Response of Soybean to Soil-Site Parameters and Crop Management

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Abstract : *Field experiments were conducted at Khapri Watershed near Nagpur, during kharif, 1991 and 1992 under low, medium and high levels of management in order to study the response of soybean to different soil-site parameters. The soil units Khapri-7 and Khapri-8; belonging to the Orders Inceptisols, and that of Khapri 5 of Vertisols having soil depth of 50cm or more, and $CaCO_3$ content less than 10 per cent, responded significantly. (yield 10.5 q ha^{-1}). The other soil units (Khapri-1, Khapri-2(b) and Khapri-3(b)) representing Entisols and having soil depth of less than 50cm, produced 5.4 to 6.4 qha^{-1} yield. The soil, Khapri-3(a) representing Inceptisols and having $CaCO_3$ equivalent of 10 per cent or more yielded 8.4 q ha^{-1}. The increased soil-effective rainfall and length of growing period (LGP) due to increased plant available water capacity (PAWC) was found responsible for higher yield and hence better net returns. It suggested that soil depth, PAWC and LGP should be given preference over other parameters. The yield and gross returns at low level of management in deeper soils were found to be at par with shallow soils at high level of management. (**Key words :** Soil-site parameters, level of management, PAWC, B:C, soil series).*

Soybean cultivation is getting more popular in central Vidarbha region of Maharashtra. This may be due to a short growing period of crop coupled with less input cost (on labour and plant protection) compared to other crops such as cotton. However, bringing indiscriminately any area under soybean without assessing the soil-site suitability for its cultivation, would imply blind hoeing. It is therefore, imperative that soil characteristics and also the soil climatic relationship are interpreted in terms of their suitability for soybean production. Keeping this in view, present study was conducted to develop a soil-site suitability criteria for soybean.

MATERIAL AND METHODS

The study was conducted at Khapri Watershed in Katol taluka of Nagpur district (Maharashtra). The soils of the watershed were surveyed and grouped taxonomically as per the USDA Soil Taxonomy (Balbudhe 1990). The difference in moisture holding capacity at 33 and 1500 kPa was multiplied by bulk density and soil depth to calculate the total plant available water capacity (PAWC) of each soil series.

The field experiment on eight soil series was carried out during *kharif* 1991 and 1992, with three management levels (low, medium and high) in a split plot design replicated thrice. The details of soil series included in the study are given in Table 1. Soybean variety PK 472, was sown with 37.5 x 15 cm^2 spacing. The plots with low management received fertilizer dose of 20 kg N ha^{-1} and 40 kg P_2O_5 as basal; one hoeing (15 DAS), one weeding (30 DAS), one BHC (10%) dusting. Medium management received the fertilizer dose of 25 kg N ha^{-1} and 50 kg $P_2O_5 ha^{-1}$ as basal; two hoeings (15 and 30 DAS), one hand weeding (20 DAS) and adequate plant protection measures (one spraying of Endosulfan and one dusting of BHC, 10%). High management received rhizobium seed treatment, fertilizer dose of 30 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} as basal; and additional 30 kg P_2O_5 ha^{-1} top dressed (at 30 DAS); two hoeings (15 and 30 DAS), two hand

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TABLE 1. Soil-site characteristics of Khapri watershed and their impact on growth, yield and economics of soybean

Landform	Horizon	Depth (cm)	Sand (%)	Clay (%)	Org.C (%)	$CaCO_3$ (%)	Total PAWC (mm)	Eff. rainfall (mm)	LGP (days)	LAD (days)	Yield (q ha^{-1})	Returns Gross (Rs. ha^{-1})	Returns Net (Rs. ha^{-1})	B.C ratio
ENTISOLS														
Khapri-1, Loamy, mixed, hyperthermic family of Lithic Ustorthents.														
Upper plain	Ap	0-17	25.4	59.8	0.56	6.0	24.2	356	98	151	5.4	5056	809	1.18
	Cr	17-33	—-Weathered Basalt—											
Khapri-2b, Loamy, mixed, hyperthermic family of Typic Ustorthents														
Escarpment	Ap	0-6	57.3	25.6	0.86	-	17.3	349	97	141	6.0	5605	1340	1.28
	Cr	6-15	—Weathered Basalt—											
Khapri-3b, Loamy, mixed (calcarious), hyperthermic family of Typic Ustorthents														
Upper plain	Ap	0-15	55.2	31.3	0.58	9.1	65.9	397	224	148	6.6	6253	1965	1.47
	B	15-35	58.5	27.2	0.34	9.8								
	Cr	35-50	—Weathered Basalt—											
INCEPTISOLS														
Khapri-3a, Fine loamy, mixed (calcarious), hyperthermic family of Typic Ustochrepts														
Upper plain	Ap	0-18	42.0	36.0	0.53	9.7	128.0	459	141	176	8.4	7920	3576	1.80
	B1	18-35	38.0	39.5	0.43	29.0								
	B2	35-50	50.9	29.5	0.35	32.0								
	Cr	50-80	—Weathered Basal—											
Khapri-4, Clayey, montmorillonitic (calcarious), hyperthermic family of Typic Ustochrepts														
Upper plain	Ap	0-15	18.0	54.9	1.45	3.6	105.0	384	112	157	7.1	6666	2365	1.56
	B	15-35	41.8	37.2	0.50	3.1								
	Cr	35-80	—Weathered Basalt—											
Khapri-7, Clayey, montmorillonitic (calcarious) hyperthermic family of Typic Ustochrepts														
Lower Plain	Ap	0-10	19.4	65.8	0.56	6.0	115.0	417	117	199	10.8	10197	5775	2.28
	B1	10-23	25.8	60.4	0.53	6.1								
	B2	23-36	30.2	42.3	0.44	7.1								
	B3	36-45	41.7	38.9	0.24	7.4								
	Cr	45-75	—Weathered Basalt—											
Khapri-8, Fine, montmorillonitic, hyperthermic, family of Vertic Ustochrepts														
Lower plain	Ap	0-14	13.8	56.2	1.05	0.9	120.3	421	153	193	10.2	9594	5193	2.18
	B2	14-29	13.3	60.2	0.89	1.3								
	B3k	29-51	31.8	48.2	0.62	16.3								
	Cr	51-66	—Weathered Basalt—											
VERTISOLS														
Khapri-5, Fine, montmorillonitic, hyperthermic, family of Typic Haplusterts														
Lower plain	A11	0-11	23.1	59.2	1.01	4.7	218.0	556	178	237	10.5	9862	5452	2.22
	A12	11-30	13.6	74.8	0.79	5.1								
	A13	30-56	16.1	71.8	0.75	5.3								
	A14	56-90	14.9	75.3	0.35	5.3								
	AC	90-108	50.6	43.3	0.30	8.3								
	Cr	108-120	—Weathered Basalt—											
S.Em.±											6	0.4	364	352
C.D.(5%)											11	1.1	1055	1020

B:C = Benefit cost ratio

weedings (20 and 40 DAS) and adequate plant protection measures (one spraying of Endosulfan and one dusting of BHC, 10%).

During the cropping seasons, the amount of rainfall received were 678 mm in 1991, and 437 mm in 1992 in 51 and 30 rainy days, respectively. Effective rainfall was calculated by subtracting the water surplus from the total rainfall after meeting the requirements of crop evapotranspiration and complete storage capacity of each soil series under study. Crop evapotranspiration and water surplus were estimated using Thornthwaite water balance concept as described by Rao *et al.* (1976). The length of growing period (LGP) was also calculated for each soil series following the FAO model (Higgins & Kassam 1981). However, to calculate the LGP after the cessation of rains, the actual stored soil moisture (PAWC) was used instead of the assumed 100 mm in the FAO model (Table 1).

Leaf area index cumulated as leaf area duration (LAD) was studied. Grain yield, and benefit : cost ratio (B.C) was calculated for each treatment. Statistical analysis was done by pooling.

RESULTS AND DISCUSSION

Impact of soil site characteristics on soybean growth, yield and economic returns . In different soil units, differed significantly (Table 1). The soil series *viz.*, Khapri-1, Khapri-2(b), Khapri-3(b) (Entisols) and Khapri-4 (Inceptisols) showed significantly less growth, yield and economic returns than Khapri-3(a), Khapri-7, Khapri-8 (Inceptisols) and Khapri-5 (Vertisol). It was mainly due to shallow depth (<50 cm) in the former which resulted in lesser PAWC, soil effective rainfall and thus, shorter LGP than the latter group. Among the soil-site parameters, the major factor responsible for differences in growth, yield and economic returns, was the moisture storage capacity in the solum of each soil unit *vis-a-vis* total PAWC. Deeper soils, finer texture and lesser calcium carbonate content resulted in increased moisture retention in soil and thus improving the growth and in turn the yield.

Impact of management on Soybean yield and Economics : High management brought significant enhancement in yield and economic returns over their lower management levels (Table 2). The average grain yield increased from 5.9 to 10.3 q ha^{-1}. The response to high management was 21 per cent more than medium management, and 75 per cent more than low management. Increased doses of N (as starter dose) and P under high management level might have been mainly responsible for enhanced yield of the crop. Wiess (1983) and Wadodkar (1992) also observed that soybean is a highly exhaustive crop and require higher amount of nutrients particularly P for its optimum production.

The net return increased by 91 per cent with high management level and that by 83 per cent with medium management over the farmers level of management. Benefit:Cost (B:C) ratio is highest with high management (1.84) The B:C ratio for lower management and medium levels were almost at par.

Interaction between soil-site and management levels were found significant. In general grain yield in deeper (>50 cm) soils of Inceptisols, and Vertisols (7.6 to 8.0 q ha^{-1}) at low management level were found at par with shallower depth (<50 cm) soils (7.0 to 8.3 qha) with high management level. At high management level, the benefit:cost ratio was around 2 in deeper soils as against 1.5 or less in shallow soils.

Response function : Multiple regression was worked out between grain yield and soil-site parameters (Table 3). R^2 was found to be 0.64, indicating 64 per cent variability in grain yield which could be attributed by effective depth; clay and calcium content, PAWC, effective rainfall, LGP and organic carbon content in soil. Among these, effective depth, PAWC, LGP and organic carbon content showed significant impact on yield as it was confirmed by quadratic function. The optimum values of effective depth, PAWC, organic carbon and LGP were 113 cm, 249

TABLE 2. Yield and economic returns as influenced by crop management levels in different soil-sites

Soil Unit	Management level	Yields (qha^{-1})	Cost of production	Gross return <--(Rs	Net return ha^{-1})-->	B:C ratio
Entisols						
Khapri-1	Low	3.8	3147	3580	433	1.13
	Medium	5.3	4460	4993	534	1.12
	High	7.0	5135	6595	1460	1.28
Khapri-2b	Low	3.5	3136	3255	119	1.03
	Medium	6.1	4486	5764	1278	1.28
	High	8.3	5176	7797	2622	1.51
Khapri-3b	Low	5.3	3196	5025	1829	1.57
	Medium	6.5	4499	6160	1661	1.37
	High	8.0	5168	7574	2406	1.46
Inceptisols						
Khapri-3a	Low	5.9	3215	5604	2389	1.74
	Medium	8.0	4547	7563	3017	1.66
	High	11.2	5271	10594	5323	1.99
Khapri-4	Low	5.6	3204	5255	2052	1.64
	Medium	7.4	4526	6946	2420	1.53
	High	8.3	5176	7797	2622	1.50
Khapri-7	Low	7.6	3268	7165	3896	2.17
	Medium	11.1	4646	10492	5845	2.25
	High	13.7	5350	12935	7584	2.41
Khapri-8	Low	8.0	3282	7562	4280	2.29
	Medium	9.7	4600	9113	4514	1.96
	High	12.9	5322	12107	6785	2.27
Vertisols						
Khapri-5	Low	7.4	3262	7001	3739	2.14
	Medium	11.0	4642	10351	5709	2.22
	High	13.0	5327	12235	6908	2.28
S.Em.±	Soil x Management	0.3		311	301	
C.D. (5%) soil	x Management	0.9		881	851	
Mean of low management		5.9	3214	5556	2342	1.72
Mean of medium management		8.1	4551	7673	3122	1.68
Mean of high management		10.3	5240	9704	4464	1.84
S.Em.±		0.1		154	148	
C.D.(5%)		0.3		434	420	

B:C = Benefit:Cost ratio

TABLE 3. Regression equations for the relationship between soil-site parameters and soybean yield

Parameter	Equation
Multivariate regression equation	
	YIELD = -0.231 x Effective depth** + 0.038 x clay - 0.118 x $CaCO_3$ + 0.085 x PAWC** + 0.021 x Effective rainfall + 0.066 x LGP** - 4.936 x Organic carbon - 3.838 (R^2 = 0.640)
Quadratic equation	
1. Effective depth (cm)	YD = - 0.0005 X^2 + 0.1126 x + 4.162 (R^2 = 0.667)
2. Clay content (%)	YC = - 0.00084 X^2 + 0.1477 X + 3.2504 (R^2 = 0.148)
3. $CaCO_3$ content (%)	= YCO_3 = - 0.016 X^2 + 0.42 X + 6.454 (R^2 = 0.135)
4. PAWC (mm/m)	YP = - 0.0001 X^2 + 0.0498 X + 4.527 (R^2 = 0.713)
5. LGP (Days)	YC = - 0.00032 X^2 + 0.1604 X - 6.817 (R^2 = 0.834)
6. Organic carbon (%)	YOC = 15.416 - 26.44 X + 21.72 X^2 (R^2= 0.182)
Linear Equation	
7. Effective rainfall (mm)	YR = - 3.06 + 0.027 X (R^2= 0.563)

** Significant at 5% level

mm, 0.61 per cent and 251 days, respectively. The regression equation for the relationship between yield and effective rainfall was found to be linear (r=0.66). Partial correlation coefficient between yield and different soil-site parameters *viz.* effective depth; clay and $CaCO_3$ content, PAWC, effective rainfall, organic carbon and LGP was found to be 0.488**, 0.217, 0.260, 0.439**, 0.236, 0.321** and 0.284, respectively, showing the effect of an individual soil site parameters keeping the other parameters constant.

Thus it is concluded that soils having more than

50 cm depth, higher PAWC (>100 mm), are more preferential for soybean. With appropriate management, shallow soils can also be made more productive. Further, for soil-site suitability rating, effective depth, PAWC, soil effective rainfall and LGP must be given due consideration.

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