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G Sashikala
Professor, Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

MVS Naidu
Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

K Ramana
Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

KV Nagamadhuri
Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

A Pratap Kumar Reddy
Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

P Sudhakar
Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Corresponding Author:
MVS Naidu
Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Soil-site suitability evaluation for millets cultivation in Tatrakallu village of Anantapuramu district of Andhrapradesh

G Sashikala, MVS Naidu, K. Ramana, KV Nagamadhuri, A Pratap Kumar Reddy and P Sudhakar

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Abstract
A detailed soil survey was undertaken in Tatrakallu village, Anantapuramu district of Andhra Pradesh to evaluate the suitability of soils for millets namely sorghum, pearl millet, fox tail millet and little millets. The soil belongs to Inceptisols, Entisols, Vertisols and Alfisols orders. Fourteen soil series namely Tatrakallu-1 (TTK1), TTK2, TTK3, TTK4, TTK5, TTK6, TTK7, TTK8, TTK9, TTK10, TTK11, TTK12, TTK13 and TTK14 were identified based on soil depth, texture, color, coarse fragments and calcareousness were evaluated for soil-site suitability. The soil series *viz*., TTK1, TTK2, TTK4, TTK5, TTK6, TTK7, TTK8, TTK10 and TTK 14 were marginally suitable (S3) for growing millets namely sorghum, pearl millet, fox tail millet and little millets with limitations of wetness, soil fertility characteristics like organic carbon, pH and sodicity etc. whereas soil series such as TTK3, TTK9, TTK11, TTK12 and TTK13 were not suitable (N) for growing all the crops namely sorghum, pearl millet, fox tail millet and little millets crops with limitations of rooting depth, alkalinity, texture, slope, organic carbon, pH and gravelliness.

Keywords: Soil site suitability, sorghum, pearl millet, fox tail millet and little millets

Introduction
The demand of food will increase proportionately with growth in world population. Increasing population and escalating needs for food, groundwater potential and carrying capacity of the soil is exploited in unashamed manner. At present about 50% of world's total calorie intake is derived directly from cereals. This creates pressure on soil fertility and groundwater potential. Millets cultivation can be a solution to this problem as these can grow on shallow, low fertile soils with a pH of soil ranging from acidic 4.5 to basic soils with pH of 8.0. Millets are small-grained cereals that are grown with little input mostly under unfavorable agricultural situations. These crops mainly originated in Africa and Eurasia and were later domesticated in many other countries. The most widely grown millet is pearl millet, which is an important crop in India and parts of Africa. Finger millet, Proso millet, and Foxtail millet are also important crop species.

Land evaluation is the ranking of soil units on the basis of their capabilities to provide highest returns per unit area and conserving the natural resources for future use. The land suitability evaluation for field crops forms a pre-requisite for land use planning (Sys *et al.* 1991) [14]. Performance of any crop is largely influenced by soil-site parameters as conditional by climate and topography and management level (Sehgal, 1991) [10]. Thus, it is essential to interpret the soil-site suitability for major crops grown in the area. However, each plant species requires specific soil and climatic conditions for its optimum growth. Production oriented crop cultivation on appropriate soils (taxonomic unit) appeared to be more beneficial (Selvaraj and Naidu 2012) [9]. Information on soil site suitability for millets in Tatrakallu village in particular and Anantapuramu district of Andhra Pradesh in general is very much lacking. Hence, in this study an attempt has been made to evaluate the soil suitability for major millet crops *viz*., for sorghum, pearl millet, fox tail millet and little millets on Inceptisols, Entisols, Vertisols and Alfisols in Tatrakallu village of Anantapuramu district, Andhra Pradesh.

Materials and Methods
Tatrakallu village which lies in between 14° 58´ to 15° 00´ N latitudes and 77°19´ to 77°25´ E longitudes with a spatial extent of 2469.29 ha was selected for land evaluation (Fig. 1). The study area comes under the Scarce Rainfall Zone of Andhra Pradesh.

The study area is characterized by semi-arid sub-tropical monsoonic climate with distinct summer, winter and rainy seasons. The mean annual atmospheric temperature was 27.52 °C and the mean annual rainfall was 528.40 mm. Tatrakallu village in Anantapuramu district of Andhra Pradesh is predominantly under rainfed farming with erratic rainfall distribution (APSAC, 2018) [1] associated with low crop productivity. The natural vegetation of the study area was *Acacia nilotica, Borassus flabellifer, Tamarindus indica, Tephrosia purpurea, Parthenium hysterophorus, Azadirachta indica, Cassia auriculata, Calotropis gigantea, opuntia humifusa, Prosopis juliflora, Zizyphus jujube, Pongamia pinnata, Cactus spp etc.,*

Field survey

The detailed soil resource inventory of Tatrakallu village was carried by using, the merged data of Cartosat-1 (2.5 m resolution) and Resourcesat-2 (LISS-IV 5.8 m resolution) in the form of digital and geo-coded false colour composites (FCC) in the scale of 1: 10000 and toposheet of survey of India (SOI) on 1:50000 scale. The pedons were exposed and studied for their morphological properties following the procedure outlined by Soil Survey Staff (2014) [12]. The physicochemical properties (horizon wise) were estimated following standard procedures (Black and Hartge, (1986) [2], Jackson, (1973) [6], Olsen *et al*., (1954) [8], Subbiah and Asija, (1956) [13]. Fourteen soil series were identified in the study area based on soil depth, texture, color, coarse fragments and calcareousness. The weighted mean of each property was calculated and soil-site characteristics of different soil units were obtained as shown in Table 1. These weighted average data have been used to evaluate the soil-site suitability.

Results and Discussion

Morphological Characteristics

The morphological characteristics of the soils showed that most of the soils were shallow to very deep. The pedons were moderately well drained to poorly drained. The soil colour varied from 5.0 YR to 10 YR. The variation in soil colour appears to be the function of chemical and mineralogical composition as well as textural makeup of soils and conditioned by topographic position and moisture regime (Sireesha and Naidu, 2013) [11].

Physicochemical Characteristics

The soils of Tatrakallu showed wide textural variation ranging from loamy sand, sandy loam, sandy clay loam, sandy clay, clay, clay loam and silty clay loam (Table 1). The pH of the soils ranged from 6.5 to 9.0. This wide variation in pH of Tatrakallu village soils was attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium. The electrical conductivity (EC) in soils of Tatrakallu village was ranged from 0.01 to 1.90 dS m^{-1} indicating that the soils in study area were non-saline. The low EC in these soils was due to leaching of soluble salts by percolating water. Organic carbon (OC) content was low to medium ranging from 0.10 to 0.67%. The CEC in all the pedons estimated by ammonium acetate extract varied from 6.4 to 50.6 c mol(p+) kg^{-1} soil which corresponds to clay content in the horizons, organic carbon content and also type of clay mineral present in these soils. Exchangeable bases in all pedons were in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and Ca being the dominant cation on the exchange complex. The base saturation varied from 55 and 99%. The higher base saturation observed in almost all pedons might be due to higher amount of Ca^{2+} occupying exchange sites on the colloidal complex. The differences in base saturation indicated the degree of leaching. The variation in base saturation of the soils might also be due to variation in nature and / or content of soil colloids and relatively high base saturation in surface layer could be attributed to the recycling of basic cations through vegetation (Devi *et al*. 2015) [3].

Site characteristics

The site characteristics such as elevation, slope, erosion and drainage varied with topographic position of soils. The slope of Tatrakallu village range from 0 to 35% in uplands and 0 to 3% in case of plains. The pedons located in uplands were moderately well to well drained while pedons occurring in plains (P16 to P20) were somewhat poorly to poorly drained. Fourteen soil series were identified namely Tatrakallu-1 (TTK1), TTK2, TTK3, TTK4, TTK5, TTK6, TTK7, TTK8, TTK9, TTK10, TTK11, TTK12, TTK13 and TTK14 on soil depth, texture, color, coarse fragments and calcareousness (Natarajan *et al*. 2016) [7]. These fourteen soil series were evaluated for soil-site suitability for major millets namely sorghum, pearl millet, fox tail millet and little millet.

Soil site suitability for Millets

Crop suitability analysis in Tatrakallu village was carried for four major millet crops *viz*., sorghum, pearl millet, fox tail millet and little millet crops using procedure given by FAO, 1976 [4]. This evaluation procedure includes comparision of landscape and soil characteristics (such as slope, wetness physical soil characteristics (texture/structure, % coarse fragments by volume, soil depth in cm, $CaCO_3$), soil fertility characteristics (apparent CEC (cmol (p+) kg^{-1} clay), % base saturation, sum of basic cations (cmol (p+) kg^{-1} soil), pH (H_2O), % organic carbon, salinity (EC, dsm^{-1}) and alkalinity (ESP)] of the study area with landscape and soil requirements for these four millet crops (sorghum, pearl millet, fox tail millet and little millet) as adopted from Sys *et al*. (1991) method of land evaluation and crop requirements.

Millets grow and mature under conditions of low rainfall and soil fertility, with little or no attention. The temperature range for growth is 16 - 32ºC. Millets require an annual rainfall of 150 – 1350 mm per cycle, well drained, aerated, depth (0.5 m to 2.0 m) with loamy to clayey texture and optimum pH 5.6 – 7.6. The soil series *viz*., TTK1, TTK2, TTK4, TTK5, TTK6, TTK7, TTK8 and TTK10 were marginally suitable (S3sf) for growing millets namely sorghum, pearl millet, fox tail millet and little millets (Table 2) with limitations of physical soil limitations such as shallow depth, coarse fragments, texture and soil fertility characteristics like organic carbon, pH and sodicity etc. whereas soil series TTK14 is marginally suitable (S3wf) for growing all four major millets with limitations of wetness *ie* poor drainage and soil fertility characteristics such as organic carbon. Soil series such as TTK3, TTK9, TTK11, TTK12 and TTK13 were not suitable (N) for growing all the crops namely sorghum, pearl millet, fox tail millet and little millets crops with limitations of rooting depth, alkalinity, texture, slope, organic carbon, pH and gravelliness. Similar results were found by Hegde *et al*. (2018) [5] in Matki -3 microwatershed of Karnataka.

All the above said limitations can be managed by adopting management practices such as, lowering down soil pH by application of amendments like gypsum or locally available spent wash or pressmud compost. Organic carbon in these soils can be improved by the application of FYM or green manuring with legumes. Wetness / drainage can be improved

by adoption of broad bed and furrow method of irrigation. Shallow depth can be changed to good by the adoption of land improvement practices such as deepening of top soil by ridging, deep ploughing or breaking up of soil crust.

The results demonstrate that the available data can be best utilized for agricultural development of an area especially in scarce rainfall areas like Tatrakallu village of Anantapuramu district where rainfall, shallow rooting depth, alkalinity, gravelliness, low to high fertility status (OC, N, P, K, S and exchangeable bases) are the limiting criteria for lower productivity. It has been also found that the present land-use options can be changed to profitable ones by integrated use of organic manures in combination with inorganic fertilizers not only paves the way for better economic returns and sustainable resource management of the given land, which could not have been possible through conventional land evaluation methods.

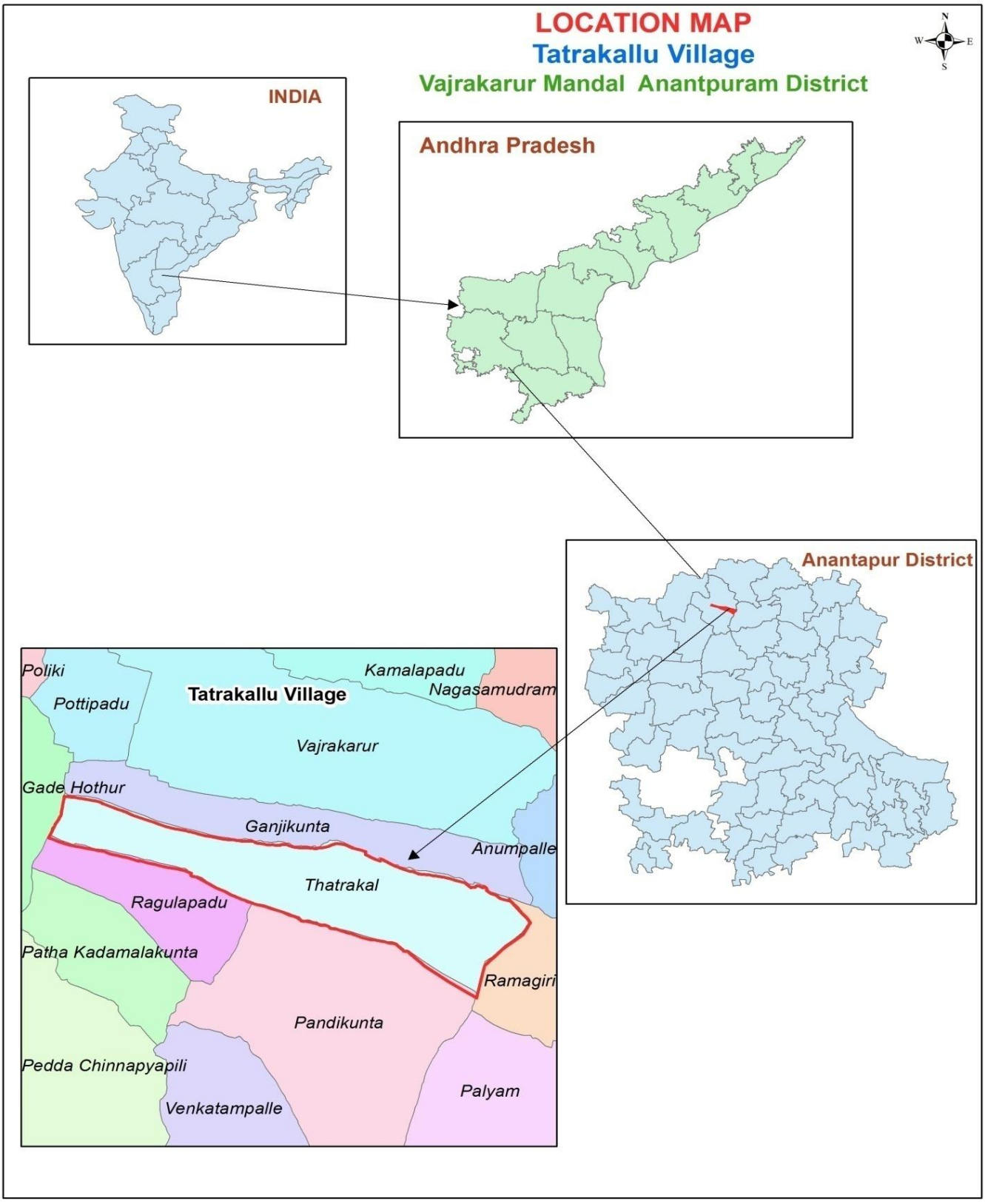

Fig 1: Location map of Tatrakallu village

Table 1: Site and soil characteristics of studied profiles for crop suitability classification

Pedon No.	Soil	Land form	Parent material	Wetness (W) drainage	Physical soil characteristics (s)	Soil fertility characteristics (f)							Salinity and alkalinity (n)		
					Texture	Coarse fragments volume (%)	Soil depth (m)	$CaCO_3$ (%)	Apparent CEC [c mol (p+) kg^{-1} soil]	Sum of basic cations [c mol (p+) kg^{-1} soil]	BS	pH 1:2.5	OC	EC (dSm^{-1})	ESP
1	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gscl	15-40%	0.20	5.85	15.52	10.16	65.46	7.15	0.38	0.19	0.64
2	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gscl	15-40%	0.30	6.67	14.66	9.29	67.91	7.20	0.36	0.08	0.58
3	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gscl	15-40%	0.41	5.46	12.38	11.31	89.89	7.70	0.33	0.07	0.73
4	Loamy-skeletal, mixed, isohyperthermic, Typic Haplustept	Upland	Granite-gneiss	Well drained	gscl	15-40%	0.81	5.01	15.61	12.26	57.55	7.25	0.46	0.05	0.95
5	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gsc	15-40%	0.20	8.30	21.16	14.20	67.18	6.65	0.44	0.08	0.70
6	Loamy-skeletal, mixed, isohyperthermic, Typic Haplustalf	Upland	Granite-gneiss	Well drained	gscl	15-40%	0.40	4.85	15.66	6.97	72.99	6.99	0.43	0.19	1.00
7	Loamy-skeletal, mixed, isohyperthermic, Lithic Haplustept	Upland	Granite-gneiss	Well drained	gsl	15-40%	0.45	1.41	7.50	6.56	59.92	6.76	0.38	0.05	1.13
8.	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gsl	15-40%	0.41	8.78	6.48	12.97	91.49	8.40	0.42	0.15	1.63
9.	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gscl	15-40%	0.15	3.70	11.49	7.71	67.10	7.01	0.39	0.08	1.39
10.	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gsl	15-40%	0.44	0.50	9.12	5.29	70.16	6.86	0.39	0.06	3.13
11	Coarse loamy, smectitic, isohyperthermic, Typic Ustifluvent	Upland	Granite-gneiss	Well drained	sl	None	1.20	9.76	11.54	12.00	89.22	8.29	0.59	0.16	3.27
12	Fine loamy, mixed, isohyperthermic, Typic Haplustalf	Upland	Granite-gneiss	Well drained	sl	3-15%	0.91	7.26	10.00	8.51	87.84	8.26	0.41	0.11	4.48
13	Loamy-skeletal, mixed, isohyperthermic, Fluventic Haplustept	Upland	Granite-gneiss	Well drained	sl	None	1.10	3.57	12.86	12.31	88.13	8.38	0.56	0.12	4.12
14	Loamy-skeletal, mixed, isohyperthermic, Typic Haplustept	Upland	Granite-gneiss	Well drained	gsl	15-40%	0.41	16.54	13.35	12.60	89.14	8.21	0.50	0.12	3.55
15	Loamy-skeletal, mixed, isohyperthermic, Lithic Haplustalf	Upland	Granite-gneiss	Well drained	gsl	15-40%	0.40	1.90	19.10	8.46	62.55	7.87	0.40	0.08	3.83
16	Fine, smectitic, isohyperthermic, Sodic Haplustert	Plain	Limestone/shale	Poorly drained	c	None	1.51	7.25	39.20	36.62	85.33	8.42	0.43	1.90	22.29
17	Fine, smectitic, isohyperthermic, Sodic Calciustert	Plain	Limestone	Poorly drained	c	None	1.10	11.83	45.50	36.38	85.46	8.45	0.67	0.12	9.09
18.	Fine, smectitic, isohyperthermic, Sodic Haplustert	Plain	Limestone	Some what poorly drained	cl	None	1.60	13.82	42.04	34.33	93.43	8.97	0.64	0.71	31.64
19.	Fine, smectitic, isohyperthermic, Typic Haplustert	Plain	Limestone	Some what poorly drained	cl	None	1.50	9.90	39.41	36.73	95.80	8.26	0.46	0.15	6.29
20.	Fine, smectitic, isohyperthermic, Leptic Haplustert	Plain	Limestone	Poorly drained	cl	None	0.75	7.44	47.22	45.33	89.64	8.05	0.52	0.11	1.30
21.	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gls	15-35%	0.45	1.01	9.54	9.41	77.14	6.72	0.38	0.03	2.21
22.	Loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent	Upland	Granite-gneiss	Well drained	gsl	15-35%	0.20	2.43	7.66	8.26	92.70	6.60	0.46	0.15	6.52

Table 2: Suitability analyses of soil series for Millets in Tatrakallu village

Tentative soil series	Pedon No.	Sorghum	Pearlmillet	Fox tail millet	Little millet
TTK1	1,2, 5, 9, 22	S3sf	S3sf	S3sf	S3sf
TTK2	3, 8, 10, 21	S3sf	S3sf	S3sf	S3sf
TTK3	11	N	N	N	N
TTK4	4	S3sf	S3sf	S3sf	S3sf
TTK5	14	S3sf	S3sf	S3sf	S3sf
TTK6	7	S3sf	S3sf	S3sf	S3sf
TTK7	13	S3sf	S3sf	S3sf	S3sf
TTK8	6	S3sf	S3sf	S3sf	S3sf
TTK9	12	N	N	N	N
TTK10	15	S3sf	S3sf	S3sf	S3sf
TTK11	16, 18	N	N	N	N
TTK12	17	N	N	N	N
TTK13	19	N	N	N	N
TTK14	20	S3wf	S3wf	S3wf	S3wf

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