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RESEARCH PAPER

Restoration of rainwater techniques and fertilizer split application methods on yield and total nutrient uptake of rainfed sorghum under vertisols (*Typic haplusterts*)

V. Sanjivkumar*, K. Baskar[1], S. Manoharan[1], M. Manikandan[1], A.Solaimalai[1] **and** G. Ravindrachary[2]
Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Agricultural Research Station, Kovilpatti (T.N.) India
(Email: sanjivkumarv@rediffmail.com)

Abstract : In rainfed situation soil erosion, low plant nutrients availability and soil moisture stress during cropping season are among the major limitations to high crop production and sustainable land management in a rainfed Semi-Arid Tropics (SAT) in India. A field experiment was conducted to study the effect of land configuration practices and fertilizer split application methods under vertisols condition in *Rabi* sorghum. The results revealed that the *in-situ* soil moisture conservation practices *viz.*, broad bed furrow registered the highest yield attributes, yield, soil fertility status and plant nutrient uptake in rainfed sorghum. Under vertisols rainfed condition soil moisture conservation methods *viz.,* broad bed furrow recorded higher yield (1611 kg/ha), net income (Rs.6675/ha), BC ratio (1.37) and RWUE (4.49 kg/hamm). But in case of fertilizer treatments, the treatment applied with 20 kg N as urea + 20 kg P_2O_5 enriched with farm yard manure + 10 kg K_2O/ha as basal application and top dressing as 20kg N as urea and 10kg K kg/ha registered higher yield attributes, grain yield (1734 kg/ha), stalk yield (4357 kg/ha), net income (Rs.10607), BC ratio (1.70) and RWUE (4.81 kg/hamm) and plant nutrient uptake *viz.,* nitrogen uptake (67.82 kg/ha), phosphorus uptake (19.30 kg/ha), potassium uptake (108.06 kg/ha) and zinc uptake (117.1), respectively.

Key Words : Land configuration, Sorghum, Vertisols, Soil moisture, Rainfed

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INTRODUCTION

The area and production of sorghum (*Sorghum bicolor*) in India for the year 2011 were 7.3 million hectares and 7.4 million tonnes, respectively with average productivity of 1013 kg /ha (Anonymous, 2011). Grain sorghum is used as food for human and feed for poultry and piggery. Sorghum plant is nutritious fodder for dairy animals which is used as both green and dry fodder. Grains are also used in production of alcoholic beverages and biodiesel. Being drought and heat tolerant, it is especially important in arid regions. It is the main food

***Author for correspondence:**
[1]ICAR-AICRP on Dryland Agriculture, Agricultural Research Station, Kovilpatti, (T.N.) India
[2]Project Coordinator, ICAR-All India Co-ordinated Research Project on Dryland Agriculture, CRIDA, Hyderabad (Telungana) India

grain for over 750 million people in the semi-arid tropics of Africa, Asia and Latin America. Sorghum is a rich source of carbohydrates, proteins, minerals and vitamin B_1 and B_2 (Bender and Bender 2005). *Rabi* sorghum is the most important post rainy season (*Rabi*) cereal crop in peninsular India, grown predominantly under rainfed conditions. The area under *Rabi* sorghum is mainly concentrated in semi arid region of Deccan plateau consisting the states like Maharashtra, Karnataka and Andhra Pradesh. There is decline in the productivity of rabi sorghum under rainfed areas. Limited and erratic rainfall in the rainfed area creates moisture stress conditions during the various critical growth stages of crop life, resulting in severe yield reduction. Even when the rainfall is high, it is often lost as runoff, when the surface of the soil is not suitably formed. Soil moisture conservation, therefore, plays a key role in the successful crop production of *Rabi* sorghum in the vertisols of peninsular India. Adequate soil moisture is the key to successful crop production in dry land areas. Along with the conservation of soil moisture, its utilization for crop at proper time has tremendous importance.

The change and increase of energy prices will increase cost of agricultural inputs, such as land management, fertilizer and fuel and make future food security a major concern (Delgado *et al.,* 2011). Further, climate change threatens to increase erosion, reduce soil quality, soil depth and soil nutrient availability resulting in 10 to 20 per cent lower agricultural productivity, making it one of the most severe challenges to be faced in 21 century (Lal *et al.,* 2011). Farmers in the high potential regions of developed countries have increased crop yields by around 5 per cent annually while agricultural growth is less than one per cent in the Semi-Arid Tropics (SAT) of Asia including India during recent years. Crop yields range from one to two tones per hectare in almost all rainfed areas (Falkenmark *et al.,* 2001), indicating that productivity can be improved in the rainfed areas. Though India is currently self sufficient in food production, it needs to produce at least 281 Mt food grains, 53.7 Mt oilseeds, 22 Mt pulses, 127 Mt vegetables and 86 Mt fruits by 2020-21. In Vertisols of South India, nearly 10-20 per cent of rainfall goes as runoff from the agricultural fields and only small amount of water is the green water for crop production system. Thus crop production in rainfed Vertisols is prone to sever drought stress during post monsoon from September to January (Mishra and Patil, 2011). Adopting rainwater conservation techniques during rainy season (June to September) conserves rainwater reduces runoff and increases soil moisture storage in the profile (Takate *et al.,* 2014). In addition, farmers rarely adopt rainwater conservation techniques.This ultimately results in lower soil moisture and nutrient availability to the crops during growth period resulting in frequent failure of crops or decline in productivity. Split application of fertilizers can play an important role in nutrient management strategy that is productive, profitable and environmentally responsible. Split application can help growers to enhance nutrient efficiency, promote optimum yields and mitigate the loss of nutrients.

MATERIAL AND METHODS

Site and soil characteristics :

The Kovilpatti is situated between 8 ° 48’ and 9 ° 20’ North latitude and 78 ° 25’ east longitude at 90 MSL. It is a semi arid region with an annual rainfall of 737 mm. The normal maximum and minimum temperature is 35º C and 22º C, respectively. This research work was conducted at black soil farm of Agricultural Research station, Kovilpatti between 2011-2015. Every year *Rabi* season, sorghum (K 8) pre-monsoon sowing has been taken at the last week of September in black soil farm (Vertisols) to evaluate the land configuration methods along with the application of plants nutrients under rainfed condition. This tract is the representation of dryland agriculture in Southern parts of Tamil Nadu. In Thoothukudi district, the black soil covers an area of 70 per cent and the remaining 30 per cent of redsoil. The depth of the black soil varies from 110 to 150 cm with the infiltration rate of 0.9cm hr^{-1}. Soil develop typical cracks with at least one cm wide and reaching a depth of 50cm or more in the period of moisture stress. Considering the mechanical fraction, the soil is clayley with clay content of 46.4 to 61.2 per cent, 10.0 to 17.5 per cent silt and 12.6 to 24.5 per cent coarse sand. The soil bulk density varies from 1.21 to 1.36 kg m^{-3} with field capacity of 35 per cent and permanent wilting point of 14 per cent (Sunflower as an indicator plant). The soil has sub-angular blocky structure with pH generally neutral to a tendency towards alkalinity at lower depths (7.8 to 8.2). Regarding soil fertility status of the experimental site, the soil available nutrients *viz.,* low in soil available nitrogen (125 kg ha^{-1}), low to medium in soil available phosphorus (9.9 to 15.6 kg ha^{-1}), high in soil available potassium (670 kg ha^{-1}), low in soil available zinc (1.2 ppm) and low in soil available magnesium.

The experiment was conducted in split plot design with replicated twice under rainfed condition.

Table A : Treatments

Main plot (M)

Moisture conservation:

M_1: Broad bed furrow

M_2: Flat bed

M_3: Ridges and furrows

Sub plot (S)

Fertilizer application:

	Basal	Top dressing
S_1	FYM @12.5 t/ha	-
S_2	FYM @ 5 t/ha + $NP_2O_5K_2O$ 4 : 10 : 0	$NP_2O_5K_2O$ 16 : 0 : 0 in 2 splits
S_3	$NP_2O_5K_2O$ 40 : 20 : 0	-
S_4	$NP_2O_5K_2O$ 8 : 20 : 0	$NP_2O_5K_2O$ 32 : 0 : 10 in 2 splits
S_5	$NP_2O_5K_2O$ 20 : 20 as EFYM : 10	$NP_2O_5K_2O$ 20 : 0 : 10 in 2 splits
S_6	FYM 5 t/ha + $NP_2O_5K_2O$ 4 : 10 :0	$NP_2O_5K_2O$ 16 : 0 : 10 in 2 splits
S_7	Control	-

Sowing was done by hand dibbling method with plant spacing of 45×15 and recommended dose of fertilizer was applied using urea, DAP and muriate of potash as basal application and top dressing as per the fertilizer schedule in individual plots. The post harvest soil samples were collected from the experimental plots. Plant samples were collected at harvest stage. The collected samples were dried in a hot air oven at 65 °C and the dry weight was recorded. Chopped oven dried plant materials were grounded in a Willey mill and stored in wide-mouthed stoppered bottles. After suitable sub sampling, the samples were analyzed for total plant nutrient uptake *viz.,* nitrogen (Kjeldahl digestion method by Jones and Case (1990)), phosphorus (Vanadomolybdate yellow colour method by Piper (1966)) and Potassium uptake (Flame photometry method by Piper (1966)) as per standard procedures. The collected soil samples were processed through 2 mm size sieve and analysed for the various soil available nutrients. For soil organic carbon content soil passed through 0.2 mm sieve size. The determination of soil pH by Potentiometry in soil and water suspension (1:2) method by (Jackson,1973), Electrical conductivity by conductometry in soil and water suspension (1:2) method by (Jackson,1973), soil available nitrogen by Alkaline permanganate method (Subbiah and Asija,1956), soil available phosphorus by Olsen' s method (Olsen *et al.,*1954), soil available potassium by Neutral normal ammonium acetate, (Stanford and English,1949) and soil organic carbon by (Walkley and Black,1934). All the cultural practices were followed as per the package of practices. Sorghum was harvested at physiological maturity. The data on various growth and yield attributes were recorded under various treatments. The collected data from the experimental site is statistically analysed (Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

In soil moisture conservation studies, practicing of broad bed furrow recorded higher panicle weight (44.0g), test weight (36.0 g), ear head length (26.6 g), grain yield (1611 kg/ha) and stalk yield (4043 kg/ha) followed by the ridges and furrows. Among the fertilizer treatments, application of 20 kg N as urea + 20 kg P_2O_5 enriched with farm yard manure + 10 kg K_2O/ha as basal application and top dressing as 20kg N as urea and 10 kg K kg/ha registered higher yield attributes, grain yield (1734 kg/ha) and stalk yield (4357 kg/ha) and it was followed by the treatment applied with 8 kg N as urea + 20 kg P_2O_5 kg/ha as basal application along with 32 kg N as urea + 10 kg K_2O/ha, respectively. This might be due to broad bed furrow system helps in the safe disposal of excess water through furrows when there is high intensity rainfall with minimal soil erosion, at the same time it serves as land surface treatment for *in-situ* moisture conservation and there by increases the yield in cotton crop. Similar findings was reported by Devaranavadgi (2014). This findinds was also confirmed with Gnanasoundari and Balusamy (2015), Yadav *et al.* (2019) and Hanamant and Angadi (2019).

Under rainfed situation, land configuration methods *viz.,* formation of Broad bed furrow recorded the highest yield (1611 kg/ha), net income (Rs. 6675), BC ratio (1.37) and RWUE(4.49 kg/hamm) and it was followed by the ridges and furrow. In fertilizer treatments, the treated received 20 kg N as urea + 20 kg P_2O_5 enriched with farm yard manure + 10 kg K_2O/ha as basal application and top dressing as 20kg N as urea and 10kg K_2O/ha registered yield (1734 kg/ha), net income (Rs. 10607/ ha), BC ratio (1.70) and RWUE (4.81kg/hamm) when compared to other treatments. Similar results was reported by Patel *et al.* (2016).

In the present investigation, result showed that the pH and electrical conductivity of the soil did not differ significantly with respect to *in situ* moisture conservation practices and nutrient management practices. In vertisols deep black soils, land configuration methods *viz.,* formation of broad bed furrow registered the highest soil

Table 1 : Effect of *in-situ* moisture conservation techniques and fertilizer split application methods on yield and yield attributes of sorghum (K 8) in Vertisols

Treatments	Plant height (cm)	Panicle weight (g)	Test weight (g)	Earhead length (cm)	Grain yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
Main plot: Moisture conservation /Land configurations (M)						
Broad bed furrow (M_1)	125.9	44.0	36.0	26.6	1611	4043
Flat bed (M_2)	123.5	41.3	34.6	24.8	1540	3864
Ridges and furrow (M_3)	127.5	43.6	35.5	25.4	1567	3923
S.E.±	1.44	0.60	0.35	0.30	12.5	19.1
C.D. (P=0.05)	4.01	1.64	0.99	0.83	34.7	53.0
Sub Plot : Fertilizer applications (S)						
S_1	123.6	39.6	35.0	24.9	1471	3765
S_2	124.3	42.0	33.5	25.5	1587	3942
S_3	126.3	39.9	32.0	25.0	1530	3956
S_4	127.0	45.7	38.8	26.5	1618	4014
S_5	122.0	50.0	44.1	27.4	1734	4357
S_6	126.0	44.1	36.0	25.8	1601	4007
S_7	100.5	38.2	29.5	24.2	1462	3561
S.E.±	1.41	0.40	0.43	0.24	18.7	41.4
C.D. (P=0.05)	2.95	0.84	0.91	0.51	39.4	87.0
M× S S.E.±	2.44	0.69	0.75	0.42	32.4	72.1
M× S C.D. (P=0.05)	5.12	1.46	1.58	0.88	68.2	151.0
S × M S.E.±	2.56	0.84	0.74	0.47	31.0	65.0
S × M C.D. (P=0.05)	5.9	2.05	1.67	1.12	68.1	140.3

Table 2: Effect of *in-situ* moisture conservation techniques and fertilizer split application methods on yield and economics of sorghum (K 8) in Vertisols

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Net income (Rs./ha)	B:C	Rain water use efficiency (kg/ha/mm)
Main plot : Moisture conservation /Land configurations (M)					
Broad bed furrow (M_1)	1611	4043	6675	1.37	4.49
Flat bed (M_2)	1540	3864	6194	1.33	4.28
Ridges and furrow (M_3)	1567	3923	6296	1.34	4.36
S.E±	12.5	19.1			
C.D. (P=0.05)	34.7	53.0			
Sub Plot : Fertilizer applications (S)					
S_1	1471	3765	7047	1.46	4.11
S_2	1587	3942	8495	1.53	4.43
S_3	1530	3956	7588	1.50	4.26
S_4	1618	4090	8834	1.56	4.47
S_5	1734	4357	10607	1.70	4.81
S_6	1601	4007	8601	1.54	4.45
S_7	1462	3561	6513	1.37	4.09
S.E±	18.7	41.4			
C.D. (P=0.05)	39.4	87.0			
M× S S.E±	32.4	72.1			
M× S C.D. (P=0.05)	68.2	151.0			
S × M S.E±	31.0	65.0			
S × M C.D. (P=0.05)	68.1	140.3			

Table 3 : Effect of in-situ moisture conservation techniques and fertilizer split application methods on soil available nutrients of sorghum (K 8) in Vertisols

Treatments	pH	EC (dSm^{-1})	Available nitrogen ($kgha^{-1}$)	Available phosphorus ($kgha^{-1}$)	Available potassium ($kgha^{-1}$)	Available zinc ($mg\ kg^{-1}$)	Organic carbon ($g\ kg^{-1}$)
Main plot: Moisture conservation /Land configurations (M)							
Broad bed furrow (M_1)	7.99	0.29	139	13.4	431	12.7	3.0
Flat bed (M_2)	8.04	0.28	125	12.2	350	11.3	2.2
Ridges and furrow (M_3)	8.09	0.29	131	13.1	425	12.1	2.6
S.E.±	0.070	0.003	1.7	0.14	3.8	0.16	0.004
C.D. (P=0.05)	NS	NS	4.7	0.40	11.0	0.44	0.012
Sub Plot : Fertilizer applications (S)							
S_1	7.85	0.25	129	14.0	426	11.1	3.1
S_2	7.91	0.27	133	12.1	428	14.3	3.0
S_3	8.12	0.32	137	13.0	388	10.6	2.6
S_4	8.15	0.31	147	12.7	456	12.2	2.4
S_5	8.05	0.28	159	15.8	467	20.1	3.2
S_6	8.08	0.27	145	14.8	455	16.7	3.0
S_7	8.13	0.30	115	10.5	381	10.2	2.4
S.E.±	0.083	0.002	1.6	0.17	5.1	0.12	0.003
C.D. (P=0.05)	NS	NS	NS	NS	10.8	0.25	0.006
M× S S.E.±	0.143	0.003	2.8	0.30	8.9	0.21	0.005
M× S C.D. (P=0.05)	NS	NS	NS	NS	18.7	0.44	0.010
S × M S.E.±	0.141	0.004	3.0	0.30	8.6	0.24	0.006
S × M C.D. (P=0.05)	NS	NS	NS	NS	19.4	0.58	0.015

NS= Non-significant

Table 4: Effect of *in-situ* moisture conservation techniques and fertilizer split application methods on plant nutrient uptake of sorghum (K 8) in Vertisols

Treatments	Nitrogen uptake ($kgha^{-1}$)	Phosphorus uptake ($kgha^{-1}$)	Potassium ($kgha^{-1}$)	Zinc uptake (g/ha)
Main plot : Moisture conservation /Land configurations (M)				
Broad bed furrow (M_1)	39.4	12.7	57.6	40.4
Flat bed (M_2)	28.7	11.6	48.3	34.3
Ridges and furrow (M_3)	35.3	12.0	52.4	37.8
S.E.±	0.63	0.151	0.44	0.60
C.D. (P=0.05)	1.74	0.420	1.22	1.68
Sub Plot : Fertilizer applications (S)				
S_1	30.1	17.91	62.0	73.2
S_2	30.0	17.15	57.3	81.3
S_3	42.2	12.25	65.7	46.3
S_4	62.3	10.20	99.4	47.6
S_5	67.8	19.30	108.0	117.1
S_6	60.3	18.72	101.5	109.3
S_7	26.1	9.46	50.5	35.7
S.E.±	0.50	0.110	0.63	0.57
C.D. (P=0.05)	1.06	0.231	1.32	1.20
M× S S.E.±	0.88	0.202	1.10	1.10
M× S (P=0.05)	1.84	0.401	2.30	2.10
S × M S.E.±	0.98	0.224	1.04	1.05
S × M C.D. (0.05)	2.34	0.540	2.31	2.45

available nutrients *viz.,* soil available nitrogen (139 kg/ha), available phosphorus (13.3 kg/ha), available potassium (431 kg/ha), available zinc (12.7 mg/kg) and organic carbon (3.0 g/kg) and it was followed by the ridges and furrow. But in case of fertilizer application methods the treatment applied with 20 kg N as urea + 20 kg P_2O_5 enriched with farm yard manure + 10 kg K_2O/ha as basal application and top dressing as 20kg N as urea and 10 kg K_2O/ha recorded the higher soil available nutrients *viz.,* soil available nitrogen (159 kg/ha), available phosphorus (15.8 kg/ha), available potassium (467 kg/ha), available zinc (20.1mg/kg) and organic carbon (3.2 g/kg) and it was followed by the treatment applied with 8 kg N as urea + 20 kg P_2O_5 kg/ha as basal application along with 32 kg N as urea + 10 kg K kg/ha respectively. Similar results was obtained by Singh *et al.* (2013) and Patil and Sheelavantar (2001).

Regarding plant nutrient uptake, soil moisture conservation methods *viz.,* Broad bed furrow registered the highest plant nutrient uptake *viz.,* nitrogen uptake (39.4 kg/ha), phosphorus uptake (12.7 kg/ha), potassium uptake (57.6 kg/ha) and zinc uptake (40.4 g/ha) and it was followed by the ridges and furrow, respectively. When applied with 20 kg N as urea + 20 kg P_2O_5 enriched with farm yard manure + 10 kg K_2O/ha as basal application and top dressing as 20kg N as urea and 10kg K_2O/ha recorded highest nutrient uptake *viz.,* nitrogen uptake (67.82 kg/ha), phosphorus uptake (19.30 kg/ha), potassium uptake (108.06 kg/ha) and zinc uptake (117.1) and it was followed by the treatment applied with 8 kg N as urea + 20 kg P_2O_5/ha as basal application along with 32 kg N as urea + 10 kg K_2O /ha. The interaction effect of in-situ moisture conservation practices and split application of fertilizer showed significant differences between the treatments. This attribute is might be due to higher availability of moisture and nutrients in broad bed and furrow laid out plots resulted in the higher uptake of nutrients might have accelerated the better root growth, number of nodules and dry matter production. This results was confirmed by Chavan (2011), Jat *et al.* (2012) and Jnanesh *et al.* (2016).

Conclusion:

Under rainfed semiarid region of southern Tamil Nadu tract of agriculture practicing of in-situ moisture conservation *viz.,* broad bed furrow along with the application of 20 kg N as urea + 20 kg P_2O_5 enriched with farm yard manure + 10 kg K_2O/ha as basal application and top dressing as 20kg N as urea and 10kg K_2O/ha is suitable for increasing the yield in rabi sorghum and there by doubling the farmers income.

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REFERENCES

Bender, D. A. and Bender, A. E. (2005). A dictionary of food and nutrition. New York: Oxford University Press. pp. 126.

Chavan, S.R. (2011). Impact of in-situ moisture conservation measures in maize - chickpea sequence cropping in vertisol of model watershed in Dharwad district. M.Sc. Thesis, Department of Agronomy, University of Agricultural Sciences, Dharwad (Karnataka) India.

Delgado, J.A., Groffman, P., Nearing, M.A., Goddard, T., Reicosky, D., Lal, R., Kitchen, N., Rice, C., Towery, D. and Salon, P. (2011). Conservation practices to mitigate and adapt to climate change. *Journal of Soil and Water Conservation,* 66 (4) : 118-129.

Devaranavadgi, V.S. and Bosu, S.S. (2014). Effect of *in-situ* moisture conservation practices in deep clay soils on growth and yield of maize (*Zea mays* L.) under rainfed condition. *Karnataka J. Agricultural Sciences,* **27**(4) : 507–510.

Falkenmark, Malin, Fox, Patrick, Persson, Gunn and Rockström, Johan (2001). *Water harvesting for upgrading of rainfed agriculture*. Published by Stockholm International Water Institute, Sveavägen 59, SE-113 59 Stockholm, Sweden. ISBN 91-974183-0-7.

Gnanasoundari, P. and Balusamy, M. (2015). Evaluation of land configuration and mulching on soil moisture retention and yield of rainfed cotton. *Popular Kheti,* **3** (3) : 161-163.

Gomez, K.A. and Gomez, A.A. (2010). *Statistical procedures for agricultural research* (2nd Ed.), John Wiley and Sons, New York, U.S.A..

Hanamant, M. Halli and Angadi, S.S. (2019). Influence of land configuration on rain water use efficiency, yield and economics of cowpea (*Vigna unguiculata* L.) in maize cowpea sequence cropping under rainfed condition of Northern Transitional Zone. *Legume Research,* **42** : 211-215.

Jackson, M.L. (1973). *Soil chemical analysis*, Prentice Hall of India (pvt.) Ltd., New Delhi, India.

Jat, R.A., Arvadia, M.K., Tandel, B., Patel, T.U. and Mehta, R. S. (2012). Response of saline water irrigated greengram (*Vigna radiata*) to land configuration, fertilizers and farm yard manure in Tapi Command area of South Gujarat. *Indian J. Agron.,* **57** (3) : 270–274.

Jnanesha, A., Alagundagi, C.S.C., Manur, C.P. and Kumar, Ashish (2016). Effect of broad bed and furrow and integrated nutrient management practices on growth and yield of maize.*The Ecoscan,* **10** : 1017-1021.

Jones, B.J. and Case, V.W. (1990). Sampling, handling and analyzing plant tissue samples. In : R. L. Weatherman (Ed.); *Soil testing and plant analysis*. III Eds., Soil Sci. Soc. America, Inc. Madison, Wisconsin, USA.

Lal, R., Delgado, J.A., Groffman, P.M., Millar, N., Dell, C. and Rotz, A. (2011). Management to mitigate and adapt to climate change, *J. Soil & Water Conservation,* **66** (4) : 276-285.

Mishra, P.K. and Patil, S.L. (2011). Rainwater harvesting and related soil and water conservation technologies at the farm level. Water harvesting bringing Green Revolution to Rainfed Areas. Proceedings of the International Symposium held on 23-25th June 2008 at the Tamil Nadu Agricultural University, Coimbatore, India. Ed.Arumugam Kandiah, K. Ramaswamy and A.Sampathrajan,**1**:12-29.

Olsen, S.R.,Cole, C.V., Watanabe, F.S. and Dean, A.L. (1954). Estimation of available phosphorus in soils by extraction with sodium carbonate. Circular No. 939 USDA.

Patel, H.H., Patel, T .U., Patel, H.M. and Patel, P.S. (2016). Response of *Rabi* sorghum to land configuration and nutrient management. *Agricultural Research J.,* **53** (4) : 480-482.

Patil, S.L. and Sheelavantar, M.N. (2001). Effect of *in-situ* moisture conservation practices and integrated nutrient management on nutrient availability and grain yield of rabi sorghum (*Sorghum bicolor*) in the Vertisols of semi-arid tropics of south India. *Indian J. Agric. Sci.,* **71** (4) : 229-233.

Piper, C.S. (1966). *Soil and plant analysis*. Hans Publisher, Bombay, M.S. (India).

Singh, P., Sumeriya, H.K. and Kaushik, M.K. (2013). Effect of in-situ soil moisture conservation practices and its interaction with nutrients in yield, quality and economics of sorghum [*Sorghum bicolor* (L.) Moench]. *Adv. Res. J. Crop Improv.,* **4** (2) : 88-92.

Stanford, S. and English, L. (1949). Use of flame photometer in rapid soil tests of K and Ca. *Agron. J.,* **41** : 416-447.

Subbiah, B. V. and Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci*., **25**: 259-260.

Takate, A.S., Sheetal, R. Tatpurkar, S.R., Shelke, D.B., Bhanvase, Pawar, A.B. and Kadam, J.R. (2014). Rainwater conservation techniques with integrated phosphorus management on productivity of pigeonpea under dryland conditions. *Indian J. Dryland Agric. Res. & Dev.,* **29** (1) : 79-84.

Walkley, A. and Black, C.A. (1934). An examination of the degitijareff method for determining soil organic matter and a proposed modification of the chronic acid titration method. *Soil Sci*., **40** : 233-243.

Yadav, A.C., Husain, K., Verma, V.K., Tiwari, U.S., Khan, N. and Siddiqui, M. Z. (2019). Effect of land configuration and nutrient management on growth and yield of hybrid maize. *J. Pharmacognosy & Phytochemistry,* **8** (4) : 602-606.

WEBLIOGRAPHY

Anonymous (2011). *http://www.biocircle-project.eu.*