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In-Situ Rainwater Harvesting Strategies on Soil Properties and Crop Performance in Saline and Rainfed Sodic Soils of TBP Command

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June-2013

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Dr. B.V.PATIL
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FOREWORD

I am glad to know that AICRP- Saline Water Scheme, Agricultural Research Station, Gangavati is bringing out a technical bulletin entitled "In-situ rainwater harvesting strategies on soil properties and crop performance in saline and rainfed sodic soils of TBP command".

Dryland agriculture suffers from adequate soil moisture to support plant growth. Paradoxically, saline and sodic soils are also associated with arid and semiarid soils. Therefore, apart from soil moisture limitation, management of dry land salinity/sodicity offers more challenges due to poor soil physicochemical properties, crust formation, germination failure, poor growth and lower yield of crops.

In-situ rainwater harvesting is an important approach to retain excess rainwater as soil moisture for subsequent crop especially in arid and semiarid situations. The effectiveness of in-situ rainwater harvesting technology however, depends on surface features of the land. Manipulation of land surface feature to boost in-situ rainwater harvesting is perhaps a great difficult task. Reclamation of sodic soils wherein the replacement of excess Na on the soil exchange complex with Ca present in soil amendments like gypsum is also a matter of concern in dryland sodic soils. Hence, dissolution and reaction of applied gypsum requires effective in-situ rainwater harvesting field layout or design.

This bulletin addresses the effectiveness of various field layouts or design on in-situ rainwater harvesting, soil properties and crop performances along with benefit:cost ratio.

I complement the scientists for bringing out this bulletin. I hope this publication will be found useful by all those concerned for conservation of soil and water and crop production in rainfed saline and sodic soils.

Date: 12-06-2013

Place: Raichur

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PREFACE

In Karnataka, two third (9.0 mha) of cultivated land is under rainfed which is second largest rainfed area in India next only to the state of Rajasthan. Rainfall has profound influence on agriculture more so in arid and semi-arid regions. Due to small and fractured land holdings rainwater is not being effectively utilized for agriculture but rather causing soil erosion. Hence, under dryland situation rainwater harvesting is an important strategy to conserve rainwater as soil moisture to sustain crop production.

In rainfed areas where annual evapotranspiration exceeds the annual precipitation may also lead to the development of dryland salinity/sodicity and hence poses great challenge for profitable/sustainable crop production. The management of dryland salinity/sodicity requires special skills not only to harvest rainwater but also to facilitate enough soil moisture to leach down excess soluble salts at the root zone. Further, need to provide optimum soil moisture at germination, applied gypsum solubilization and facilitate leaching of sodium out of root zone in saline and sodic soil.

This bulletin entitled "In-situ rainwater harvesting strategies on soil properties and crop performance in saline and rainfed sodic soils of TBP command" presents a comprehensive picture of the suitable in-situ rainwater harvesting strategies including manipulation of surface feature of land into various land layouts.

I compliment the scientists for conducting trials at farm and on farmers' field on arriving at a suitable In-situ rainwater harvesting field layout and bringing the results in the form of a technical bulletin. I hope the information contained in the bulletin is useful for the dryland farmers, extension personnel, planners etc., in the management of salinity/sodicity through effective in-situ rainwater harvesting technique.

Date: 12.06.2013

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Our acknowledgement is incomplete without expressing sincere special thanks to formerly Principal Scientist & Head and scientists associated with this work at AICRP-SAS&USW, Gangavati centre.

AUTHORS

1 Effect of Different In-Situ Moisture Harvesting Practices on Soil Properties and Crop Performance in Salt Affected Soils

1.1 Preamble

Salt affected soils form sizable area in India. An area of 6.73 million ha of salt-affected soils was estimated for the entire country (Sharma et al. 2009). Salt-affected soils are widely distributed in arid and semi-arid regions, where the annual evapotranspiration exceeds the annual precipitation. Primary salinization occurs naturally where the soil parent material is rich in soluble salts, or in the presence of a shallow saline groundwater table. The semi-arid climate particularly in situations with deep black soil cover is unable to leach the soluble salts leading to their accumulation in the weathering zone. Secondary salinization can also occur when significant amounts of poor quality underground water are provided by irrigation. Saline soils are often recognised by the presence of white salt encrustation on the surface and have predominance of chloride and sulphate of Na, Ca and Mg in quantities sufficient to interfere with growth of most crop plants.

Saline soils are characterized with electrical conductivity of soil saturation paste (ECe) of > 4.0 dS/m, pH (1:2.5) <8.5 and exchangeable sodium percentage (ESP) < 15. In case of sodic soil, generally soil pH, ECe and ESP would be > 8.5, <4.0 dS/m and >15 respectively. Saline-sodic soils will have properties intermediatory to saline and sodic soils. Soil salinity and sodicity are the universal problem where management of dryland salinity/sodicity offers more challenges due to poor soil physical properties, crust formation, delayed/reduced germination or complete failure, poor growth, foliar damage and lower yield. Management of salt-affected soils requires a combination of agronomic, engineering practices and socioeconomic considerations. Further, management of dryland salinity offers more challenges due to lack of inadequate leaching of the salts. Management of saline soils under dryland agriculture therefore require special skills to utilize limited available water and harvest rainwater so as to solubilise and leach down soluble salts out of plant root zone or solubilise applied gypsum and facilitate leaching of sodium out of root zone in sodic soil. In other words, land and water management strategies play a key role in dryland agriculture especially under salinized area.

1.2 Land and Water Management

Land and water are basic resources in agriculture. Proper utilization of these resources and their conservation is essential to sustain a high level of production indefinitely. Soil and water conservation emphasize soil erosion control, moisture conservation, land development, irrigation, groundwater development and wells, agricultural drainage as well as watershed management. The rainfall in arid and semiarid regions is not only scanty but also erratic therefore rainfall is the most controlling factor in dryland agriculture. Effective utilization of rainfall through conservation practices is needed for which effective land layouts for rain water harvesting are very crucial. In this regard, experiments were carried out at research station and on farmers' field to evaluate the effect of different in-situ rain water harvesting practices and land layouts on soil salinity, moisture conservation and sunflower crop performance under saline soils.

1.3 Technique

A field experiment was carried out for three years during 2003-04 to 2005-06, to evaluate the effect of different in-situ rain water harvesting practices and land layouts on soil salinity, moisture retention and performance of sunflower under saline soils at Agriculture Research Station Gangavati, Karnataka. The ECe of the experimental site varied from 6.6 to 7.2 dS/m before the initiation of the experiment. The treatment comprised of compartment bunding, deep ploughing, bedding, ridges and furrows and tied ridges and furrows. These were compared with traditional land layout of flatbed as control. The experiment was laid out in randomised block design with four replications. Different in-situ rain water harvesting practices and land layouts were made during the beginning of monsoon (June) and were allowed to harvest sufficient rain water to facilitate conservation of moisture and leaching of salts. During 2004, 2005 and 2006 the amount of rainfall received was 466, 498 and 442 mm respectively. The sunflower crop was sown in September and fertilised with 60:33:50 kg NPK/ha.

1.4 Results

At germination stage surface soil (0-15 cm) had the highest moisture content of 35.7, 35.5 and 35.3% in the tied ridges and furrows land layout in 2003-04, 2004-05 and 2005-06 respectively (Table 1). Further, soil moisture content was 14.8, 11.6, 7.4, 5.5, 4.5% more in the tied ridges and furrows, ridges and furrows, bedding compartment, bunding and deep ploughing land layouts respectively during 2003-04. Similar trends were observed during 2004-05 and 2005-06. The three years mean values (2003-04 to 2005-06) also revealed that soil moisture content at surface soil was 21.0, 17.6, 12.2 and 11.7% more than control (Fig. 1) at tied ridges and furrows, ridges and furrows, bedding, compartment bunding and deep ploughing respectively. At seed setting stage 15.3% more moisture was recorded in tied ridges and furrows as compared to control, followed by ridges and furrows (14.3%), compartment bunding (4.9%), deep ploughing (4.5%) and bedding (1.8%) during 2003-04. The three years mean values (2003-04 to 2005-06) also revealed that soil moisture content at seed setting in surface soil was 25.7, 17.4, 17.0 and 10.8% more than control at tied ridges and furrows, ridges and furrows, bedding, compartment bunding and deep ploughing respectively.

Table 1. Effect of different in-situ rain water harvesting practices on moisture content and soil salinity

Year	Treatment	Moisture Content (%)		Soil Salinity (dS/m)		
		At germination	At seed setting	Initial	At germination	At harvest
2003-04	Compartment bunding	32.8	23.4	7.4	5.8	7.8
	Deep ploughing	32.5	23.3	6.7	5.4	8.2
	Bedding	33.4	22.7	6.6	5.1	6.7
	Ridges and furrows	34.7	25.5	7.6	5.8	6.3
	Tied ridges and furrows	35.7	25.7	7.6	5.5	5.8
	Control	31.1	22.3	7.2	6.6	9.7
2004-05	Compartment bunding	32.6	22.6	8.2	6.1	8.8
	Deep ploughing	29.6	19.7	9.0	7.6	9.9
	Bedding	33.4	22.8	8.1	5.8	8.6
	Ridges and furrows	34.1	23.6	7.7	5.5	8.0
	Tied ridges and furrows	35.5	25.0	7.9	5.0	7.1
	Control	27.5	18.2	9.2	8.5	10.9
2005-06	Compartment bunding	32.9	22.2	7.9	5.2	7.4
	Deep ploughing	31.9	21.6	8.5	6.7	8.7
	Bedding	33.6	23.0	8.3	5.1	7.9
	Ridges and furrows	34.7	24.2	8.2	5.0	6.9
	Tied ridges and furrows	35.3	25.1	8.3	4.7	6.5
	Control	29.4	17.8	9.5	7.8	9.3

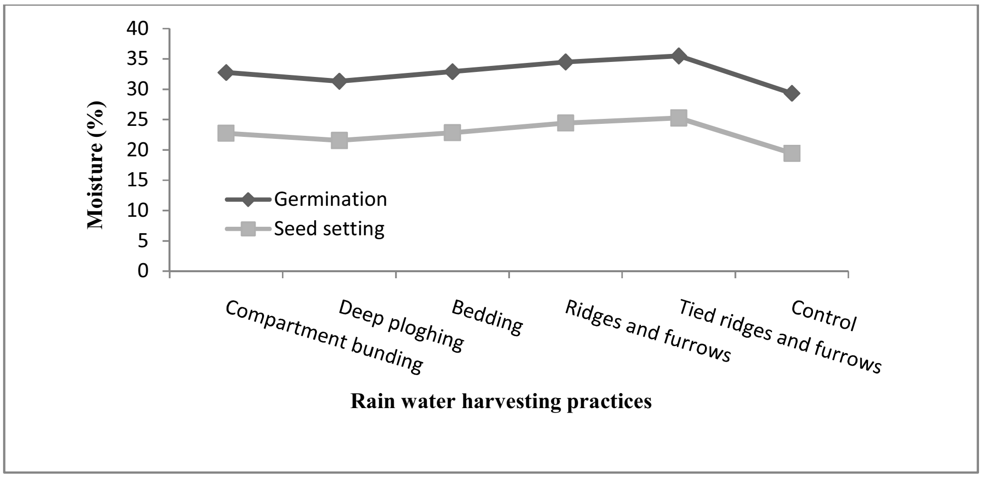

Fig. 1. Effect of different in-situ moisture harvesting practices on mean soil moisture content (mean of 3 years)

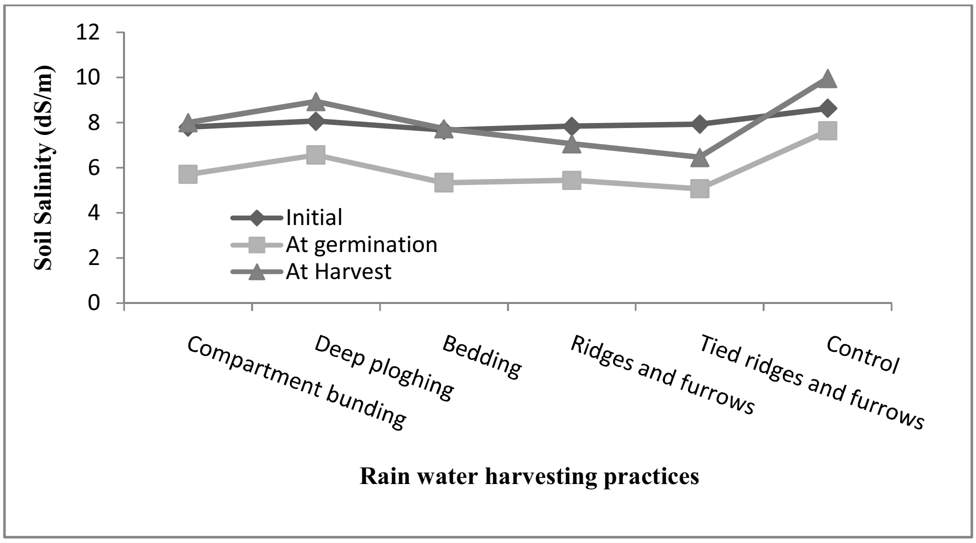

Fig. 2. Effect of different in-situ moisture harvesting practices on mean soil salinity (mean of 3 years)

The initial soil salinity was reduced at germination stage (Table 1) probably due to leaching of salts by rain water in all the land layouts. Maximum decrease in soil salinity to the extent of 27.6, 36.7 and 43.3% compared to initial was observed in tied ridges at germination stage due to leaching of salts by the harvested rainwater during 2003-04, 2004-05 and 2005-06, respectively. The soil salinity observed at germination stage however was increased again at harvesting stage of the crop in all the land layouts probably due to capillary rise as evaporative demand increases during the crop growth. However, the per cent increase in soils salinity was more in control (32, 22 and 16% during 2003-04, 2004-05 and 2005-06 respectively) than the other land layouts. The soil salinity at harvest was less in tied ridges and furrows as compared to initial soil salinity during all the years, which was not observed in the other land layouts.

Germination percentage, plant height and head diameter were significantly influenced by the different in-situ moisture harvesting practices and land layouts (Table 2) during all the years of experimentation. Mean of three years data showed that the highest (94.5%) germination percentage was observed in bedding method followed by ridges and furrows (89.9%), tied ridges and furrows (89.3), compartment bunding (84.7), deep ploughing (81.3) and was least in control (73.4). Significantly higher plant height and head diameter was recorded in tied ridges and furrows, followed by ridges and furrows, bedding, compartment bunding, deep ploughing and least in control. Consequently, the seed weight (100 seeds) was also highest in tied ridges & furrows (145.9g) which was however on par with ridges, furrows & bedding treatments.

The seed yield was significantly influenced by the rainwater harvesting practices and land layouts (Table 3). Highest pooled seed yield (0.97 t/ha) was observed in the tied ridges and furrows, followed by ridges and furrows (0.93 t/ha), bedding (0.90 t/ha), compartment bunding (0.77 t/ha), deep ploughing (0.75 t/ha) and the least (0.53 t/ha) in control. The highest yield in tied ridges and furrows is attributed to higher soil moisture and lower salinity that resulted in increased plant height and production of bigger ear heads that in turn lead to increased yield. The results are in agreement with the findings of Habbara *et al* (2005)

The gross returns, net returns and B:C was significantly influenced by different in-situ rain water harvesting practices and land layouts (Table 3). The highest pooled gross returns (Rs 21,303/ha), net returns (Rs 11,644/ha) and benefit : cost ratio (2.18) was observed in tied ridges and furrows, followed by ridges and furrows, bedding, compartment bunding, deep ploughing and least in control.

Table 2. Effect of different in-situ rain water harvesting practices on germination and yield parameters

Treatment	Properties			
	2003-04	2004-05	2005-06	Pooled
		Germination (%)		
Compartment bunding	84.5	83.5	84.0	84.7
Deep ploughing	82.5	81.5	81.7	81.3
Bedding	94.7	94.5	94.2	94.5
Ridges and furrows	91.0	90.2	88.5	89.9
Tied ridges and furrows	93.0	91.7	90.7	89.3
Control	72.5	74	73.7	73.4
CD (P=0.05)	7.69	7.5	6.8	4.8
		Plant height (cm)		
Compartment bunding	124.2	120.5	164.9	136.5
Deep ploughing	123.1	117	162.4	134.2
Bedding	127	124.1	168.2	139.8
Ridges and furrows	132.1	127.6	170.2	143.3
Tied ridges and furrows	135.4	130.4	172	145.9
Control	118.4	113.7	149	127.9
CD (P=0.05)	10.24	9.4	9.08	7.09
		Ear head diameter (cm)		
Compartment bunding	13.1	12.2	13	12.8
Deep ploughing	13	12	12.7	12.5
Bedding	14.4	13.4	13.3	13.7
Ridges and furrows	14.6	13.6	13.4	13.9
Tied ridges and furrows	14.8	13.7	13.8	14.1
Control	11.4	10.6	9.1	10.4
CD (P=0.05)	1.06	0.95	1.1	0.71
		100 seed weight (g)		
Compartment bunding	124.2	120.5	164.9	136.5
Deep ploughing	123.1	117	162.4	134.2
Bedding	127	124.1	168.2	139.8
Ridges and furrows	132.1	127.6	170.2	143.3
Tied ridges and furrows	135.4	130.4	172	145.9
Control	118.4	113.7	149	127.9
CD (P=0.05)	10.24	9.4	9.08	7.09

Table 3. Effect of different in-situ rain water harvesting practices on sunflower yield and economics

Treatment	Year			
	2003-04	2004-05	2005-06	Pooled
		Yield (tonnes/ha)		
Compartment bunding	0.71	0.71	0.9	0.77
Deep ploughing	0.70	0.69	0.86	0.75
Bedding	0.86	0.81	1.03	0.90
Ridges and furrows	0.9	0.83	1.05	0.93
Tied ridges and furrows	0.94	0.87	1.1	0.97
Control	0.53	0.51	0.56	0.53
CD (P=0.05)	0.1	0.08	0.08	0.06
		Gross return (Rs/ha)		
Compartment bunding	14247	15807	21522	17392
Deep ploughing	13932	15257	20694	16702
Bedding	17370	17869	24894	20120
Ridges and furrows	18120	18282	25344	21006
Tied ridges and furrows	18937	19178	26316	21303
Control	10620	11336	13644	11740
CD (P=0.05)	2041	1958	2021	1539
		Net returns (Rs/ha)		
Compartment bunding	5097	6507	12022	7876
Deep ploughing	4832	5957	11194	7328
Bedding	8210	8569	15394	10724
Ridges and furrows	8620	8582	15344	10841
Tied ridges and furrows	9337	9378	16216	11644
Control	4585	2535	4644	3066
CD (P=0.05)	3441	1958	2022	1502
		Benefit : cost ratio		
Compartment bunding	1.56	1.7	2.26	1.84
Deep ploughing	1.53	1.64	2.18	1.77
Bedding	1.91	1.92	2.61	2.14
Ridges and furrows	1.97	1.88	2.53	2.15
Tied ridges and furrows	1.97	1.97	2.6	2.18
Control	1.23	1.29	1.51	1.34
CD (P=0.05)	0.22	0.2	0.22	0.18

1.5 Summary

Tied ridges and furrows land layout was found to be superior followed by ridges and furrows with respect to soil moisture conservation and reduction in soil salinity. Accordingly, the seed yield and B:C ratio was also found to be superior in case of tied ridges and furrows method of in-situ rainwater harvesting land layout in saline soil (as compared to other land layout.

2. In-Situ Rainwater Harvesting Strategies on Soil Properties and Crop Performance in Rainfed Sodic Soils of TBP Command (in Farmers' Field)

2.1 Preamble

The addition of salts to the soil may result in saturating the soils exchangeable complex with sodium (Na). The process of progressively increasing the Na saturation of the soils exchange complex is called sodication and the exchangeable sodium percentage is generally >15. The soils formed are called sodic soils, solods, solonetz, or black alkali soils. Unlike saline soils, sodic soils contain measurable to appreciable quantities of sodium carbonate which imparts to these soils a high pH, always more than 8.2 when measured on a saturated soil paste and up to 10.8 or so when appreciable quantities of free sodium carbonate are present and undergo physical degradation of soil properties. Under field conditions after rainfall or irrigation, sodic soils typically have convex surfaces. The soil a few centimetres below the surface may be saturated with water while at the same time the surface is dry and hard. Upon dehydration cracks 1-2 cm across and several centimetres deep form and close when wetted. The cracks, generally, appear at the same place on the surface each time the soil dries unless it has been disturbed mechanically.

Gypsum ($CaSO_4.2H_2O$) is an amendment generally used for the reclamation of a sodic soil wherein upon dissolution in soil solution, the excess Na on the soil exchange complex is replaced by calcium (Ca) of gypsum. The dissolution of gypsum as well as for the reaction to replace Na, soil moisture is crucial. Under rainfed situation, in-situ rainwater harvesting would greatly compliment the purpose of adding gypsum to the sodic soil. Therefore, to study the effect of different in-situ moisture harvesting practices on soil properties and crop performance of sunflower and to find out the suitable moisture harvesting methods for better rainwater harvesting practices in combination with gypsum application this study was undertaken.

2.2 Technique

A field experiment was initiated during 2007-08 on sodic Vertisol with ESP 23.1 and maximum ECe of 2.2 dS/m at Kyarihal village, near ARS, Gangavati and continued till 2010-11. The different in-situ moisture harvesting practices were constructed during the beginning of monsoon (June) and required gypsum was applied @ 75 and 50% of gypsum requirement (GR). Sunflower (var. Ganga Kaveri) was sown during rabi (September) and the performance of crop was evaluated. The amount of rainfall received during the years of experimentation was 442.4, 172.9, 720.4, 301.3, 914.9, and 421 mm during 2006, 2007, 2008, 2009, 2010 and 2011 respectively.

Treatment Details

Design: RBD Replications: 3 Crop: Sunflower Variety: Ganga-kaveri

T_1-Deep ploughing + 75% GR

T_2-Deep ploughing + 50% GR

T_3-Tied Ridges + 75% GR

T_4-Tied Ridges + 50% GR

T_5-Compartment bunding + 75% GR

T_6-Compartment bunding + 50% GR

T_7- Flat bed + 75% GR

T_8- Flat bed + 50% GR

T_9-Control (Flat bed without gypsum)

2.3 Results

Pooled data of four years on the effect of different land management practices on soil moisture content, ESP and soil salinity (Table 1). Indicated that at germination the highest soil moisture content (36%) was observed in tied ridges with 75% GR and tied ridges with 50% GR followed by compartment bunding with 75% GR (35.3%). Flat bed (0, 75 and 50% GR) treatments were not effective in conserving/harvesting rain water as there was lowest soil moisture content (30.3 to 30.7%) compared to others. Similar trend was observed at seed setting stage as well wherein tied ridges with 75% GR and tied ridges with 50% GR maintained the highest soil moisture content. Though 5-6 per cent variation in soil moisture content was observed, there was not much variation in soluble salts concentration in the soil. The ECe (dS/m) was within 2 dS/m in all the treatments at the time of sowing indicating that the soils are non-saline (< 4 dS/m) at the time of sampling. The exchangeable sodium percentage however was different among the treatments and except the control; ESP was less than the initial value i.e., 23.1. Among the treatments, compartment bunding with 75% GR (T_1) and tied ridges with 75% GR (T_3) treatments had the least (16.1 and 16.4) ESP levels compared to other treatments. Flat bed without gypsum (control) had the highest ESP (22.5). Higher soil moisture content in T_1 and T_3 coupled with higher rates (75%) of gypsum application might have resulted in reducing the soil ESP to the greatest extent compared to other treatments.

Table 1. Soil moisture content, soil salinity and ESP as influenced by different moisture conservation practices and amendment application.

Treatments	Soil moisture content (%)		ECe (dS/m)	ESP
	At Germination	At Seed setting		
Compartment bunding with 75% GR	35.3	28.0	1.93	16.1
Compartment bunding with 50% GR	33.7	27.9	1.75	18.3
Tied Ridges with 75% GR	36.0	30.0	1.78	16.4
Tied Ridges with 50% GR	36.0	29.5	1.78	19.0
Deep ploughing with 75% GR	34.4	27.8	1.80	17.6
Deep ploughing with 50% GR	33.2	27.7	1.70	19.8
Flatbed +75% GR	30.3	25.2	1.75	21.5
Flat bed + 50% GR	30.6	25.0	1.83	21.8
Flat bed without gypsum (control)	30.7	25.0	1.83	22.5

Table 2. Effect of different moisture conservation practices and amendment application on growth and yield of sunflower.

Treatments	Germination (%)	Head diameter (cm)	Plant height (cm)	100 seed weight (g)	Yield (t/ha)
Compartment bunding + 75% GR	90.4	12.2	145.3	4.7	0.89
Compartment bunding + 50% GR	88.5	11.6	143.5	4.6	0.86
Tied Ridges + 75% GR	93.9	14.0	155.1	4.8	1.04
Tied Ridges +50% GR	92.6	13.7	152.3	4.7	1.00
Deep Ploughing+75%GR	88.7	12.1	143.6	4.6	0.87
Deep Ploughing+50%GR	87.1	11.8	141.4	4.5	0.83
Flat bed + 75% GR	81.4	10.5	128.3	3.6	0.74
Flat bed + 50% GR	79.4	10.1	127.8	4.4	0.69
Flat bed without gypsum (Control)	75.2	9.4	125.7	4.5	0.58
CD (P=0.05)	90.4	12.2	145.3	4.7	0.07

As a result, pooled data (four years) on germination percentage, head diameter, plant height and 100 seed weight (Table 2) also revealed that the higher germination percentage (93.9) was observed in tied ridges with 75% GR followed by tied ridges with 50% GR (92.6) and least in control (flat bed, 75.2) treatment. Highest plant height (155.1 cm) and head diameter (14.0cm) were also observed in tied ridges with 75% GR followed by tied ridges with 50% GR and least in control treatment. Consequently, seed yield of sunflower was significantly higher (1.04 t/ha) in the tied ridges with 75% GR (Table 2) which was on par with the tied ridges with 50% GR (1 t/ha). The next best treatment remained compartment bunding with 75% GR (0.89 t/ha) followed by deep ploughing with 75% GR (0.87 t/ha), compartment bunding with 50% GR (0.86 t/ha), deep ploughing with 50% GR (0.83 t/ha), flat bed with 75% GR (0.74 t/ha) and flat bed with 50% GR (0.69 t/ha). The treatments T_1, T_2, T_5 and T_6 were on par at each other. Significantly lowest yield of 0.58 t/ ha was recorded in the control (flat bed without gypsum application).

2.4 Economic analysis

As shown in Table 3, the highest gross return (Rs. 31200 /ha), net return (Rs. 21500 /ha) and benefit: cost ratio (3.3) was observed in tied ridges and furrows with 75 % GR which may be attributed to significantly increased seed yield in this treatment over control. Though the net return in T_4 was slightly less than T_3, the B:C ratio was found to be similar (3.3) to that of T_3. The least gross return (Rs. 17550 /ha), net return (Rs. 9050 /ha) and benefit:cost ratio (2.1) was observed in control treatment.

Table 3: Gross return, net return and B:C ratio as influenced by different moisture harvesting practices and amendment application

Treatments	Gross return	Net return	B:C Ratio
Compartment bunding + 75% GR	26700	17000	2.8
Compartment bunding + 50% GR	25725	16425	2.8
Tied Ridges + 75% GR	31200	21500	3.3
Tied Ridges +50% GR	29925	20625	3.3
Deep Ploughing+75%GR	26175	16475	2.8
Deep Ploughing+50%GR	24825	15525	2.7
Flat bed + 75% GR	22275	12575	2.4
Flat bed + 50% GR	20850	11550	2.3
Control	17550	9050	2.1

2.5 Summary

Soil moisture is an important factor affecting crop yields in rainfed agriculture. In addition, soil sodicity affects crop performance including germination and the availability of essential plant nutrients. For enhancing yield and retention of rain water in soil as soil moisture through constructing tied ridges in the field prior to the onset of south-west monsoon and reducing soil ESP through application of gypsum @ 50% gypsum requirement was found to be ideal under rainfed sodic Vertisols in TBP command for sunflower.

3. References

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