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Suitability assessment of soils occurring on different landforms of Chittorgarh district, Rajasthan

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Abstract : Fifteen pedons, occurring on different landforms were studied in Chittorgarh district for their suitability assessment with reference to maize, wheat, groundnut, soybean, gram and mustard. In general, the soils occurring on gentle plains are moderately suitable for agricultural crops across the geomorphic units (i.e Eastern Rajasthan Uplands, Pathar and Bundelkhand Plateau and Malwa Plateau). Soils of steeper slope and hill tops of the three geomorphic units should be put under grassland and trees. Shallow depth, gravelliness, steep slope, lower organic carbon, lower available water capacity, etc are the productivity constraints in these geomorphic units.

Additional key words: *Alternate land use, geomorphic units, landforms, soil-site suitability*

Introduction

The agro-climate and soil characteristics of any region largely determine the degree of success of any cropping enterprise. Though this fact is recognized widely, studies to generate quantified information on combined influence of agro-climate and soil-characteristics on crop performance are scattered. Quantitative information on land evaluation helps in better land use ,planning as yield levels have to be higher to sustain the increasing non-farming population (Tang and Ranst 1998).

Land suitability evaluation is the process of determining the potential of the land for current and alternative uses and forms a pre-requisite for land use planning (Sehgal 1995). It integrates soil characteristics with climate and land use. Soil-site characteristics determine the degree of suitability for land use and help in planning expansion of area under a particular crop. Studies relating soil and site characteristics and crop requirements form the basis for soil suitability evaluation and formulation of meaningful land use plan. Such studies in Chittorgarh district, in particular and Rajasthan state, in general, are scanty (Giri *et al.* 1994; Singh *et al.* 1998; Sharma *et al.* 2001).

In the present study, an attempt has been made to evaluate five pedons, each occurring on different landforms viz Eastern Rajasthan Upland (ERU), Pathar and Bundelkhand Plateau (PB) and Malwa Plateau (MP) in Chittorgarh district, Rajasthan for major crops grown in the district namely, wheat, groundnut, soybean, gram and mustard.

Materials and Methods

The study area is situated between 23° 12′ and

25° 13′ N latitudes and 74° 12′ to 75° 49′ E longitudes in the south-eastern part of Rajasthan. It falls under AESR 5.2 and is characterized as hot, moist, semi-arid eco-sub region (Velayutham *et al.* 1999). The annual rainfall of Chittorgarh district is 1008 mm and is received during the monsoon season of which nearly 80% occurs in the months of July and August. The mean annual temperature is 24.4°C. May is the hottest month with the average temperature being 40°C whereas January is the coolest month with the average temperature of 4°C. The length of growing period is 120 to 150 days.

Fifteen representative pedons were selected on different landforms. The profiles were dug up to 150 cm depth or up to parent rock whichever was shallower, and studied for their morphological characteristics (Soil Survey Staff 1995). The samples were collected horizon-wise, air dried and ground to pass through 2 mm sieve. Relevant physical and chemical properties were determined using standard laboratory techniques and the soils were classified as per Soil Taxonomy (Soil Survey Staff 1998). Based on the soil-site characteristics and the crop requirements, the soil-site suitability class was assigned as per the criteria suggested by Sys *et al.* (1993) and NBSS&LUP (1994).

Each suitability class has been given a rating based on percentage performance of expected yield. Thus, highly suitable class (S1) is given to soils with an expected performance of > 80 %, moderately suitable (S2) to soils performing between 60 to 80% of expected performance, marginal suitable (S3) to soils performing between 40 to 60 % of the expected and N as not suitable to those soils performing below 40 % of the expected performance.

Results and discussion

Soil characteristics

The depth of the soils ranged from very shallow (<25cm) to deep (>120cm). Shallow soils were found on steep slopes or upper pediments whereas deep soils were found on nearly level to very gently sloping plain in all the geomorphic surfaces. The colour of the soils ranged from brown (10YR 4/3) to dark brown (7.5YR 3/2). Soils on upper portion of the landscape were redder and of grey shade on nearly level pediments or plains. The structure of the soils varies from single grain to weak, moderate, fine to medium in the surface layer of cultivated soils. In most of the soils, the structure is sub angular blocky. In general, clay content increased with depth. The available water capacity (AWC) of the soils ranged from 0.18 to 0.34 m m^{-3} and followed the trend of clay distribution.

The physical and chemical characteristics of the soils are presented in table 1. The cation exchange capacity (CEC) varied from 10.31 to 26.33 cmol (p+) kg^{-1} soil. The CEC of soils increased as the clay content increased. The organic carbon content ranged from 1.90 to 7.5 g kg^{-1}. The content was higher in soils occurring on hill or hill slopes owing to better vegetative cover. The pH varied from 7.0 to 8.6 and was found to increase as the slope flattened. It also depended on the type of parent material from which the soil had developed. Similarly, the electrical conductivity ranged from 0.19 to 1.60 dSm^{-1}. The $CaCO_3$ content varied from 24 to 196.5 g kg^{-1} and increased with depth. Exchangeable Ca, Mg, K, and Na ranged between 7.10 to 17.30, 2.30 to 7.10, 0.12 to 0.60 and 0.50 to 2.40 c.mol (p+) kg^{-1} soil, respectively.

Suitability of soils for maize, soybean, groundnut, wheat, mustard, and gram

The suitability classes of different soils of the three geomorphic surfaces occurring over different landform types are shown in table 2 and briefly described below.

Suitability of soils of different landforms for wheat

Area under irrigated wheat is more and the crop is irrigated 5 to 10 times depending on the type of soil and availability of underground water. Irrigation through canal is in limited area. It requires a cool climate and, in general, the temperature should not exceed 20°C throughout the growing stage and at

Table 1. Physico-chemical characteristics of soils

Depth (cm)	B.D. (Mg m^{-3})	AWC (m^3 m^{-3})	pH (1:2.5)	EC (dS m^{-1})	$CaCO_3$ (g kg^{-1})	O.C. (g kg^{-1})	Exchangeable bases				CEC	ESP
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}		
							(cmol (p^{+}) kg^{-1})					
P1 Akola: Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents (3-8% gently sloping foot slopes of dissected hills and ridges)												
0-20	1.67	0.21	7.12	0.19	43.5	3.0	7.1	2.3	0.5	0.2	10.31	4.95
P2 Gariawas: Loamy, mixed (calcareous), hyperthermic, Typic Ustorthents on 1-3% very gently sloping pediments												
0-15	1.46	0.20	7.00	0.25	45.1	5.0	8.32	3.75	0.70	0.31	13.21	5.35
15-26	1.48	0.26	7.13	0.35	51.0	3.9	8.00	2.80	0.80	0.31	12.32	6.72
26-46	1.59	0.24	7.15	0.36	61.6	3.0	10.10	3.38	0.50	0.22	14.85	3.52
P3 Chanderupa: Loamy, mixed, hyperthermic Lithic Ustorthents (1-3% very gently sloping pediments)												
0-16	1.34	0.21	7.12	0.32	47.0	6.3	8.10	2.70	0.90	0.40	12.23	7.44
16-32	1.49	0.23	7.15	0.33	58.0	4.6	7.90	2.60	0.70	0.35	13.24	6.06
P4 Gariawas: Loamy-skeletal, mixed (calcareous), hyperthermic Typic Ustorthents (1-3%, very gently sloping pediment s)												
0-16	1.39	0.20	7.30	0.34	51.0	6.9	10.00	4.70	1.60	0.50	17.14	9.52
16-40	1.41	0.18	7.42	0.42	52.0	5.1	9.80	4.60	1.10	0.60	16.32	6.83
P5 Kanarwa: Fine-loamy, mixed (calcareous), hypertherimic Typic Haplustepts (1-3% very gently sloping pediments)												
0-18	1.49	0.23	7.20	0.37	59.0	5.9	9.30	3.40	0.60	0.20	14.12	4.44
18-36	1.51	0.28	7.34	0.40	68.9	4.5	8.10	2.80	0.70	0.31	12.33	5.88
36-62	1.55	0.20	7.50	0.40	79.6	3.1	9.00	2.90	0.60	0.35	13.24	4.67
Mean (P1-P5)	**1.49**	**0.22**	**7.22**	**0.34**	**56.1**	**4.7**	**8.70**	**3.27**	**0.79**	**0.34**	**13.57**	**5.94**
P6 Manpura: Fine, smectitic (calcareous), hyperthermic Typic Haplusterts (1-3% very gently sloping pediments)												
0-30	1.23	0.26	7.35	0.42	49.0	7.5	14.60	6.60	2.10	0.40	24.23	8.86
30-60	1.29	0.29	7.46	0.47	51.0	5.2	12.20	5.20	2.20	0.30	20.12	11.06
60-90	1.31	0.34	7.48	0.39	60.1	3.9	15.90	7.10	2.40	0.40	26.23	9.30
90-120	1.35	0.27	8.10	0.43	99.8	2.6	14.90	6.90	2.20	0.40	25.13	9.02
P7 Anoppura: Loamy, mixed (calcareous), hyperthermic Lithic Haplustepts (3-8% gently sloping undulating upper pediments)												
0-15	1.46	0.19	8.10	0.53	61.0	5.9	9.30	2.70	0.70	0.50	13.42	5.30
15-38	1.50	0.25	8.35	0.72	115.0	3.6	10.60	3.70	0.80	0.60	16.21	5.10
P8 Sadi: Loamy, mixed (calcareous), hyperthermic Typic Haplustepts (3-8% gently sloping intervening valley)												
0-17	1.51	0.25	8.10	0.90	49.0	5.8	10.10	3.31	0.50	0.22	14.81	3.54
17-40	1.59	0.25	8.20	0.98	55.0	4.0	11.20	3.30	0.50	0.21	15.32	3.29
P9 Kanena: Loamy, mixed (calcareous), hyperthermic Lithic Ustorthents (1-3% gently sloping plain)												
0-20	1.60	0.24	7.18	0.70	32.0	3.5	10.9	3.8	0.8	0.4	16.84	5.03
P10 Karunda: Loamy, mixed (calcareous), hyperthermic Lithic Haplustepts (1-3% very gently sloping alluvial plain)												
0-13	1.61	0.23	8.25	1.00	48.5	3.5	11.30	3.20	0.50	0.25	15.89	3.28
13-32	1.67	0.24	8.27	1.30	43.0	2.5	11.60	3.50	0.60	0.30	16.31	3.75
Mean (P6-P10)	**1.47**	**0.25**	**7.89**	**0.71**	**60.3**	**4.4**	**12.05**	**4.48**	**1.21**	**0.36**	**18.59**	**6.14**
P11 Devgarh: Loamy-skeletal, mixed (calcareous), hyperthermic Typic Ustorthents (3-8% gently sloping plateau top)												
0-10	1.60	0.27	8.11	0.99	37.5	2.0	9.10	3.00	0.50	0.35	13.28	3.86
10-20	1.63	0.22	8.31	1.00	43.0	1.9	12.10	2.50	0.60	0.30	15.73	3.87
P12 Suhagpura: Clayey-skeletal, mixed (calcareous), hyperthermic Typic Ustorthents (1-3% % very gently sloping plateau)												
0-10	1.32	0.30	8.45	1.35	39.0	4.5	17.30	5.50	0.75	0.40	24.84	3.13
10-20	1.45	0.27	8.41	1.56	39.8	3.0	13.20	5.20	0.86	0.50	20.32	4.35
P13 Jaliyan: Fine, smectitic (calcareous), hyperthermic Typic Haplusterts (1-3% very gently sloping pediment plain)												
0-15	1.30	0.31	8.25	1.40	56.0	6.5	14.30	5.20	2.20	0.30	22.31	10.00
15-30	1.31	0.32	8.35	1.54	59.4	4.9	14.70	5.30	2.30	0.40	23.18	10.13
30-60	1.40	0.33	8.45	1.60	58.0	3.6	15.10	4.10	2.10	0.30	21.84	9.72
60-80	1.42	0.33	8.55	1.59	69.0	3.8	15.90	4.80	2.30	0.40	24.19	9.83
80-114	1.43	0.31	8.54	1.60	68.1	2.9	14.90	5.20	2.10	0.30	23.86	9.33
P14 Banekhan: Fine, smectitic (calcareous), hyperthermic Typic Haplusterts (1-3% very gently sloping alluvial plain)												
0-25	1.31	0.29	8.13	0.98	24.0	7.1	14.80	4.90	1.90	0.12	22.18	8.75
25-40	1.33	0.29	8.24	1.2	32.0	5.3	16.20	5.60	1.60	0.31	24.32	6.75
40-55	1.39	0.29	8.45	1.35	43.5	3.9	17.00	5.20	2.10	0.20	25.31	8.57
55-80	1.40	0.31	8.50	1.36	41.9	4.0	16.30	4.90	1.70	0.35	24.84	7.31
80-100	1.46	0.32	8.43	1.40	63.5	2.6	14.30	5.30	2.10	0.20	23.18	9.59
P15 Nimbahera: Fine-loamy, mixed (calcareous), hyperthermic Typic Haplustepts (1-3% very gently sloping pediments)												
0-17	1.51	0.25	8.15	0.98	140.0	5.1	14.50	3.32	0.60	0.30	19.84	3.21
17-37	1.57	0.27	8.23	1.36	140.0	3.3	13.30	3.30	0.90	0.20	18.32	5.08
37-60	1.60	0.28	8.32	1.39	170.0	3.3	11.70	3.60	0.70	0.30	17.84	4.29
60-90	1.61	0.27	8.50	1.40	196.5	3.2	12.10	4.10	1.10	0.20	18.16	6.29

ripening, the temperature should be around 23 to 25°C with full sunshine. Temperatures lower than 10°C are very beneficial during tillering stage. At dough stage and grain hardening stage, the temperature should be around 18 to 22°C. In case of power drawn implements, the slope should be less than 8 per cent; with nearly level to very gently sloping lands (1-3 per cent) being the most desirable. Soils should be deeper than 50 cm with a depth greater than 100 cm as most desirable. Soils should be well drained and should not have any root limiting layer. The texture of the soils should be sandy clay loam or finer. With irrigation, sandy loam or fine loamy sand textured soils are also suitable. The organic carbon content should be more than 0.8 per cent and the CEC should be more than 16 cmol (p+) per kg soil. Calcium carbonate content should be less than 30 per cent and the pH should be from 6.5 to 7.5. Wheat can tolerate high ESP so it may be set aside during its consideration as a criterion. Electrical conductivity should be less than 4dSm^{-1}. Based on the crop requirements stated above, the soils occurring over different landforms in the three geomorphic surfaces were put into different suitability classes.

Eastern Rajasthan upland

The pedon P1 located on moderate slopes (3-8%), has very shallow depth (<20cm), and excessive gravelliness (>35%). Soils shallower than 25 cm are considered non suitable. Therefore for wheat, soils of P1 have been found to be not suitable (N). Pedons P2, P3 and P4 were found to be marginally suitable (S3) due to the limitations of depth (<50 cm) and organic carbon content (<0.5%). The average yield, as reported by the farmers having this type of soil is 1600 to 2400 Kg ha^{-1}. Soils of P5 were evaluated as moderately suitable (S2). These soils had 50-100 cm depth, better AWC (>0.25m3 m^{-3}) and other attributes for placing the soils in S2 class (table 2). The average yield in this type of soil is 2400 to 3200 kg ha^{-1}. Under good management practices, these soils can yield up to 4 to 5 tons per hectare.

Pathar and Bundelkhand plateau

Soils of pedon P6 have been found to be deep (100-125 cm) having texture (fine loamy to fine), slightly alkaline pH (7.3 to 8.1), moderate AWC (0.26 to 0.34 m^3 m^{-3}) and medium organic carbon (0.6%). These have been adjudged as moderately suitable (S2). The average yield of wheat in this type of soil is 2500 to 2700 kg ha^{-1}. The soils of P9 have been adjudged as not suitable (N) on account of severe depth limitation (<25 cm), low organic carbon (<0.4%), low AWC (<0.25 m^{3}m^{-3}) and low CEC [15 to 16 c.mol (p+) kg^{-1} soil]. Soils of pedon P7, P8, and P10 have shallow depth (25 to 50 cm), low AWC (.20 to 0.25 m^3 m^{-3}), alkaline pH (8.0 to 8.5), low organic carbon (<0/6%) and low CEC [<16 cmol (p+) kg^{-1}soil]. The soils have been evaluated as marginally suitable (S3). The yield of wheat in this type of soil is around 1650 to 2450 kg ha^{-1}.

Malwa plateau

Soils of pedons P13, P14 and P15 are 100 to 150 cm deep having fine texture (clay>35%), good AWC (0.25 to 0.35 m^{3}m^{-3}), slightly alkaline pH (8.0 to 8.5), moderate organic carbon content (0.5 to 0.7%) and moderate CEC [17 to 25 cmol (p+) kg^{-1} soil]. These soils have been adjudged as moderately suitable (S2). The average yield of wheat in this area as per the farmers is 2450 to 3250 kg ha^{-1}. Soils of pedons P11 and P12 have been evaluated as not suitable (N) for wheat on account of very shallow depth (<25 cm), and very low organic carbon content (<0.4%). Though found not suitable, it has been observed, that farmers grow wheat even on this type of soils which are generally found on gently to moderately sloping plateau. The yield however is quite low and on an average is about 1000 to 1200 kg ha^{-1}. It is possible to grow wheat because of highly weathered basalt which provides necessary foothold.

Suitability of soils of different landforms for maize

Maize is grown commonly as a monsoon season crop though winter maize is also grown but, its occurrence is scattered. Maize requires an average

Table 2. Soil suitability for maize, soybean, groundnut, wheat, mustard and gram, major limitations and alternate land use/management practices

Pedon	Suitability		Major limitations	Alternate landuse/ management practices
	Kharif crops	Rabi crops		
P1	Maize (N), Soybean (N), Groundnut (N)n	Wheat (N), Mustard (N), Gram (N)	Slope (3-8%), Shallow depth (20 cm)	Grassland /Tree cultivation, terracing, contour cultivation
P2	Maize (S3), Soybean (S3), Groundnut (S3)	Wheat (S2), Mustard (S3), Gram (S3)	Depth (46 cm), Low O.C. (3.9 g kg^{-1})	Bunding, FYM application, fertilizer application, sprinkler irrigation
P3	Maize (S3), Soybean (S3), Groundnut (S2)	Wheat (S3), Mustard (S3), Gram (S3)	Depth (35cm), Low A.W.C. (0.22 m^3m^{-3})	Bunding, FYM application, fertilizer application, sprinkler irrigation
P4	Maize (S3), Soybean (S3), Groundnut (S3)	Wheat (S2), Mustard (S3), Gram (S3)	Depth (40 cm), Low A.W.C. (0.19 m^3m^{-3})	Bunding, FYM application, fertilizer application, sprinkler irrigation
P5	Maize (S2), Soybean (S2), Groundnut (S2)	Wheat (S2), Mustard (S2), Gram (S3)	Low O.C. (< 0.8%)	FYM addition, balanced fertilizer application, sprinkler irrigation
P6	Maize (S3), Soybean (S2), Groundnut (S2)	Wheat (S2), Mustard (S2), Gram (S2)	AWC (0.30 m^3m^3)	FYM addition, balanced fertilizer application, sprinkler irrigation
P7	Maize (S3), Soybean (S3), Groundnut (S3)	Wheat (S3), Mustard (S3), Gram (S3)	Slope (3-8%), Depth (38 cm), Low O.C. (4.5 g kg^{-1}),	Bunding, FYM application
P8	Maize (S3), Soybean (S3), Groundnut (S3)	Wheat (S3), Mustard (S3), Gram (S3)	Depth (40 cm), Slope (3-8%), Low O.C. (4.8 g kg^{-1})	Bunding, contour cultivation
P9	Maize (N), Soybean (N), Groundnut (N)	Wheat (N), Mustard (N), Gram (N)	Shallow depth (20 cm), Low O.C. (3.5 g kg^{-1})	Grassland /Tree cultivation, terracing, contour cultivation
P10	Maize (S3), Soybean (S3), Groundnut (S3)	Wheat (N), Mustard (S3), Gram (S3)	Shallow depth (32 cm), Low O.C. (2.9 g kg^{-1})	Bunding, FYM application, fertilizer application, sprinkler irrigation
P11	Maize (N), Soybean (N), Groundnut (N)	Wheat (N), Mustard (N), Gram (N)	Shallow depth (20 cm), Low O.C. (2.0 g kg^{-1})	Grassland /Tree cultivation, terracing, contour cultivation
P12	Maize (N), Soybean (N), Groundnut (N)	Wheat (N), Mustard (N), Gram (N)	Shallow depth (20 cm), Low O.C. (3.8 g kg^{-1})	Grassland /Tree cultivation, terracing, contour cultivation
P13	Maize (S2), Soybean (S2), Groundnut (S2)	Wheat (S2), Mustard (S3), Gram (S3)	*	FYM addition, balanced fertilizer application
P14	Maize (S2), Soybean (S2), Groundnut (S2)	Wheat (S2), Mustard (S3), Gram (S3)	*	FYM addition, balanced fertilizer application
P15	Maize (S2), Soybean (S2), Groundnut (S2)	Wheat (S2), Mustard (S3), Gram (S3)	*	FYM addition, balanced fertilizer application

S2 = Moderately suitable; S3 = Marginally suitable; N=Not suitable

*High pH (pH 8.0-8.5); low organic carbon (0.5-0.7%); CEC (17-25 cmol kg^{-1} soil)

precipitation of 750 to 900 mm during the growing season. The depth of the soil should be more than 50 cm. The crop grows optimally within a temperature range of 18 to 32°C. It requires well drained soils and a dry climate especially after tasselling and during grain formation and ripening. The soil texture should be finer than sandy clay loam. The soils should be neutral to slightly alkaline and free of salts. Based on the crop requirements stated above, the soils occurring on different landforms have been evaluated for their suitability for maize.

Eastern Rajasthan upland

Soils of the pedon P1 have been rated as not suitable (N) on account of severe depth limitation (<20 cm). Pedons P2, P3. P4, and P5 were evaluated as marginally suitable (S3) due to shallow depth (25 to 50 cm), low to moderate AWC (0.18 to 0.28 m^3m^{-3}) and CEC [<16 cmol (p+) kg^{-1}soil]. In the area, farmers fetch an average yield of 600 to 900 kg ha^{-1}. They also opined that due to irregularity/uncertainty of rainfall, the yield of the crop suffers significantly. Under the high agro-managements, the yield of maize is between 2 to 3 tons per hectare.

Pathar and Bundelkhand plateau

Soils of P9 have been rated as not suitable (N) for maize cultivation owing to very shallow depth (<20 cm). Soils of pedons P7, 8 and P10 have been evaluated as marginally suitable (S3) on account of shallow depth (25 to 50 cm), low organic carbon content (<0.6%), low AWC (<0.25 m^3m^{-3}), low CEC [<16 cmol (p+) kg^{-1} soil]. The yield of maize in these soils is about 600 to 900 kg ha^{-1}, however, under high level of management (research station) these soils yield 2 to 3 tons per hectare. Soils of pedon 6 have been evaluated as moderately suitable (S2) as the soils have adequate depth (>100 cm), moderate organic carbon content (0.6%), moderate AWC (0.25 to 0.35m^3m^{-3}), and moderate CEC [20 to 25 cmol (p+) kg^{-1} soil]. The yield in these soils is around 900 to 1200 kg ha^{-1}.

Malwa plateau

Soils of pedon P11 and P12 have been rated as not suitable (N) for maize cultivation due to very shallow depth (<25 cm). Soils of pedons P13, P14 and P15 have been found to be moderately suitable owing to adequate depth (90 to 150 cm), moderate AWC (0.25 to 0.35 m^3m^{-3}), moderate organic carbon content (0.6%), and moderate CEC [18 to 25 cmol (p+) kg^{-1} soil]. The yield of maize in these soils on farmer's field varies between 800 to 1200 kg per hectare.

Suitability of soils of different landforms for gram

Gram is a cool season crop and is generally grown on stored moisture and irrigated condition (in patches). Gram requires temperature of around 20-25°C during growing period. Nights should be cool and dew formation is an added advantage. Frost is harmful to the crop. Cloudy weather makes the crop susceptible to pod borer menace. Soils with clay texture are beneficial but these should be well drained. The soils should be neutral to slightly alkaline and the ESP should be less than 8 cmol (p+) kg^{-1} in case of clayey soils. In other soils like clay loam or sandy clay loam, the ESP should be less than 15 cmol (p+) kg^{-1}. As per these requirements of the crop, the soils of the region have been evaluated for their suitability for gram:

Eastern Rajasthan upland

Soils of P1 have been found to be not suitable (N) for gram cultivation on account of very shallow depth (<25 cm). Soils of pedons P2, P3 and P4 have been found to be marginally suitable (S3) for gram. These soils have shallow depth (25 to 50 cm), low AWC (<0.25 m^3m^{-3}), low organic carbon content (<0.6%) and low CEC [12 to 17 cmol (p+) kg^{-1} soil]. The yield of gram in these soils is about 300 to 400 kg per hectare. The soils of pedon P5 have been evaluated as moderately suitable (S2) owing to depth (50 -75 cm), moderate AWC (0.20 to 0.28 m^3m^{-3}). The yield of gram in these soils is around 600 to 800 kg per hectare. Under high management conditions, these soils have the potential to yield 1000 to 1500 kg per hectare.

Pathar and Bundelkhand plateau

Soils of pedon 9 have been found to be not suitable (N) on account of very shallow depth (<25 cm), low organic carbon (<3.5g kg^{-1} soil), and low CEC [16 cmol (p+) kg^{-1}soil]. Soils of pedons P7, P8 and P10 have been found marginally suitable (S3) for gram on account of shallow depth (<50 cm), low AWC (<25 m^3m^{-3}), low O.C., and low CEC [<16 cmol (p+) kg^{-1}soil]. According to the farmers of the area, these soils give an average yield of gram of about 450 to 600 kg per hectare in good rainfall years. Soils of pedon 6 have been evaluated as moderately suitable (S2) for gram on account of depth (>100 cm), moderate AWC (0.25 to 0.35 m3 m^{-3}), good CEC [>20 cmol (p+) kg^{-1} soil]. These soils, in good rainfall years, have been reported to yield 600 to 900 kg per hectare. Under high management, these soils can yield 1000 to 1500 kg per hectare.

Malwa plateau

Soils of pedons 11 and 12 have been rated as not suitable (N) for gram on account of very shallow depth (<25 cm) and low organic carbon content (<4.0 g kg^{-1} soil). Soils of the pedons P13, 14 and 15 have been evaluated as moderately suitable (S2) on account of depth (>90 cm), AWC (>0.25 $m3m^{-3}$), organic carbon content (>5.0 g kg^{-1} soil), and CEC [>16 cmol (p+) kg^{-1} soil]. These soils, in good rainfall years, are reported to yield 600 to 800 kg per hectare. If managed properly, these soils have the potential to yield about 1000 to 1500 kg per hectare.

Suitability of soils of different landforms for groundnut

Groundnut requires hot and sunny conditions. Germination takes places between temperatures 10 to 38°C (22 to 28°C being optimum). It requires a minimum precipitation of 300 mm which is even and well distributed. However, the optimum precipitation is in the range of 400 to 1100 mm. Important growth stages where moisture stress may badly affect yield are pegging stage, peak flowering and pod filling stage. Humidity or wetness during harvesting is also harmful as it may cause re-germination or rotting. The crop requires well aerated, porous soils with good soil-air-water relationship. Heavy soils like clay, silty clay, etc are not suitable both for pegging as well as during harvest. The crop requires an optimum depth of 75 cm. The pH should be in the range of 6.0 to 7.5; EC should be less than 5 dS m^{-1} and ESP less than 20 for good yield.

Eastern Rajasthan upland

The soils of pedon P1 have been found to be not suitable (N) for groundnut on account of very shallow depth (<25 cm), low organic carbon (<4.0 g kg^{-1}) and low CEC [10.3 cmol (p+) kg^{-1} soil]. The soils of the pedons P2, P3 and P4 have been found to be marginally suitable (S3) owing to shallow depth (25 to 50 cm), low AWC (<0.25 $m3m^{-3}$), and low CEC [<16 cmol (p+) kg^{-1} soil]. These soils have been reported to yield around 600 to 900 kg per hectare on farmer's field. The soils of pedon 5 have been found to be moderately suitable (S2) on account of deeper solum (>100 cm), and good AWC (>0.25 $m3m^{-3}$). The yield of groundnut on this type of soil is around 900 to 1200 kg per hectare.

Pathar and Bundelkhand plateau

The soils of pedon P9 have been found to be not suitable (N) for groundnut on account of very shallow depth (<25 cm), and low organic carbon (<4.0 g kg^{-1} soil). Soils of pedons P7, P8 and P10 have been found to be marginally suitable (S3) for groundnut. The yields of these soils have been reported to be around 600 to 900 kg per hectare. The soils of the pedon 6 have been found to be moderately suitable (S2) for groundnut on account of deeper solum (>100 cm), moderate organic carbon content (>6.0 g kg^{-1} soil), AWC (>0.25 m3 m^{-3}) and CEC [>20 c mol (p+) kg^{-1} soil]. The farmers of the area report the yield to be in the range of 900 to 1200 kg per hectare. Under good management conditions, these soils may yield between 1000 to 2000 kg per hectare.

Malwa plateau

The soils of the pedons P11 and P12 have been found to be not suitable (N) for groundnut on account

of very shallow depth (<25 cm), and low organic carbon (<4.0 g kg^{-1} soil). The soils of pedons P11, P14 and P15 have been found to be moderately suitable (S2) on account of depth (>90 cm), organic carbon content (>5.0 g kg^{-1} soil), AWC (> 0.25 $m3m^{-3}$) and CEC [>16 cmol (p+) kg^{-1} soil]. The yield according to the farmers of the area is 850 to 1100 kg per hectare. Under good management practices these soils can yield around 1000 to 2000 kg per hectare.

Suitability of soils of different landforms for soybean

Soybean requires an optimum temperature range of 20 to 30°C. The optimum rainfall during the growth period is 350 to 1100 mm. The crop grows well in the pH range of 5.5 to 7.5, EC of less than 7.5 dS m^{-1} and ESP of less than 20.

Eastern Rajasthan upland

Soils of the pedon P1 have been found to be not suitable (N) for soybean owing to very shallow depth (<25cm), low organic carbon (<4.0 g kg^{-1} soil) and low CEC [10.3 cmol (p+) kg^{-1}soil]. Soils of the pedon (P2, P3, P4) have been found to be marginally suitable (S3) for soybean on account of shallow depth (25 to 50 cm), low CEC [<16 cmol (p+) kg^{-1} soil]. Farmers generally fetch 600 to 1200 kg grain yield per hectare. The soils of the pedon P5 have been found to be moderately suitable (S2) for soybean due to more depth (>100 cm), higher organic carbon status (> 6.0 g kg^{-1} soil), AWC (>0.20 $m3m^{-3}$), and CEC [>16 cmol (p+) kg^{-1} soil]. These soils generally yield 900 to 1600 kg grain per hectare. Under good management conditions, these soils can yield up to 1500 to 2500 kg per hectare.

Pathar and Bundelkhand plateau

The soils of pedon 9 have been found to be not suitable (N) for soybean on account of very shallow depth (<25cm), low AWC (<0.25 $m3m^{-3}$), low organic carbon content (<4.0 g kg^{-1} soil) and low CEC [16 cmol (p+) kg^{-1} soil]. The soils of pedons P7, P8 and P10 have been found to be marginally suitable (S3) on account of shallow depth (25 to 50 cm), low CEC [<16 cmol(p+) kg^{-1} soil], and moderate AWC (<0.25 $m3m^{-3}$). These soils yield 600 to 1000 kg grain per hectare (in years of good rainfall). The pedon P6 has been found to be moderately suitable (S2) for soybean on account deeper solum (>100 cm), relatively high AWC (>0.25 $m3m^{-3}$), better organic carbon content (>6.0 g kg^{-1} soil) and CEC [>20 cmol (p+) kg^{-1} soil]. The soils yield around 900 to 1500 kg grain per hectare (in years of good rainfall). This soil has the potential to yield 1500 to 2500 kg per hectare.

Malwa plateau

The soils of the pedons P11 and P12 were rated as not suitable (N) for soybean on account of very shallow depth (<25 cm), and low organic carbon (<4.0 g kg^{-1} soil). The soils of the pedons P13, P14 and P15 have been found to be moderately suitable (S2) on account of better soil depth (>100 cm), AWC (>0.25 $m3m^{-3}$), organic carbon content (>6.0 g kg^{-1} soil) and CEC [>16 cmol (p+) kg^{-1} soil]. The yields on these types of soils have been reported to be around 950 to 1250 kg per hectare. Under good management conditions, these soils can yield to the extent of 1500 to 2500 kg per hectare.

Suitability of soils of different landforms for mustard

It requires optimal temperature of 15 to 20°C but is damaged if cloudiness occurs during siliqua development. It requires minimum of irrigation and can complete its life cycle with 2 to 4 irrigations in different soils. More number of irrigations delays seed setting and development. The crop grows on a variety of soils, but soils finer than sandy clay loam are desirable. The optimum soil depth is >75 cm. The pH range is 6.5 to 7.5, EC should be less than 7.0 dS m^{-1} and ESP should be less than 15.

Eastern Rajasthan upland

The soils of the pedon P1 have been found to be not suitable (N) on account of very shallow depth (<25 cm), low organic carbon content (<4.0g kg^{-1} soil) and low CEC [<16 cmol (p+) kg^{-1} soil]. Soils of pedons P2 P3 and P4 have been grouped as marginally suitable (S3) on account of shallow depth (25 to 50 cm), low AWC (<0.25 m3 m^{-3}), and low CEC [<16 cmol (p+) kg^{-1} soil]. The farmers fetch 600 to 1200 kg grains per

hectare. The soils of the pedon P5 have been found to be moderately suitable (S2) on account of soil depth (>100 cm) and AWC (>0.25 $m3m^{-3}$). The yield on this type of soils has been reported to be around 900 to 1600 kg per hectare.

Pathar and Bundelkhand plateau

The soils of pedon P9 have been found to be not suitable (N) on account of very shallow depth (<25 cm), low organic carbon content (<4.0 g kg^{-1} soil) and low CEC [16 cmol (p+) kg^{-1} soil]. The soils of pedons P7, P8 and P10 have been found to be marginally suitable (S3) on account of shallow depth (25 to 50 cm), low AWC (<0.25 m3 m^{-3}), low CEC [<16 cmol (p+) kg^{-1} soil]. Farmers reported 600 to 1150 kg per ha grain yield on these soils. The soils of pedon P6 have been rated as moderately suitable (S2) on account of depth (>100 cm), AWC (0.25 to 0.35 m3 m^{-3}), organic matter content (> 6.0 g kg^{-1} soil), and CEC [>16 cmol (p+) kg^{-1} soil]. The soils can yield 900 to 1550 kg grain yield per hectare on farmer's field. Under good agro-management, the soils have the potential to yield between 1500 to 2000 kg per hectare.

Malwa plateau

The soils of pedon P11 and P12 have been found to be not suitable (N) on account of very shallow depth (<25 cm), and low organic carbon content (<4.0 g kg^{-1} soil). The soils of pedons P13, P14 and P15 have been grouped as moderately suitable (S2) owing to deeper solum (>90 cm), organic matter content (>6.0 g kg^{-1} soil), AWC (>0.25 m3 m^{-3}) and CEC [>16 cmol (p+) kg^{-1} soil]. These soils yield 900 to 1500 kg grain per hectare. Under proper soil and fertility management, these soils have the potential to yield around 1500 to 2000 kg per hectare.

References

Giri, J.D., Shyampura, R.L. and Sahgal, J.L. (1994). Soil site suitability for maize in Banswara district, Rajasthan. *Agropedology* **4**, 75-79.

NBSS and LUP (1994). Manual on soil-site suitability criteria for major crops. NBSS Publ. **129**, Nagpur, India.

Sehgal, J. (1995). Land resource appraisal for land use planning to meet the challenges of 21st century. *Journal of the Indian Society of Soil Science* **43**, 504-528.

Sharma, R.K., Swami, B.N., Giri, J.D., Singh, S.K. and Shyampura, R.L. (2001). Soils of Haldi Ghati region of Rajasthan and their land suitability for different land uses. *Agropedology* **11**, 23-28.

Singh, K., Swami, B.N., Giri, J.D., Shyampura, R.L. and Singh, S.K. (1998). Characteristics and soil suitability evaluation for maize. Paper presented at the 16th World Congress of Soil Science, 20-26 August, 1998, Montpellier, France.

Soil Survey Staff. (1995). Soil Survey Manual. Agri. Handb. U.S. Dept. Agric. **18**, Indian Print, Scientific Publisher, Jodhpur, 437.

Soil Survey Staff (1998). Keys to Soil Taxonomy. Publ. United States Department of Agriculture, Natural Resources Conservation Service, Washington D.C 8th edition, p 326,.

Sys, Ir. (C.), Van Ranst, E., Debaveye, I.J. and Beernaert, F (1993). Land evaluation Part (III). Crop requirement: International Training Centre for Post Graduate Soil Scientist, Univ. Ghent, Belgium.

Tang, H. and Ranst, E.V. (1998). Soil property crop performance approach to land evaluation, In: 16th World Congress on Soil Science, 20-26 August, 1998, Agriculture Symposium No.**35,** Vol.III; held at Montepellier, France.

Velayutham, M., Mandal, D.K., Mandal, C, and Sehgal, J. (1999). Agro-ecological sub regions of India for planning and development. NBSS Publ. **35,** p 3 72; NBSS&LUP, India.

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