface and facilitates fast leaching. Chisel ploughing of field during summer season is to be adopted for soils having hardpan. Chiseling is to be done at 0.5 intervals in crisscross direction at 0.5 depths once in two years. Chisel plough is essential for improving yield of crops especially under dry farming. It shatters compacted subsoil layers and aids in better infiltration of water in the crop root zone.

Conclusion

Soil and water test based advisories are necessary to improve crop productivity and to increase nutrient use efficiency. Judicious application of fertilizer targeting both high yields and nutrient efficiency will benefit farmers, society, and the environment alike. The computer software "DSSIFER" can be used as one of the smart tools for enhanced fertiliser use efficiency and crop productivity.

References

Ayers, R.S. and D.W. Westcot. 1976. Water quality for agriculture, Irrigation and Drainage paper, 29, FAO, Rome.

Gupta, S.K and I.C. Gupta. 1997. Crop production in water logged saline soils, Scientific publishers, Jodhpur, India. pp 6.

Maliwal,G.L. and Somani,L.L. 2011.Soil Technology.Agrotech Publishing academy, Udaipur.

Murugappan, V., A. Bhaskaran, P. Murugesa Boopathi, R. Natesan, R. Santhi and R.Jagadeeswaran. 2004. Decision Support System for Integrated Fertilizer Recommendation (DSSIFER). In: New crop varieties, farm implements and management technologies, Directorate of Research, TNAU, Coimbatore. pp: 39-40.

Ramamoorthy, B. R.L. Narasimham and R.S. Dinesh. 1967. Fertilizer application for specific yield targets on Sonora 64 (wheat**).** Indian Fmg. 17(5): 43-45.

Ramamoorthy, B. and M.Velayutham. 2011. The "Law of Optimum" and Soil test based fertilizer use for targeted yield of crops and soil fertility management for sustainable agriculture. I[st] Dr. B. Ramamoorthy Memorial Lecture**.** Madras Agric. J. 98 (10-12): 295-307.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Hand book No.20. pp 160.

Santhi, R., A. Bhaskaran, S. Poongothai, S. Maragatham, R. Natesan, K.M. Sellamuthu, V.P. Duraisami, V. Velu, K. Appavu, and P. Murugesa Boopathi. 2010. Decision Support System for Integrated Fertiliser prescriptions, Computer software, Dept.of Soil Science & Agrl.Chemistry,TNAU, Coimbatore.

Santhi, R, S. Maragatham, K.M. Sellamuthu, R. Natesan, V.P. Duraisami, Pradip Dey and A.Subba Rao.2012. Soil Test and Yield target based Fertiliser prescriptions (Tamil), AICRP-STCR, TNAU,Coimbatore.

Singh, D., Chhonkar, P.K. and Pandey, R.N. 1999. Soil plant water analysis – a methods manual. New Delhi, IARI.

Somani, L.L. 1991. Crop production with saline water. Agro-botanical publishers, Bikaner. P-308.