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Soil properties, root growth, water-use efficiency in brinjal (*Solanum melongena*) production and economics as affected by soil water conservation practices*

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In western Rajasthan, brinjal (*Solanum melongena* L.) or eggplant is considered as one of the important vegetable crops. Because like other solanacious vegetable crops it is also a high water-requiring vegetable crop, therefore, its cultivation mainly depends on assured water availability. Further this task becomes more difficult when it comes to sandy soils of hot arid regions, where evaporation loss of applied irrigation water ranges from 50–75% (Bennie and Hensley 2000). Therefore, crop suffers from inadequate soil moisture at transplanting and establishment stages resulting in much lower average yield (11.00 tonnes/ha) of the crop than the national average (16.47 tonnes/ha). Keeping in view of the above facts some soil water conservation practices like FYM mulching, clusterbean straw mulching, local grass mulching and FYM subsurface incorporation were supposed to be very effective in reducing the evaporation loss of soil moisture vis-à-vis improving the fertility status of soil.

Organic mulching and sub-surface application of FYM as soil water conservation practices (SWCP) have shown positive effects on improving the soil physico-chemical properties such as increasing the profile water content, nutrient status of soil, root growth, water-use efficiency as well as fruit production and maintaining the optimum soil water content in the rhizosphere (Singh *et al.* 2006, Ossom 2003 and Sharma *et al.* 2009). Since, water deficit during critical growth stages such as root and fruit development interferes with cell division and elongation; hence reduce root proliferation capacity, fruit size, yield and quality. Restricted root and shoot growth also result in reduced uptake of water and poor growth of plants (Verma *et al.* 2005a).

Information on the effect of farmyard manure (FYM) mulching and other organic (straw) mulches and sub-surface FYM incorporation on root growth pattern for accounting the irrigation depths for brinjal (*Solanum melongena* L.) production and improving the fertility status of soil are scanty. Therefore, this investigation was undertaken to assess the effect of these soil water conservation practices on soil properties, root growth, water use efficiency, production of brinjal and economics under arid conditions.

Field experiments were conducted on very deep, coarse loamy sand Typic Torripsamments (sand 86%, silt 5%, clay 8%) at the research farm of the Central Institute for Arid Horticulture, Bikaner, India, located between 28° N latitude and 73° 18' E longitude and an altitude of 234.84 m above mean sea level with a mean annual rainfall of 250 mm with brinjal as the test crop during July 2004– June 2009. The experimental soil (0–30 cm) has single grain structure; bulk density 1.58–1.60 mg/m^3; soil moisture retention capacity 3.00–3.20% w/w at field capacity and 1.56–2.1% at wilting point for 0.0 to 60.00 cm depths; saturated hydraulic conductivity 25–30 cm/h; *p*H (1:2.5 soil water suspension) 8.5–8.7; EC 0.16–0.21 dS/m; organic C 0.030–0.033%; total N 0.0021%; available N 65–79 kg/ha; available (Olsen) P 5.7–6.8 kg/ha; available K 360–480 kg/ha; exchangeable Ca^{2+} 1.0–2.4; Mg^{2+} 0.3–0.4; K^+ 0.1–0.4; and Na^+ 0.3–0.7 [Cmol (p+)/kg]; available Fe 5.0–5.8; Mn 4.0–4.5; Cu 0.10–0.18; and Zn 0.10–0.15 mg/kg.

The experiment was laid out in a randomized block design with four soil water conservation treatments, namely, FYM mulch, clusterbean (*Cyamopsis tetragonoloba*) straw mulch, bui (*Aerva pseudotomentosa*) grapes straw mulch, sub-surface application of FYM and no mulch as control each replicated thrice. All the treatments were imposed after 15 days of transplanting in July of each year. The plot sizes were 5.0 m × 1.5 m. The FYM and straw mulches were applied @ 30 and 8 tonnes/ha, respectively. The sub-surface application of FYM was done @ 12 tonnes/ha. The N (urea),

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P (di-ammonium phosphate) and K (muriate of potash) were applied @ 80, 60 and 40 kg/ha, respectively. Organic mulches prior to its application were analysed for nutrient statuses. The C:N ratio, nitrogen, phosphorus and potassium contents in FYM, clusterbean straw and bui straw were 24.95, 0.855, 0.22%, 0.80%; 25.12, 1.60%, 0.17%, 1.87%; and 35.00, 1.20%, 0.93% and 1.14%, respectively. Soil samples were collected from each plot (as per the irrigation interval given below) from 0–15 and 15–30 cm depths with a 4.5 cm diameter core and their moisture contents were determined gravimetrically. Soil temperature (15 cm depth) was measured at 2.30 hr with stainless steel Fisherbrand bimetal dial thermometers.

Water-use efficiency of the crop under various treatments was computed using the equation of Viets (1962) as follows water-use efficiency (WUE) = fresh fruit yield (kg/ha)/total soil water use or ET (mm). Water used between each irrigation interval or in between the period of rain was then calculated by using the formula of soil water depletion approach. No deep drainage or surface runoff was considered. Root length under each monolith section was measured using a modified line intercept method. (Tennant 1975). Total root length was divided by the volume of monolith to compute root length density. The roots were dried in oven at 70°C to a constant weight and dry weight was determined. Root weight density was computed by dividing the dry weight by volume of monolith.

The physico-chemical properties of soil were determined by following standard methods (Jackson 1973). DTPA extractable Fe, Mn, Cu and Zn (Lindsay and Norvell 1978) were determined by atomic absorption spectrophotometer. The cost of cultivation was worked out taking into account the variable cost and the return was calculated on the basis of market prices prevailed during the study period. The data were subjected to analysis of variance using INDOSTAT packages.

There was no change in texture, structure, bulk density, particle density and porosity of soil due to application of SWCP (Table 1). However, a slight change in value of water holding capacity and hydraulic conductivity of soil was recorded. FYM mulch (3.88 and 1.54% w/w) and FYM subsurface incorporation (3.58 and 1.46% w/w) treatments were found significantly effective in increasing the soil moisture retention capacity both at field capacity and wilting point. Pertaining to hydraulic conductivity of soil, all the treatments recorded significantly lower rate of hydraulic conductivity as compared to control. The results are in consonance with the findings of Sharma *et al.* (2009).

Soil water conservation practices could not bring significant changes in values of *p*H, EC and $CaCO_3$ content of the initial soil (Table 1). The per cent organic carbon content was recorded significantly higher in all the treatments as compared to the control. The highest organic carbon (0.242%) was recorded in FYM mulch treatments and the lowest (0.038%) in control. The result is in agreement with the findings of Verma *et al.* (2005b). FYM mulch registered maximum available N (120 kg/ha) and P (13.74 kg/ha) of the soils against the minimum 78 kg/ha and 8.16 kg/ha, respectively with control. Increase in available N, P and K due to FYM application may be because of the direct addition of NPK through FYM to the available pool of the soil. Significantly higher available N and P were recorded with straw mulching as compared to control. The results are in consonance with the findings of Ossom (2003) and Singh *et al.* (2006). The effect of SWCP on the improvement of status of exchangeable cations (Ca^{2+}, Mg^{2+} and K^+) was not found consistent. As compared with the initial status, a general increase in status of micronutrients was observed in all the treated plots. However, the control plots recorded almost equal concentration of manganese to the bui straw mulch treatment.

The moisture conservation practices significantly improved most of the root growth parameters (Table 3). However, the ratio of root length to aerial mass (RL/AM) in FYM subsurface incorporation treatment were at par with control. The FYM mulch noticed maximum values of RL/AM which increased by 140% over control and exactly double in magnitude than the FYM subsurface incorporation. The moderation of hydrothermal regimes (Table 2) under FYM mulch treatment at crop harvest stage adopted, registered 370, 392 and 198% higher RLD, RMD and RV over to the control. Other SWCP too significantly affected all the root growth parameters. Verma *et al.* (2005b) also highlighted the beneficial effect of organic mulching on root growth.

The highest water-use efficiency (WUE) was noticed with

Table 1 Effect of soil water conservation practice treatments on chemical properties of soils of 0–15 cm depth (pooled data of five years)

Treatment	*p*H (1:2.5)	EC (dS/m)	$CaCO_3$ (%)	Org. C (%)	Available macronutrient (kg/ha)			Exchangeable cations [Cmol (p+)/kg]				Available micronutrient (mg/kg)			
					N	P	K	Ca^{2+}	Mg^{2+}	K^+	Na^+	Fe	Mn	Cu	Zn
FYM mulch	8.30	0.08	2.0	0.242	120	13.74	621	4.5	0.6	0.71	0.2	7.1	6.5	0.34	0.30
Clusterbean straw mulch	8.20	0.10	2.2	0.068	88	11.56	393	3.1	0.2	0.45	0.4	5.0	5.3	0.25	0.20
Grass straw mulch	8.21	0.12	1.8	0.057	89	10.50	352	3.0	0.2	0.42	0.4	4.5	4.6	0.24	0.18
FYM incorporation	8.26	0.07	2.5	0.068	95	11.72	453	3.0	0.5	0.54	0.5	5.6	5.5	0.28	0.21
Control	8.20	0.07	1.0	0.038	78	8.16	430	2.4	0.4	0.51	0.6	4.1	4.5	0.13	0.08
CD (*P*=0.05)	0.179	0.044	0.660	0.005	9.320	1.425	9.591	0.686	0.22	0.06	0.14	0.22	0.67	0.03	0.04

Table 2 Monthly average soil temperature (°C) and moisture (%, v/v) at 0 –15 cm depth under different soil water conservation practices (pooled data of five years)

Treatment	August	September	October	November	December	January
Soil temperature						
FYM mulch	31.6	30.7	28.5	27.0	21.2	19.0
Clusterbean straw mulch	34.1	32.2	30.0	26.2	20.5	18.1
Grass straw mulch	34.6	32.5	30.4	25.5	18.8	17.5
Control	36.0	35.6	31.0	24.3	17.0	16.5
CD (*P*=0.05)	0.23	0.17	0.43	0.13	0.41	0.26
Soil moisture						
FYM mulch	6.6	7.1	9.9	11.2	12.3	12.9
Clusterbean straw mulch	6.3	6.5	8.8	9.6	11.0	11.8
Grass straw mulch	5.8	6.3	7.7	8.5	10.4	10.7
FYM incorporation	4.9	5.5	6.5	7.3	8.20	8.7
Control	2.7	3.5	4.4	6.0	7.10	7.9
CD (*P*=0.05)	0.49	0.46	0.44	0.31	0.15	0.43

Table 3 Effect of soil water conservation practices on root growth properties (pooled data of five years)

Treatment	Root length density (m $m^{-3} \times 10^3$)	Root mass density (g $m^{-3} \times 10^3$)	Root volume (m^3 $m^{-3} \times 10^{-3}$)	Ratio of root length to aerial parts (cm root/ mg shoot)	WUE (kg/ha/mm)	Fruit yield (tonnes/ha)	B: C ratio
FYM mulch	1.703	0.818	2.526	0.060	46.29	30	1.91
Clusterbean straw mulch	0.752	0.323	1.850	0.035	35.66	26	1.26
Grass straw mulch	0.539	0.234	1.390	0.034	26.58	21	1.21
FYM incorporation	0.450	0.193	1.043	0.030	17.24	15	1.00
Control	0.362	0.166	0.846	0.025	11.50	11	0.83
CD (*P*=0.05)	0.030	0.009	0.048	0.006	4.17	2.79	0.13

FYM mulch treatment (46.29 kg/ha/mm) while the lowest in bare soil (11.50 kg/ha/mm) (Table 3). The mean annual water use efficiency in FYM mulch treatment was approximately two-and-half times than those in the FYM incorporation (17.24 kg/ha/m). More WUE under the mulches compared to no mulch demonstrated the effectiveness of mulch in reducing soil evaporation and increased plant respiration (Singandhupe *et al.* 2003).

Soil water conservation practices registered significant increase in fruit yield (Table 3) from 4 tonnes/ha (FYM incorporation), 10 tonnes/ha (*Aerva pseudotomentosa* straw mulch), 15 tonnes/ha (cluster bean straw mulch) and 19 tonnes/ha (FYM mulch) as compared to the control. The fruit yield recorded with cluster bean straw mulch and FYM mulch was at par. It seems that buffered hydrothermal regimes under different treatments may have resulted in higher fruit yield. The results are in accordance with the findings of Aggarwal *et al.* (2003) and Awasthi *et al.* (2006). Applied soil water conservation practices were proved to be economically effective and beneficial in enhancing the production potential of eggplant under hot arid ecosystem (Table 3).

SUMMARY

A field experiment was conducted during 2004–09 to study the effect of soil water conservation practices on soil properties, root growth, water-use efficiency, production, and economics of brinjal (*Solanum melongena* L.) under irrigated condition in loamy sand soil of hot arid environment. Application of mulch treatments was found superior with respect to moderation of hydrothermal regimes of soil. The moisture retention capacity and hydraulic conductivity of soil were enhanced by 7.6 to 28% due to FYM mulch as compared to control. FYM mulch, generally, increased the soil chemical fertility status (available N, P and K, exchangeable Ca, and K) by 39 to 87%. The root length density, root mass density and root volume were higher by 370, 392 and 198%, respectively under FYM mulch treatment as compared to the control. These treatments also increased water use efficiency and fruit yield by 24.16 to 34.79 kg/ha-mm and 15 to 19 tonnes/ha, respectively over control. Results indicated that application of soil water conservation practices in arid tropical soils improved soil properties, root growth, water use efficiency and crop yield of brinjal.

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