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Standardization of Sub-soiling Schedule and Spacing for Effective Rainwater Conservation and Enhancing Production Potential of Rainfed Soybean

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ABSTRACT: Soybean is a major crop in the domain districts of Marathwada region of Maharashtra State. The monsoon behavior has become very uncertain during recent years. The rainfall, its uneven distribution and prolonged dry spells during *kharif* season affect the crop productivity particularly in Marathwada region. Therefore, effective management of rainwater using *in-situ* conservation is the key point for sustaining productivity. Sub-soiling is one of the technique for higher rainwater / moisture conservation. Therefore, an experiment was conducted for standardization of sub-soiling schedule and its spacing for effective rainwater conservation and enhancing crop productivity. The treatment of sub soiling in alternate year with selected spacings of 1.5 m is found significantly superior over the treatment of sub soiling once in three years with selected spacings and at par with sub soilng in alternate year with a horizontal spacing of 2.0 m and sub soiling in every year with horizontal spacing of 1.5 m and 2.0 m. Thus, it is concluded that sub soiling in alternate year or every year with horizontal spacing of 1.5 m or 2.0 m is found suitable with respect to yield advantage and moisture conservation. The trend of GMR, NMR and BC ratio is also found to be similar in the interaction effect. Higher soil moisture % was observed in the treatment of sub soiling in alternate year and sub soling in every year with horizontal spacing of 1.5 m and 2.0 m. The minimum runoff and soil loss were observed under sub soiling in every year followed by sub soiling in alternate year whereas maximum runoff and soil loss were observed in sub soiling once in three years. Among sub soiling spacing treatments, minimum runoff and soil loss were observed in sub soiling at 1.5 m spacing and sub soiling at 2.0 m spacing whereas maximum runoff and soil loss were observed in sub soiling at 3.0 m spacing. Sub-soiling increases infiltration rate and maintained the bulk density. The energy output-input ratio was found higher in the treatment of sub soiling in alternate year with a sub-soiling spacing of 1.5 to 2 m.

Key words: Infiltration, rainwater, sub-soiling, soybean, stage level recorder

Introduction

Soybean has become an important oilseed crop in India in a very short period with approximately 10-million ha area under its cultivation. There has been an unprecedented growth in soybean area which was just 0.03 m ha in 1970 and has reached to 9.30 million ha in 2010. The mean national productivity has increased from 0.43 t ha^{-1} in 1970 to 1.36 t ha^{-1} in 2010. Soybean is called as golden bean and it belongs to legume family. The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, and Chhattisgarh. Despite having made rapid stride for both coverage and total production, soybean still suffers on productivity front. There are a number of constraints, pertaining to climate, production, and technology aspects. Most of the area under soybean cultivation is a rainfed. Erratic behaviour of monsoon affects the production potential. Large spatial and temporal variability in rainfall, soil moisture stress at critical growth stages, especially seed-filling stage, high-temperature stress at critical growth stages, biotic interferences to crop growth, limited mechanization, poor adoption of improved production technology and low risk covering ability are the major constraints in achieving the targeted production potential.

Productivity of soybean can be increased by sub-soiling techniques. Sub-soiling can be found effective in rainwater conservation and yield enhancement. Sub-soiling was accomplished by using a sub-soiler at a soil depth ranging from 30 to 40 cm. Sub-soiling will not overturn the top-soil but disturbs and breaks the plough layer, which result in improving the permeability of soil water, creating a "water reservoir" underneath the soil surface, increasing the efficiency of rainwater use and improving the ability of water conservation in arid areas. Subsequently, sub-soiling can minimize the effect of drought and lead to an increase in crop yield. Subsoiling facilitates downward water movement and enhances drainage so as to induce deeper penetration and consequently better root growth (Gajri *et al.*, 1991). Annual sub-soiling reduced bulk density by 4.9% compared with no-till control plots on silty loam soils. Sub-soiling can increase soil porosity and decrease the soil bulk density up to 3-4% (Solhjou and Niazi, 2001). Consequently, infiltration rate in sub-soiled soils has been significantly improved than control (Soltanabadi *et al.*, 2008). Sub-soiling breaks the hard pan layer of the soil and thus favours the percolation and enhances the drainage and consequently induced deeper root penetration (Ishaq *et al.*, 2001). Asgari *et al.* (2014) observed increased soil bulk density with increasing soil compaction and therefore to avoid negative effects of soil compaction on crop yield, it must be eliminated using sub-soiler. Subsoiling improved soil structure by lowering soil strength besides eliminating soil compaction and thus increased both yield as well as water use efficiency (Pikul and Aase, 2003). These findings elucidate that compaction limits crop root development and decrease the yield and sub-soiling in such cases has beneficial effects.

Soybean is grown on 13 lakh ha area in Marathwada region of Maharashtra state. Majority of the small and marginal farmers are preferring to grow soybean during *kharif* season. The average productivity of soybean varies depending of monsoon behavior. Occurrence of frequent dryspells affects the productivity of soybean in the region. Marathwada region of Maharashtra state comprises 8 districts with average annual precipitation of 807 mm. Though the majority area falls under assured rainfall zone, it is characterized by 2-3 prolonged dry spells during crop growth. In Marathwada region, situations of deficit rainfall in last decade has aggravated in drylands and resulted in reduced crop production and productivity and overall socio-economic condition of farmers.

Materials and Methods

The experiment was initiated in the year 2018-19 to 2020-21 for a period of three years and was conducted in the research farm of All India Coordinated Research Project for Dryland Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani, Maharashtra. The average rainfall of the region is 892 mm. The soils of the area are medium black. The experiment was laid out in split plot with 4 replications. The experimental plot size was 4.5 m x 5.0 m and soybean was sown at 45 x 10 cm spacing. The recommended dose of fertilizer i.e. FYM 5 t ha^{-1} & (30:60:30 NPK Kg ha^{-1}) was applied. The experiment was executed with three main treatments viz., S_1 - Sub soiling in every year, S_2 - Sub soiling in alternate year and S_3 - Sub soiling once in three years with five sub treatments viz., D_1 - Sub-soiling at every 1.0 m horizontal distance, D_2 - Sub-soiling at every 1.5 m horizontal distance, D_3 - Sub-soiling at every 2.0 m horizontal distance, D_4 - Sub-soiling at every 2.5 m horizontal distance and D_5 - Sub-soiling at every 3.0 m horizontal distance. Soybean was sown using tractor drawn seed drill. The infiltration rate under different treatments was determined by conducting infiltration test using double ring infiltrometer. Automatic stage level recorders with H-flume and stilling basin were installed for measurement of runoff and soil loss under different treatments.

Results and Discussion

Weather experienced during 2018-21

During the period of experimentation, normal rainfall was received. However, 3 to 4 dry spells were observed during the month of June, July and August which had created a situation of moisture stress during the critical growth stages of soybean. Every year, early dry spell was observed in the month of June just after sowing. Also, mid-season dry spells were observed in the month of July and August. Terminal dry spells were observed during 2019 and 2020 in the month of October. The data on crop seasonal rainfall and dry spells during 2018-20 is presented in Table 1.

Table 1 : Crop seasonal rainfall and dry spells during 2018-20

2018		2019		2020	
Crop seasonal rainfall, mm					
802.4		859.4		1004.5	
Dry spells					
Duration (days)	Date & month	Duration (days)	Date & month	Duration (days)	Date & month
9	June 12 to June 20	10	July 01 to July 10	09	June 17 to June 25
25	Jul. 22 to Aug. 15	13	July 14 to July 26	12	July 30 to Aug 10
33	Aug. 28 to Sept. 30	16	Aug 15 to Aug 30	10	Aug 28 to Sep 06
		18	Oct 02 to Oct 19	09	Oct 02 to Oct 10

The data with respect to soybean grain yield, GMR, NMR, BC ratio and RWUE was analyzed and the pooled data (2018-19 to 2020-21) is presented in Tables 2 to 6.

Effect of sub soiling years on soybean yield

The effect of sub soiling years on mean soybean yield was found to be significant. The mean soybean yield recorded by treatment S_2 i.e. sub soiling in alternate year was significantly higher (961 kg ha^{-1}) and it was found to be significantly higher than S_1 i.e. sub soiling in every year and on per with S_2 i.e. sub soiling in once in three years.

Effect of sub soiling horizontal distance / spacing on soybean yield

The effect of sub soiling horizontal distance / spacing on soybean yield was found to be significant. The soybean yield recorded by treatment D_2 i.e. sub soiling at every 1.5 gm horizontal distance was significantly higher (1024 kg ha^{-1}) than rest of the treatments except sub soiling at every 2.0 m horizontal distance.

Table 2 : Soybean seed yield kg (ha^{-1}) during 2018-19 to 2020-21

Treatments	Year			
	2018-19	2019-20	2020-21	Mean
Sub soiling rotation / years				
S_1 - Sub soiling in every year	857	805	1093	918
S_2 - Sub soiling in alternate years	802	965	1117	961
S_3 - Sub soiling once in three years	801	1050	988	946
SE $\pm$	60	78	32	57
CD at 5%	184	234	98	172
Sub soiling horizontal spacing				
D_1 - Sub soiling at every 1.0 m horizontal distance	860	785	1038	894
D_2 - Sub soiling at every 1.5 m horizontal distance	941	1022	1109	1024
D_3 - Sub soiling at every 2.0 m horizontal distance	862	985	1098	981
D_4 - Sub soiling at every 2.5 m horizontal distance	834	850	980	888
D_5 - Sub soiling at every 3.0 m horizontal distance	755	815	952	840
SE $\pm$	46	56	26	43
CD at 5%	138	168	79	129
Interaction effects (S x D)				
SE $\pm$	72	112	30	71
CD at 5%	218	336	88	214
Mean		907	1047	

Effect of sub soiling rotation / years on economics

The effect of sub soiling years on GMR was found to be significant. The higher GMR was observed with treatment S_2 i.e. sub soiling once in alternate year was significantly higher (35443 Rs./ha) and it was found to be significantly higher than S_1 i.e. sub soiling in every year and on par with S_3 i.e. sub soiling in once in three years.

Effect of sub soiling horizontal spacing on economics

Significantly higher GMR was obtained with treatment D_2 i.e. sub soiling at every 1.5 m horizontal distance (Rs.37019 ha^{-1}) and it was found to be significantly higher than rest of all the treatments. The trend of NMR is also similar to GMR.

Table 3 : Gross monetory returns (GMR) Rs ha^{-1} during 2018-19 to 2020-21

Treatments	Years			
	2018-19	2019-20	2020-21	Mean
Sub soiling rotation / years				
S_1 - Sub soiling in every year	29052	29865	42408	33775
S_2 - Sub soiling in alternate year	27188	35802	43339	**35443**
S_3 - Sub soiling once in three years	27154	38955	38350	34819
SE $\pm$	1785	1545	1075	1468
CD at 5%	5469	4635	3219	4441
Sub soiling horizontal spacing				
D_1 - Sub soiling at every 1.0 m horizontal distance	27520	29124	40274	32306
D_2 - Sub soiling at every 1.5 m horizontal distance	30112	37916	43029	**37019**
D_3 - Sub soiling at every 2.0 m horizontal distance	27584	36544	42602	35576
D_4 - Sub soiling at every 2.5 m horizontal distance	26688	33019	38024	32577
D_5 - Sub soiling at every 3.0 m horizontal distance	14160	30237	36937	27111
SE $\pm$	1422	1122	1085	1209
CD at 5%	4266	3366	3255	3629
Interaction effects (S x D)				
SE $\pm$	1688	1323	1075	1365
CD at 5%	5065	3969	3240	4091
Mean		33933	40620	

B:C ratio and rain water use efficiency

The highest B:C (2.02) ratio and RWUE (1.58) was recorded by treatment S_2. Among the treatments of sub soiling horizontal spacing, highest BC ratio (2.02) and RWUE (2.27) were observed in treatment of D_2 treatment followed by D_3 and D_4.

Table 4 : Net monetory returns (NMR) Rs ha^{-1} during 2018-19 to 2020-21

Treatments	Years			
	2018-19	2019-20	2020-21	Mean
Sub soiling rotation / years: (3)				
S_1 - Sub soiling in every year	8052	12975	21408	14145
S_2 - Sub soiling in alternate year	8188	19912	23339	17256
S_3 - Sub soiling once in three years	8354	24065	19350	17147
SE $\pm$	1775	1238	659	1224
CD at 5%	5437	3714	1985	3712
Sub soiling horizontal spacing				
D_1 - Sub soiling at every 1.0 m horizontal distance	10147	14324	19274	14582
D_2 - Sub soiling at every 1.5 m horizontal distance	12739	21026	22529	18765
D_3 - Sub soiling at every 2.0 m horizontal distance	10211	20154	22602	17656
D_4 - Sub soiling at every 2.5 m horizontal distance	9315	17179	18524	15006
D_5 - Sub soiling at every 3.0 m horizontal distance	6787	14847	17937	13190
SE $\pm$	1535	942	990	1156
CD at 5%	4605	2826	2980	3470
Interaction effects (S x D)				
SE $\pm$	1265	1050	809	1042
CD at 5%	3796	3150	2440	3128
Mean		19310	20620	

Table 5 : Benefit-cost ratio during 2018-19 to 2020-21

Treatment	Year			
	2018-19	2019-20	2020-21	Mean
Sub soiling rotation / years				
S_1 - Sub soiling in every year	1.38	1.76	2.02	1.72
S_2 - Sub soiling in alternate year	1.43	2.25	2.16	2.02
S_3 - Sub soiling once in three years	1.44	2.62	2.01	1.94
SE $\pm$	0.08	0.08	0.03	0.06
CD at 5%	0.27	0.24	0.09	0.2
Sub soiling horizontal spacing				
D_1 - Sub soiling at every 1.0 m horizontal distance	1.58	1.96	1.91	1.82
D_2 - Sub soiling at every 1.5 m horizontal distance	1.73	2.24	2.09	2.02
D_3 - Sub soiling at every 2.0 m horizontal distance	1.58	2.22	2.13	1.98
D_4 - Sub soiling at every 2.5 m horizontal distance	1.53	2.08	1.95	1.85
D_5 - Sub soiling at every 3.0 m horizontal distance	1.39	1.96	1.94	1.76
SE $\pm$	0.10	0.09	0.05	0.08
CD at 5%	0.31	0.27	0.15	0.24
Interaction effects (S x D)				
SE $\pm$	0.09	0.07	0.04	0.06
CD at 5%	0.28	0.21	0.13	0.20
Mean		2.14	2.03	

Table 6: Rain water use efficiency (RWUE) during 2018-19 to 2020-21

Treatment	Year			
	2018-19	2019-20	2020-21	Mean
Sub soiling rotation / years				
S_1 - Sub soiling in every year	1.53	1.41	1.58	1.50
S_2 - Sub soiling in alternate years	1.43	1.69	1.61	1.58
S_3 - Sub soiling once in three years	1.43	1.84	1.42	1.56
SE $\pm$	0.09	0.03	0.02	0.04
CD at 5%	0.28	0.09	0.08	0.15
Sub soiling horizontal spacing				
D_1 - Sub soiling every 1.0 m horizontal distance	3.04	1.37	1.50	1.97
D_2 - Sub soiling every 1.5 m horizontal distance	3.32	1.89	1.60	2.27
D_3 - Sub soiling every 2.0 m horizontal distance	3.05	1.72	1.59	2.12
D_4 - Sub soiling every 2.5 m horizontal distance	2.95	1.55	1.42	1.97
D_5 - Sub soiling every 3.0 m horizontal distance	2.67	1.42	1.37	1.82
SE $\pm$	0.09	0.03	0.03	0.05
CD at 5%	0.28	0.09	0.09	0.15
Interaction effects (S x D)				
SE $\pm$	0.10	0.03	0.04	0.05
CD at 5%	0.31	0.09	0.12	0.17
Mean		1.61	1.33	

Mean soil moisture

The data on mean soil moisture (%) at various depth below the ground surface during the crop growth period of 2018-19 to 2020-21 indicated that higher soil moisture % was observed in the treatment of sub soiling at alternate year and sub soling at every year with horizontal spacing of 1.5 m and 2.0 m (Table 7).

Table 7: Mean soil moisture (%) at different depths as influenced by various treatments

Treatment	15 cm depth	30 cm depth	45 cm depth	60 cm depth	Mean
Sub soiling rotation / years					
S_1 - Sub soiling in every year	29	28	28	30	29
S_2 - Sub soiling in alternate year	28	27	29	32	29
S_3 - Sub soiling once in three years	27	27	29	29	28
Sub soiling horizontal spacing					
D_1 - Sub soiling at every 1.0 m horizontal distance	30	29	28	28	29
D_2 - Sub soiling at every 1.5 m horizontal distance	29	29	29	30	29
D_3 - Sub soiling at every 2.0 m horizontal distance	30	29	28	30	29
D_4 - Sub soiling at every 2.5 m horizontal distance	28	27	27	27	27
D_5 - Sub soiling at every 3.0 m horizontal distance	27	27	27	26	27
Mean	28	28	28	29	28

Runoff and soil loss

Treatment wise runoff and soil loss were measured with the help of automatic stage level recorders combined with H-flume and stilling basin during crop growth period (Table 8).

Runoff

On an average a minimum runoff of 178 mm was observed under sub soiling at every year followed by sub soiling in alternate year whereas maximum runoff of 202 mm was observed in sub soiling once in three years. Among sub soiling spacing treatments, minimum runoff of 156 mm was observed in sub soiling at 1.5 m spacing and sub soiling at 2.0 m spacing whereas maximum runoff of 253 mm was observed in subs soiling at 3.0 m spacing.

Table 8 : Mean runoff (mm) and mean soil loss (t ha^{-1}) as influenced by sub soiling schedule and spacing

Treatment	D1 1.0 m	D2 1.5 m	D3 2.0 m	D4 2.5 m	D5 3.0 m	Mean
Runoff, mm						
S_1 - Sub soiling in every year	155	148	150	202	234	178
S_2 - Sub soiling in alternate year	165	159	155	217	252	189
S_3 - Sub soiling once in three years	172	163	162	238	274	202
Mean	164	156	156	219	253	190
Soil loss, t ha^{-1}						
S_1 - Sub soiling in every year	3.05	2.79	2.85	3.56	4.13	3.28
S_2 - Sub soiling in alternate year	2.89	2.32	2.42	3.21	3.85	2.94
S_3 - Sub soiling once in three years	2.81	2.20	2.36	3.26	3.79	2.88
Mean	2.92	2.44	2.54	3.34	3.92	3.03

Soil loss

On an average minimum soil loss of 2.88 tons ha^{-1} was observed under sub soiling at once in three years followed by sub soiling in alternate year whereas maximum soil loss of 3.28 tons ha^{-1} was observed in sub soiling in every year. Among sub soiling spacing treatments, minimum soil loss of 2.44 tons ha^{-1} was observed in sub soiling at 1.5 m spacing followed by sub soiling at 2.0 m spacing whereas maximum soil loss of 3.92 tons ha^{-1} was observed in subs soiling at 3.0 m spacing. Therefore, it is observed that sub soiling in alternate years with a spacing of 1.5 m proved to be the best combination in reducing runoff and soil loss and thus effective in rainwater conservation.

Sub-soiling reduced the runoff but did not significantly reduce the soil erosion after equilibrium had been reached between water application and runoff rates. However, the sub-soiled treatments reduced the amount of runoff for the first runoff event after tillage (Jasa and Dickey,1991). Similar results were obtained in the present study.

Infiltration rate and bulk density

Data indicated that infiltration rate was found higher under the treatment of sub soiling in every year with a spacing of 1.5 m and 2.0 m (Table 9). The bulk density was found lower in the treatment of sub soiling in every year with a spacing of 1.5 m and 2.0 m. It was observed that sub-soiling increased infiltration rate, decreased soil bulk density and increased soil moisture content. The highest reduction of soil bulk density was at 0-40 cm soil depth at shank spaces of 50 and 75 cm. Soil moisture content and wheat grain yield increased by 15% and 21% respectively, with using sub-soiler at 75 cm shanks spaces in comparison with treatment which was not used sub-soiler (Eskandari and Hemmat, 2003). The results of the bulk density obtained in the study confirms with the previous works.

Table 9 : Infiltration rate (cm/hr) and bulk density (g/cm^3) as affected by sub soiling schedule and spacing

Treatment	D1 1.0 m	D2 1.5 m	D3 2.0 m	D4 2.5 m	D5 3.0 m	Mean
Infiltration rate, cm hr^{-1}						
S_1 - Sub soiling in every year	1.66	1.69	1.72	1.56	1.54	1.63
S_2 - Sub soiling in alternate year	1.65	1.66	1.68	1.55	1.53	1.61
S_3 - Sub soiling once in three years	1.62	1.64	1.65	1.52	1.47	1.58
Mean	1.64	1.66	1.68	1.54	1.51	1.61
Bulk density, Mg m^{-3}						
S_1 - Sub soiling in every year	1.27	1.27	1.28	1.29	1.29	1.28
S_2 - Sub soiling in alternate year	1.29	1.28	1.31	1.32	1.32	1.30
S_3 - Sub soiling once in three years	1.35	1.33	1.35	1.35	1.36	1.35
Mean	1.30	1.29	1.31	1.32	1.32	1.31

Energy input, output and energy use efficiency

The energy use efficiency was found to be more in the treatment of sub soiling in alternate year and sub soiling once in three years and lower in the treatment of sub soiling in every year due to more energy input. Similarly, energy output-input ratio was found higher in sub soiling at 1.5 m and 2.0 m spacing (Table 10).

Table 10 : Energy input, energy output and energy use efficiency as influenced by various treatments

Treatment	Energy input	Energy output	Energy use efficiency (output: input ratio)
Sub soiling rotation / years			
S_1 - Sub soiling in every year	7428	70145	9.44
S_2 - Sub soiling in alternate year	6969	69965	10.03
S_3 - Sub soiling once in three years	6650	69622	10.46
Sub soiling horizontal spacing			
D_1 - Sub soiling at every 1.0 m horizontal distance	7927	74585	9.40
D_2 - Sub soiling at every 1.5 m horizontal distance	7458	72363	9.70
D_3 - Sub soiling at every 2.0 m horizontal distance	7245	70265	9.69
D_4 - Sub soiling at every 2.5 m horizontal distance	6962	66258	9.51
D_5 - Sub soiling at every 3.0 m horizontal distance	6725	63366	9.42

Conclusion

Sub soling in alternate year or once in three years with horizontal spacing of 1.5 m or 2.0 m was found suitable for higher grain yield, moisture conservation and higher energy use efficiency.

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