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FOREWORD

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Water is one of the most critical inputs for agriculture and various human needs. In the present climate change situations, lot of inter-annual variability in precipitation is observed that results in lower crop yields and hence adaptation of various *in-situ* rainwater harvesting techniques is inevitable to sustain crop yields in long run. Rainfed agriculture in semi-arid regions of the world and especially in the Vertisols of Semi-Arid Tropic (SAT) regions of South India, is highly influenced by extreme variability in rainfall (amount and distribution), few rainfall events of high-intensity and increasing number of dry spells and droughts.

Further, due to low infiltration of black soils nearly 10 to 30% of rainfall goes as runoff. In the Northern dry zone of Karnataka and adjacent districts of Anantapur and Kurnool of Andhra Pradesh the rainfall varies from 500 to 650 mm and is ill distributed. In a decade, four severe drought, two drought, two normal and two above normal rainfall years have been reported in the region. Hence, adopting moisture conservation practices especially suitable tillage practices with application of organic amendments along with fertilizers is one of technologies available for reducing runoff, conserving rainwater *in-situ* in the soil profile. This practice improves soil-water and nutrient availability to the crops and ensure sustainability of crop yields under present climate change scenario. In the Vertisols of South India soils should be deep tilled to18-20 cm once in two years followed by two harrowing once in June, second time in August and two intercultivations at 25 and 40 days after sowing with one hand-weeding along with integrated nutrient management conserves the top fertile soil and improves the soil moisture and nutrient availability to the crops and produces higher crop yields.

November, 2021
Dehradun

(M. Madhu)

CONTENTS

1.0 INTRODUCTION

Soil and water are the two important natural resources that needs to be conserved during rainy and post-rainy seasons and be used judiciously for higher yields especially in rainfed Vertisols of South India. Drylands, in these regions, are prone to erosion, especially during rainy season (June to September) as no crops are cultivated and bears no vegetative cover for longer periods of time. Faulty land and crop management practices resulted in enormous soil loss and estimated average annual soil loss in the country is 1535 t km^{-2} $year^{-1}$ (Sharada and Ojasvi, 2016) and in total it accounts for 5.37 to 8.40 Mt of nutrients loss which aggravate soil degradation process in India (Sharada *et. al.,* 2017). Degradation can be reduced by adopting suitable erosion control measures both at terrace and inter-terrace levels that conserves rainwater and top fertile soil. Vertisols in Semi-Arid Tropic (SAT) region of South India are clayey (45% to 60% clay content), with poor soil structure, low in infiltration rate (0.8 mm hr^{-1}), highly erodible, alkaline in reaction (around 8.5 pH) and cracks heavily on drying. Due to poor soil physical conditions, these soils are problematic and can be cultivated only in narrow range of soil moisture content. Moreover, mean annual rainfall in the region is low (517.6 mm mean average of 1956 to 2020) and erratic with uneven distribution (Anon., 2021). Due to low intake rate of these soils, nearly 10% to 30% of annual rainfall goes as runoff. Frequent droughts and recurrent crop failures have become epidemic in the region which is affecting the socio-economic conditions of farmers (Mishra and Patil, 2008). Hence, the farmers in the dryland black soil regions of South India should aim to harvest every drop of rainwater *in-situ* through various agronomic measures which include tillage operations, *in-situ* moisture conservation practices, mulching, vegetative barriers, application of organic materials, crop residue management and alternative cropping systems with better advantage of reducing surface runoff (water, soil and nutrient losses) and increase soil profile water and nutrient content for better crop growth and higher crop productivity.

Therefore, adopting appropriate tillage practices along with integrated nutrient management through application of both organic materials and fertilizers conserves the rainwater *in-situ*, recharges soil profile, reduces loss of top fertile soil and increases the soil water and nutrients availability, thereby, enhance crop productivity on sustainable basis in the form of climate resilient agriculture.

The technology of conventional tillage, which includes a deep tillage once in two years after harvest of *rabi* (Post-rainy season) crops followed by two-three harrowing and two intercultivations and one hand weeding (CT) with integrated nutrient management through organic materials and fertilizers can easily be adopted by the farmers in the medium to deep black soils of Deccan Plateau region of South India.

2.0 EXISTING PRACTICE

- In medium to deep black soils with <750 mm annual rainfall in the SAT region of South India, generally, lands are kept fallow during rainy *(kharif)* season during which erosion of top fertile soil is very common. During *rabi* crops like sorghum, sunflower, chickpea, safflower and coriander are cultivated.

Plate 1: Various tillage practices being adopted in Vertisols of South India; mouldboard ploughing (a), tractor drawn blade harrowing (b), bullock drawn blade harrowing (c) and bullock drawn hoeing (d).

- Low infiltration rate (<0.8 mm hr^{-1}) coupled with low or nil crop residues application leads to more runoff and causes insufficient soil moisture in the profile.
- Hence, in medium to deep black soils with <750 mm annual rainfall in the SAT region of South India, a deep tillage (18-20 cm) is done once in three-four years after harvest of winter season crops during February-March followed by two harrowing (June end to August end), two intercultivations (25 and 40 days after sowing) and one hand weeding with integrated nutrient management is a common practice being adopted by the farmers in the region (Plate 1). In the year where deep tillage is not done a shallow tillage with blade harrow (6-8 cm) is done during February-March.
- In shallow to medium black soils during normal to above normal rainfall years, short duration pulse crops like greengram and cowpea are cultivated during *kharif* season. During *rabi* season sorghum, chickpea, sunflower, safflower and coriander crops being cultivated.

3.0 IMPROVED TECHNOLOGY DETAILS

- Technology involves mouldboard ploughing with a tractor to a depth of 18-20 cm once in two years soon after harvest of *rabi* crops during February or after first showers during April/May followed by two criss-cross harrowing (10-12 cm) and leveling done during first week of July and last week of August, respectively *i.e.* prior to sowing of *rabi* crops.
- After *rabi* crops are sown, two hoeing, *i.e.* inter-row cultivation, 5-7 cm deep with a bullock drawn blade hoe at 25 and 40 days after sowing and one manual hand weeding at 30 days after sowing in different *rabi* crops were done to reduce soil moisture loss, giving physical support to the plants as well to control of unwanted plants (weeds) that are grown in the fields.
- In succeeding year when mouldboard ploughing was not done, tillering (12-15 cm) with tractor is generally done during May.
- Application of green manures like fresh *Leucaena* lopping (if available) at 5.0 t ha^{-1} or farmyard manure at 2.5 t ha^{-1} is done manually during last week of August to first week of September. These organic amendments are incorporated manually in top 7.5 cm depth of soil to supply Nitrogen *i.e.* 50% of recommended rate of Nitrogen and other nutrients.

The rest 50% of Nitrogen is applied through urea at sowing in the normal rainfall years. During above normal rainfall year, Nitrogen top dressing is done by applying additional 20 kg N ha^{-1} through urea (50% of the recommended rate of Nitrogen) at 30 days after sowing to sorghum and sunflower crops.

- Deep tillage along with organic amendments incorporation provides more opportunity time for rainwater to infiltrate into the soil and wet soil profile completely for early sowing of winter crops. In addition, deep tillage with two harrowing and inter cultivation conserves top soil from erosion, reduces the evaporation and crack formation due to soil mulching, produces better crop growth with higher crop yields as compared to the reduced tillage practices.

4.0 PERFORMANCE OF TILLAGE TECHNOLOGY IN BLACK SOILS

Physical properties of soil

- At Vijayapura in medium to deep black soils, deep tillage once in two years produced higher infiltration rate by 21% and 59% compared to medium and shallow tillage practices. Even bulk density reduced by 7% in deep tillage compared to shallow tillage. Improved soil physical properties resulted in higher soil water conservation in the top 60 cm soil profile with deep tillage compared to medium and shallow tillage (Table 1).
- Deep tillage created favorable soil physical properties and conserved greater soil moisture and increased nutrient availability in the root zone resulted in better root development of 67 cm of root length compared to 57.6 cm in medium tillage and 41.7 cm in shallow tillage (Table 1).

Table 1: Effect of tillage practices on infiltration rate, bulk density and root growth of winter sorghum in the Vertisols of Vijayapura.

Tillage practices	Infiltration rate (mm hr^{-1})	Bulk density (Mg m^{-3})	Root length (cm)
Deep tillage	9.7+0.6	1.23+0.03	67.0
Medium tillage	8.0+0.5	1.27+0.02	57.6
Shallow tillage	6.1+0.7	1.31+0.05	41.7

(Source: Patil and Sheelavantar, 2006)

- Deep tillage produced 27% higher winter sorghum yield over medium and 57% over shallow tillage during drought year (Year I) as compared to increase in yield by 17% and 34% over medium and shallow tillage during normal year (Year II) in the medium to deep black soils of Bijapur (present, Vijayapura) thus indicating greater effect of deep tillage on grain yields during drought year as compared to normal year. Mean winter sorghum grain yield increase varied from 22% to 45% in deep tillage compared to medium and shallow tillage practices (Table 2).

Table 2: Effect of tillage practices on grain yield of winter sorghum in the Vertisols of Bijapur (present, Vijayapura), Karnataka.

Tillage practices		Grain yield (kg ha^{-1})	
	Year I	Year II	Pooled
Deep tillage	1919	1835	1877
Medium tillage	1509	1562	1635
Shallow tillage	1223	1368	1296
S.Em+	42	47	32
LSD *(P=0.05)*	164	186	103

(Source: Patil and Sheelavantar, 2006)

Grain yield

- In Vertisols of Ballari, the increase in winter sorghum grain yield was higher with conventional tillage as compared to reduced tillage (10%) and low tillage (19%) during severe drought year than the normal year wherein conventional tillage produced 7% and 15% higher grain yield over reduced tillage and low tillage, respectively, whereas during mild drought year the yield variation among tillage practices was (5% to 8%) with reduced and low tillage compared to conventional tillage practices (Table 3).

Table 3: Grain yield of winter sorghum as influenced by tillage practices during different rainfall situations

Tillage practices	Grain yield (kg ha^{-1})		
	Severe drought year	Mild drought year	Normal rainfall year
Conventional tillage	358	1741	2221
Reduced tillage	325	1652	2074
Low tillage	302	1610	1936

(Source: Patil, 2013; Patil *et. al.,* 2016)

Economics

- Deep tillage with application of *Leucaena* loppings at 2.5 t ha^{-1} with N application at 50 kg ha^{-1} produced net additional profit of ₹ 7,190 ha^{-1} in black soils of Vijayapura over farmer's practice.

Water use efficiency

- Among the tillage practices, the variation in water use efficiency was greater during severe drought year (9% to 14%) compared to normal rainfall situations (3% to 7%) with reduced and low tillage compared to conventional tillage indicating water is better utilized for production of winter sorghum grain yield during severe drought year compared to normal rainfall situations in Vertisols of Ballari (Table 4).

Table 4: Water use efficiency of winter sorghum as influenced by tillage practices during different rainfall situations

Tillage practices	Water use efficiency (kg ha^{-1} mm^{-1})		
	Severe drought year	Mild drought year	Normal rainfall year
Conventional tillage	2.21	7.90	8.76
Reduced tillage	2.01	7.67	8.49
Low tillage	1.87	7.65	8.20

(Source: Patil and Sheelavantar, 2006; Patil, 2013; Patil *et. al.,* 2016)

- During winter season, in the medium to deep black soils of Ballari improved conventional tillage produced 13% and 32% greater sunflower seed yields and 15% and 9% and higher straw yields over reduced and low tillage practices, respectively (Table 5).

Table 5: Grain and straw yield of sunflower as influenced by tillage practices

Tillage practices	Grain yield (kg ha^{-1})			Straw yield (t ha^{-1}) pooled	Oil yield (litres ha^{-1}) pooled
	2007-08	2008-09	Pooled		
Conventional tillage	1610	1229	1420	1.60	535.2
Reduced tillage	1328	1175	1252	1.47	499.7
Low tillage	1211	938	1075	1.39	386.4

(Source: CSWCRTI 2008 and 2009)

- Improved conventional tillage produced 7% and 39% greater sunflower oil yield per ha compared to reduced and low tillage practices in the medium to deep Vertisols of Ballari during winter season (Table 5).

Demonstration at farmers field

- Demonstrations of deep tillage with integrated nutrient management during 2007-08 and 2008-09 in farmers' fields in Ballari district of Karnataka and Kumool district of Andhra Pradesh produced 25% higher grain yield in *rabi* sorghum, 23% in chickpea and 25% in sunflower, whereas water use efficiency increase varied from 24% (chickpea) to 26% (sorghum and sunflower) compared to the tillage practices adopted in farmers fields (Fig. 1 and 2).

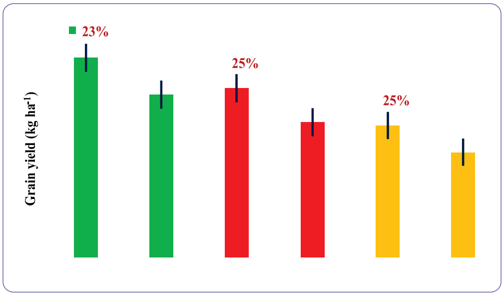

Fig. 1: Grain yield (kg ha^{-1}) as influenced by improved tillage practices

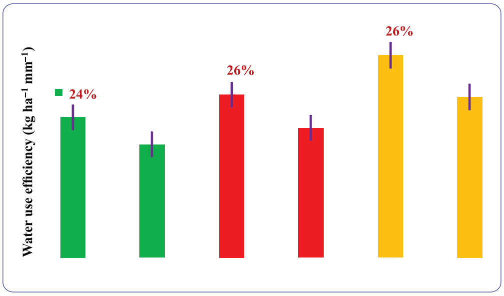

Fig. 2: Water use efficiency (kg ha^{-1} mm^{-1}) as influenced by improved tillage practices

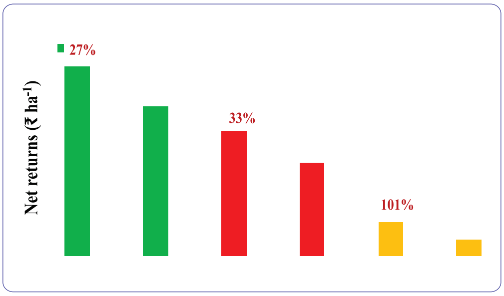

Fig. 3: Net returns (₹ ha^{-1}) as influenced by improved tillage practices

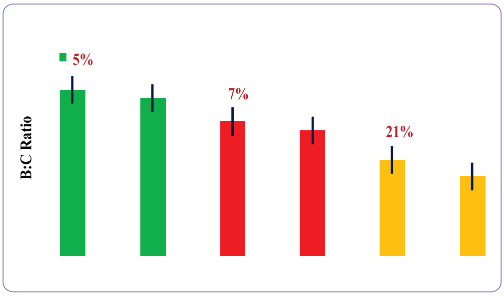

Fig. 4: B:C Ratio as influenced by improved tillage practices

- The improved practice of conventional tillage with INM produced higher net returns varying from 27% in chickpea to 33% in sunflower and 101% in winter sorghum compared to the farmer's practice of tillage and INM being adopted in the region (Fig. 3).

- The B:C ratio increased from 5% in chickpea to 7% in sunflower and as high as 21% in winter sorghum with improved conventional tillage and INM compared to the farmers practice being adopted in the Vertisols of Karnataka and Andhra Pradesh (Fig. 4).

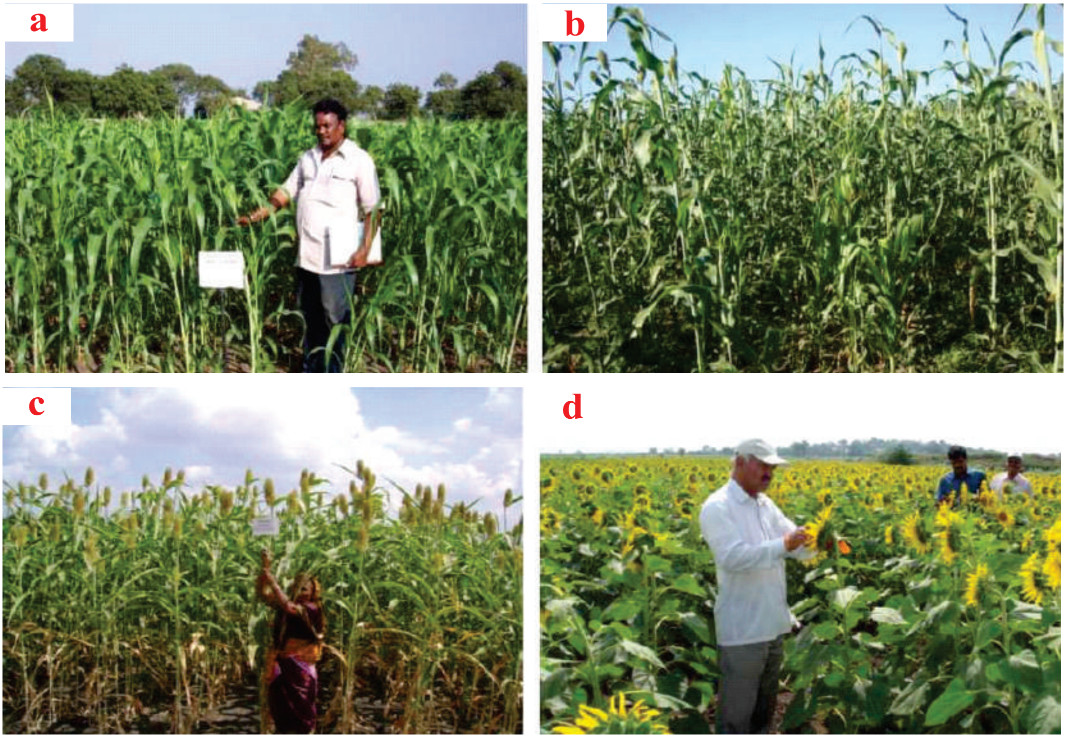

Plate 2: Winter sorghum (a-c) and sunflower (d) crops with improved tillage and nutrient management practices in the Research Farm, Ballari.

Plate 3: Crop performance in the farmers fields with adoption of improved tillage and integrated nutrient management practices.

- The impact of improved conventional tillage practices with integrated nutrient management (application of combination of chemical fertilizers, farmyard manure and organic amendments) in the black soils was greater during sub-normal/drought rainfall years compared to normal and above normal-rainfall years. This was attributed to higher rainwater conservation and storage of soil moisture in the soil profile with higher nutrient availability.

5.0 IMPACT AND UPSCALING

- The technology of improved tillage practices has greater scope for adoption in sunflower and winter sorghum crops cultivated on medium to deep black soils of Akola and Sholapur districts of Maharashtra, Vijayapura, Bagalkot, Gadag, Koppal, Haveri, Dharwad, Chitradurga and Ballari districts of Karnataka, Kurnool, Anantapur and Kadapa districts of Andhra Pradesh, Mehabubnagar district of Telangana and Dindigul district of Tamil Nadu in the Semi-Arid tropical region receiving less than 750 mm mean annual rainfall.
- The technology upscaling in the region requires on farm demonstrations by Agricultural Department, Krishi Vigyan Kendras (KVKs), Agricultural Technology Management Agency (ATMA) and Non-Governmental Organizations (NGOs).
- Further, establishment of Government supported, Custom Hiring Farm Machinery Service Centres will ensure timely availability of machinery and equipment for adoption of technology and sustains crop yields in SAT Vertisols.

Crop performance in the Research Farm with adoption of improved tillage and integrated nutrient management practices

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