

Impact of cropping systems and soil-moisture conservation techniques on fodder productivity under semi-arid environment

S.L. MEENA¹, S.S. MEENA² AND R.P. NAGAR³

ICAR-Indian Grassland and Fodder Research Institute, Avikanagar, Tonk, Rajasthan 304 501

Received : July 2015; Revised accepted : December 2015

ABSTRACT

A field experiment was conducted during 2011–13 at Avikanagar, Rajasthan, to study the effect of cropping systems and soil-moisture conservation techniques on growth and yield of fodder crops. The treatments were comprised 7 cropping systems, viz. sole buffelgrass (*Cenchrus ciliaris* L.) sole pearl millet [*Pennisetum glaucum* (L.) R. Br.], sole clusterbean [*Cyamopsis tetragonoloba* (L.) Taubert], sole butterfly pea (*Clitoria ternatea* L.), *C. ciliaris* + clusterbean (1 : 1), pearl millet + clusterbean (1 : 1), and *C. ciliaris* + *C. ternatea* (1 : 1) in main plots and 4 moisture-conservation techniques [control, dust mulch, straw mulch @ 5 t/ha and farmyard manure @ 5 t/ha] in subplots. Straw mulching and the application of farmyard manure (FYM) were found significantly superior to dust mulching and the control in terms of growth and dry-fodder yield. Dry-fodder yield of *Cenchrus ciliaris* L., *Cyamopsis tetragonoloba*, *Pennisetum glaucum*. and *Clitoria ternatea* L. was significantly higher under straw mulching (3,607; 2,243; 7,041 and 1,746 kg/ha) over rest of the soil-moisture conservation treatments. The dry-fodder yield was also found significantly more under application of FYM (3,338; 2,046; 6,339 and 1,604 kg/ha) than the dust mulching (2,191; 1,864; 6,094 and 1,395 kg/ha) and control (2,012; 1,741; 5,718 and 1,182 kg/ha) respectively. The maximum soil moisture (%) was retained under the cropping system of *C. ciliaris* (4.83) alone followed by *C. ciliaris* + *C. ternatea* (4.09), *C. ciliaris* + clusterbean (3.99), *C. ternatea* (3.58), pearl millet (3.55), pearl millet + clusterbean (3.44) and clusterbean (3.42). Soil-moisture content also retained significantly more under the application of straw mulching (4.27) over dust mulching (3.71) and the control (3.41) but at par with FYM (3.99). Straw mulching under *C. ciliaris* cropped with *C. ternatea* was found effective for conserving soil moisture and improving forage productivity under semi-arid ecosystems.

Key words: *Cenchrus ciliaris*, *Clitoria ternatea*, Cropping system, Fodder yield, FYM, Mulching

Livestock farming has been lifeline for the rural people in semi-arid regions. The livestock population is increasing continuously, and the available fodder is not sufficient to meet the requirement of animals in the region. Moreover the area under permanent pastures is also shrinking. Buffelgrass is a dominant range grass of arid and semi-arid regions. Among different rangeland grasses, it is considered palatable and nutritious for all kinds of grazing animals. It contains high percentage of protein (8–10), with 60–70% digestibility. *Clitoria ternatea* is a promising range legume for improvement of rangelands. It is hardy in nature and can survive under low rainfall on poor sandy soils, can be used for cut-and-carry, and conserved as hay and dry-leaf meal. The dry-matter production potential

ranges from 2 to 3 t/ha/year, with 18–20% protein content and 80% digestibility. Besides range grasses and legumes, the annual cultivated fodder crops like pearl millet and clusterbean play a significant role in arid and semi-arid regions. Soil-moisture management needs greater attention in arid and semi-arid regions for enhancing productivity. For enhancing nutritional value and efficient use of soil moisture in grassland, integration of range legume will be beneficial because grasses are shallow rooted and legumes are deep-rooted, so there will be less competition for scarce moisture. Mustard crop is predominant crop of the region and straw may be used as mulching material to conserving soil moisture. Therefore, the present study was undertaken to evaluate the productivity of forage cropping systems under different soil-moisture conservation techniques.

¹Corresponding author Email: dr_slmeena@yahoo.co.in

¹Senior Scientist, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012; ²Principal Scientist; ³Senior Scientist, ICAR-Indian Grassland and Fodder Research Institute, Avikanagar, Tonk, Rajasthan 304 501

MATERIALS AND METHODS

A field experiment was conducted during 2011–13 at

Western Regional Research Station of the Indian Grassland and Fodder Research Institute, Avikanagar, Rajasthan to study the effect of soil-moisture conservation techniques on plant growth and fodder yield and identify the best suitable cropping system in the semi-arid regions. The soil was sandy loam, low in organic carbon content (0.33%), available N (157.6 kg/ha) and medium in available phosphorus (17.9 kg/ha) and potassium (204.1 kg/ha), with pH 7.8. The average monthly maximum and minimum humidity was 69 and 45% and temperature of 34 and 20°C, respectively, during the cropping seasons. The monthly average wind velocity was 4 km/hr and average sunshine was 8 hours in a day. The average annual rainfall was 608 mm, received during June–August. The experiment was laid out in a split-plot design replicated thrice. The treatments comprised 7 cropping systems, viz. sole *Cenchrus ciliaris* ‘IGFRI 3108’, sole pearl millet ‘AVKB 19’, sole clusterbean ‘Bundel Guar 1’, sole *Clitoria ternatea* ‘local strain’, *C. ciliaris* + clusterbean (1 : 1), pearl millet + clusterbean (1 : 1), and *C. ciliaris* + *C. ternatea* (1 : 1). Three moisture-conservation techniques were: dust mulch, straw mulch @ 5 t/ha and FYM @ 5 t/ha with 1 control. Each treatment was applied in a net plot size of 12 m². Farmyard manure was mixed a month before the sowing, and straw mulch was spread out after emerging the crops. Soil-moisture samples were taken after 48 hours of every effective rainfall during the cropping season for estimating soil moisture content. Crop-growth parameters were recorded from 10 random plants. Dry-fodder yield was recorded on whole-plot basis and converted as t/ha at 50% flowering stage. The data were statistically analyzed by standard tools for interpretation of the results. CD values at $P=0.05$ were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Growth and fodder yield

Cenchrus ciliaris: Plant height was significantly higher under the cropping system of *C. ciliaris* + *C. ternatea* over *C. ciliaris* + clusterbean and *C. ciliaris* alone, while tillers/plant were more under *C. ciliaris* + *C. ternatea* than *C. ciliaris* alone and at par with *C. ciliaris* + clusterbean system of cropping. Dry-fodder yield was significantly higher under sole cropping than the other cropping systems because of more tussocks per hectare. Taller plants and more number of tillers/tussock were observed under straw mulching, followed by the application of FYM, dust mulching over the control (Table 1). The dry-fodder yield increased by 49% in straw mulching followed by 38% in FYM and by 17% in dust mulching compared with the control. Choudhary *et al.* (2013) also reported higher grain and stover yield with paddy-straw mulching over no-mulch.

Clusterbean: Clusterbean performed better with *C. ciliaris* than pearl millet intercropping, may be owing to less competition for sunlight. Taller plants of clusterbean were observed under planting of clusterbean + pearl millet which were significantly higher than the other cropping systems, while number of branches/plant were significantly higher in clusterbean alone but at par with clusterbean + *C. ciliaris* (Table 2). Considering the plant height and number of branches/plant, the suitability of clusterbean as an intercrop with *C. ciliaris* and pearl millet was found inferior. The reduction in the number of branches and fodder yield of clusterbean under intercropping indicated more competition and shading effect of pearl millet on clusterbean. Singh *et al.* (1998) also reported similar results in lentil-based cropping system. Dry-fodder yield was significantly higher under sole cropping

Table 1. Influence of cropping systems and soil-moisture conservation techniques on growth and yield of *Cenchrus ciliaris* under semi-arid environment (pooled data of 3 years)

Treatment	Plant height (cm)	Tillers/clump	Dry fodder yield (t/ha)
<i>Cropping system</i>			
<i>Cenchrus ciliaris</i> alone	133.9	47.1	3.22
<i>Cenchrus ciliaris</i> + clusterbean	136.3	54.8	2.53
<i>Cenchrus ciliaris</i> + <i>Clitoria ternatea</i>	142.9	63.0	2.60
SEm±	1.36	4.17	0.057
CD (P=0.05)	4.13	12.57	0.176
<i>Soil moisture conservation technique</i>			
Control	133.0	45.7	2.01
Dust mulch	135.7	49.7	2.19
Straw mulch @ 5 t/ha	142.7	64.7	3.61
FYM @ 5 t/ha	139.3	59.3	3.34
SEm±	1.6	4.8	0.068
CD (P=0.05)	4.8	14.5	0.203

than intercropping. This is because of higher density of plants under solid planting. Plant height, branches/plant and dry-fodder yield of clusterbean were influenced greatly by the application of soil-moisture techniques. Fodder yield was enhanced by 29% in straw mulching, 18% in FYM, 7% in dust mulching compared with the control. Lal *et al.* (2014) similar results observed through adopting moisture conservation practice in chickpea.

Pearlmillet: Taller plants of pearl millet were observed in pearl millet + clusterbean intercropping but did not differ significantly from rest of the cropping systems (Table 3). Number of tillers/plant were significantly higher under cropping of pearl millet with clusterbean over solid planting, may be due to less competition for soil moisture and nutrients supplementation by clusterbean. Goswami *et al.* (2002) also reported similar results. Dry-fodder yield was also significantly higher under sole cropping than all the intercropping systems. Plant height, tillers/plant and dry fodder yield were influenced greatly by the application of straw mulching, followed by FYM and dust mulching (Table 3). Fodder yield was enhanced by 23% under straw mulching, 11% in FYM and 7% in dust mulching compared with the control. The increased fodder productivity with application of moisture-conservation practices extend the period of water-storage in soil due to reduction in evaporation and FYM increases water holding capacity. Jat and Gautam (2001) reported similar results in pearl millet by summer ploughing and *in-situ* moisture-conservation practices under semi-arid conditions.

Clitoria ternatea: Plant height and branches/plant of *C. ternatea* were higher under the intercropping of *C. ternatea* + *C. ciliaris* compared to *C. ternatea* alone under straw mulching over rest of the soil-moisture conservation techniques. Less competition for resources might be the

reason for enhancement in growth (Table 4). It was more under the application of straw mulching, followed by FYM and dust mulch. As observed in the other crops, dry-fodder yield was higher under sole cropping. The highest increment (48%) was obtained with application of straw mulching, followed by 36% in FYM and 18% in dust mulching compared with the control (1.18 t/ha).

Protein yield

Total crude protein yield (Fig.1) was higher in pearl millet alone, followed by the combination of *C. ciliaris* + clusterbean, clusterbean alone, *C. ciliaris* + *C. ternatea*, clusterbean + pearl millet, *C. ciliaris* alone and pearl millet alone. The greater amount of crude protein yield in all 4 fodder crops was recorded under the treatment of straw mulching owing to enhancement of fodder yield and was significantly higher than the application of FYM, dust mulching and the control. Total crude protein yield of 3 years under different soil-moisture conservation

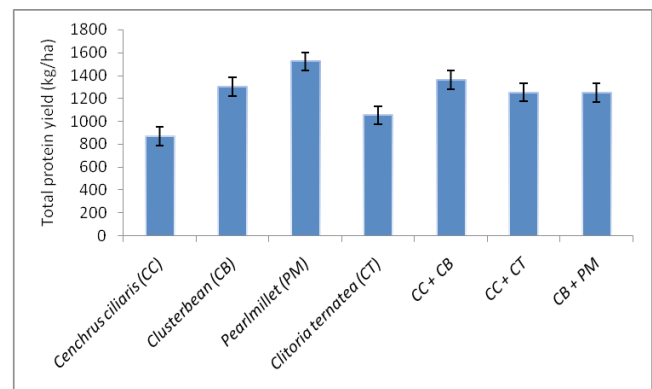


Fig. 1. Total crude protein yield of 3 years under different cropping systems

Table 2. Influence of cropping systems and soil-moisture conservation techniques on growth and yield of clusterbean under semi-arid environment (pooled data of 3 years)

Treatment	Plant height (cm)	Branches/plant	Dry fodder yield (t/ha)
<i>Cropping system</i>			
Clusterbean alone	123.7	17.3	3.10
Clusterbean + <i>Cenchrus ciliaris</i>	113.3	16.3	1.61
Clusterbean + pearl millet	140.3	7.3	1.21
SEm±	4.6	1.1	0.037
CD (P=0.05)	13.7	3.3	0.113
<i>Soil moisture conservation technique</i>			
Control	117.7	11.0	1.74
Dust mulch	121.0	12.3	1.87
Straw mulch @ 5 t/ha	132.3	17.0	2.24
FYM @ 5 t/ha	131.7	15.0	2.04
SEm±	5.3	1.3	0.044
CD (P=0.05)	15.9	3.8	0.132

techniques was significantly higher under straw mulching than FYM, dust mulching and the control (Fig. 2).

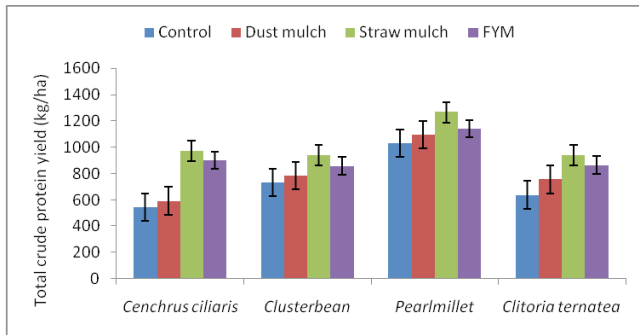


Fig. 2. Total crude protein yield of 3 years under different soil-moisture conservation techniques

Soil-moisture retention

The cropping systems for fodder production and soil-moisture conservation techniques applied to the experiment had positive impact on the soil-moisture content (%) for longer period at different depths. Maximum soil-moisture content (Fig. 3) was recorded under the cropping system of *C. ciliaris* alone, followed by *C. ciliaris* + *C. ternatea* (4.09), *C. ciliaris* + clusterbean (3.99), *C. ternatea*, pearl millet, pearl millet + clusterbean and clusterbean. In general, soil-moisture utilization (Fig. 4) by crops was greater from the top soil layer (0–30 cm). The intercropping system depleted more moisture from deeper layers than sole cropping. Soil-moisture retention was significantly higher under straw mulching over dust mulching and the control, but at par with FYM (3.99). Mulching had a significant impact on soil moisture not only during rainfall events but also during dry spells. As the rain water is colder than soil, occurrence of rainfall reduced soil tem-

perature during the rainfall events, as similar soil temperatures being observed at the end of each rainfall event in mulch cover and bare soil treatments (Montenegro *et al.*, 2013). Straw mulching @ 5 t/ha increased seed yield of *taramira* by 25% over no mulch, with increased water-use efficiency by 1.8 kg/ha/mm (Regar *et al.* 2009). Shen *et al.*

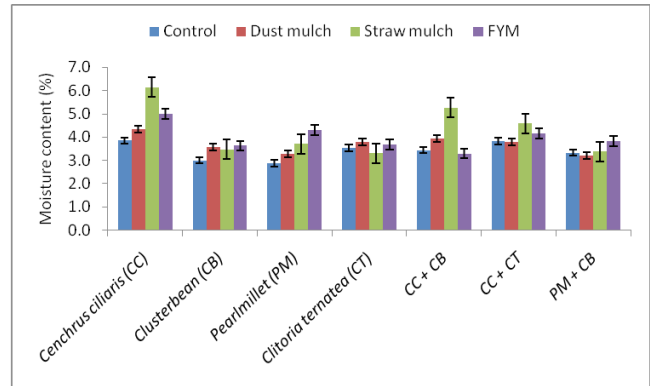


Fig. 3. Moisture content under different cropping systems and soil-moisture conservation techniques

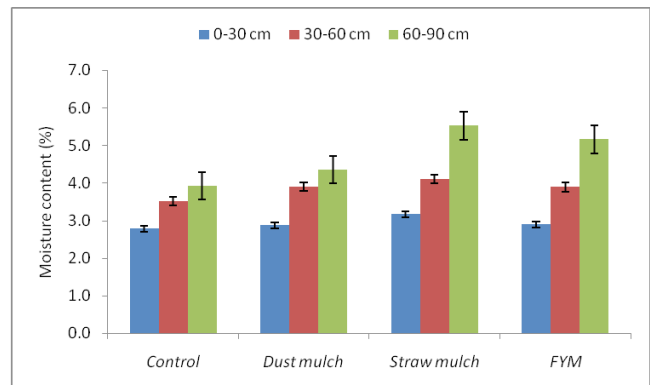


Fig. 4. Moisture content in different soil layers under soil-moisture conservation techniques

Table 3. Influence of cropping systems and soil-moisture conservation techniques on growth and yield of pearl millet under semi-arid environment (pooled data of 3 years)

Treatment	Plant height (cm)	Tillers/plant	Dry fodder yield (t/ha)
<i>Cropping system</i>			
Pearlmillet alone	278.7	5.17	8.46
Pearlmillet + clusterbean	288.7	8.33	4.13
SEm±	5.4	0.473	0.105
CD (P=0.05)	16.2	1.420	0.317
<i>Soil moisture conservation technique</i>			
Control	272.0	6.00	5.72
Dust mulch	275.3	6.33	6.09
Straw mulch @ 5 t/ha	297.7	7.67	7.04
FYM @ 5 t/ha	290.7	7.00	6.34
SEm±	7.66	0.673	0.149
CD (P=0.05)	22.97	2.013	0.448

Table 4. Influence of cropping systems and soil moisture conservation techniques on growth and yield of *Clitoria ternatea* under semi-arid environment (pooled data of 3 years)

Treatment	Plant height (cm)	Branches/plant	Dry fodder yield (t/ha)
<i>Cropping system</i>			
<i>Clitoria ternatea</i> alone	55.2	5.43	1.95
<i>Clitoria ternatea</i> + <i>Cenchrus ciliaris</i>	60.7	7.07	1.02
SEm±	1.74	0.370	0.029
CD (P=0.05)	5.28	1.090	0.088
<i>Soil moisture conservation technique</i>			
Control	54.7	5.00	1.18
Dust mulch	56.3	5.67	1.40
Straw mulch @ 5 t/ha	62.3	7.33	1.74
FYM @ 5 t/ha	58.3	7.00	1.60
SEm±	2.49	0.517	0.041
CD (P=0.05)	7.47	1.547	0.125

(2012) studied the effect of straw mulching (6 and 12 t/ha) during the summer maize-growing season to study soil-moisture content, evapotranspiration, grain yield, and water-use efficiency and reported significant improvement in soil moisture content at a depth of 20–80 cm below the ground. Evaporative losses from the non-mulched treatments were between 37% and 39% of the total water applied (Zegada-Lizarazu and Berliner, 2011). Application of FYM @ 5.0 t/ha recorded significantly higher pod yield of groundnut, while lopping of *Gliricidia* applied as mulch recorded significantly higher soil-moisture content (Vekariya *et al.*, 2014).

It can be concluded that grass and legume performed better under intercropping than their sole planting. *Cenchrus ciliaris* cropped with *Clitoria ternatea* conserved more soil moisture. Straw mulching was more effective for conserving soil moisture and improving forage productivity under semi-arid environment.

REFERENCES

- Choudhary, V.K., Kumar, P.S. and Bhagawati, R. 2013. Response of tillage and *in-situ* moisture conservation on alteration of soil and morpho-physiological differences in maize under eastern Himalayan region of India. *Journals Soil and Tillage Research* **134**: 41–48.
- Goswami, V.K., Kaushik, S.K. and Gautam, R.C. 2002. Effect of intercropping and weed control on nutrient uptake and water-use efficiency of pearl millet (*Pennisetum glaucum*) under rainfed conditions. *Indian Journal of Agronomy* **47**(4): 504–08.
- Jat, M.L. and Gautam, R.C. 2001. Productivity and water use of rainfed pearl millet (*Pennisetum glaucum*) as influenced by summer ploughing and *in-situ* moisture conservation practices under semi-arid conditions of north-west India. *Indian Journal of Agronomy* **46**(2): 266–72.
- Lal, B., Rana, K.S., Rana, D.S., Gautam, P., Shivay, Y. S., Ansari, M.A., Meena, B.P. and Kumar, K. 2014. Influence of intercropping, moisture conservation practice and P and S levels on growth, nodulation and yield of chickpea (*Cicer arietinum* L.) under rainfed condition. *Legume Research* **37**(3): 300–05.
- Montenegro, A.A.A., Abrantes, J.R.C.B., de Lima, J.L.M.P., Singh, V.P., and Santos, T.E.M. 2013. Impact of mulching on soil and water dynamics under intermittent simulated rainfall. *CATENA* **109**: 139–49.
- Regar, P.L., Rao, S.S. and Joshi, N.L. 2011. Effect of *in-situ* moisture conservation practices on productivity of rainfed taramira (*Eruca sativa*) in arid Rajasthan. *Indian Journal of Soil Conservation* **37**(3): 197–200.
- Shen, J.Y., Zhao, D.D., Han, H.F., Zhou, X.B. and Li, Q.Q. 2012. Effects of straw mulching on water consumption characteristics and yield of different types of summer maize plants. *Plant, Soil and Environment* **58**(4): 161–66.
- Singh, A.K., Singh, R.K., Singh, A.K., Singh, V.K., Rawat, S.S., Mehta, K.S., Kumar, A. Gupta, M.K. and Thakur, S. 2014. Bio-Mulching for ginger crop management: Traditional ecological knowledge led adaptation under rainfed agro-ecosystems. *Indian Journal of Traditional Knowledge* **13**(1): 111–22.
- Singh, D.P., Rajput, A.L. and Singh, S.K. 1998. Productivity and economics of lentil (*Lens culinaris*)-based cropping systems. *Indian Journal of Agronomy* **43**(4): 588–90.
- Vekariya, P.D., Sanepara, D.P., Gajera, M.S. and Akbari, K.N. 2014. Effect of alley width and organic manure on productivity of groundnut and *in-situ* moisture conservation under dryland eco-system. *Legume Research* **37**(4): 415–19.
- Zegada-Lizarazu, W. and Berliner, P.R. 2011. Inter-row mulch increases the water use efficiency of furrow-irrigated maize in an arid environment. *Journal of Agronomy and Crop Science* **197**(3): 237–48.