Indian J. Hort. 70(2), June 2013: 248-254

Effect of manuring and mulches on irrigated arid brinjal in Western India

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ABSTRACT

Field experiments were conducted during 2004-2009 under hot-arid irrigated conditions of western Rajasthan to determine the influence of manuring and mulching on hydrothermal environment of soil, root growth, fruit yield, nutrient removal and economics in brinjal. The FYM mulch and other soil management practices conserved moisture 63 to 144 and 10 to 133%, respectively throughout the crop growth period as compared to control. Mulching with FYM and cluster bean straw lowered the soil temperature by 4.9° and 3.4°C at a depth of 15 cm, and increased the soil temperature by 4.2 and 3.5°C, respectively during the winter season. FYM mulch recorded maximum values of root length to aerial mass ratio (RL/AM) which increased by 140% over control. The root length density (RLD), root weight density (RWD) and root volume (RV) were higher by 370, 392 and 198%, respectively under FYM mulch treatment. Higher fruit yield 173 and 154% were recorded under FYM and cluster bean straw mulching. The N, P and K status was higher under FYM by 363, 392 and 275% over control. Nutrient removal of crops, in general, was significantly higher under FYM mulch over all other treatments. The benefit: cost ratio was the highest (1.91) with FYM mulch as compared to control which was (0.83). The results of the study indicates the possibility that FYM mulch as soil water conservation practice could be an important strategy for the local inhabitants for increasing the production potential of brinjal crop.

Key words: Arid region, brinjal, soil moisture, soil temperature, mulching, plant growth, yield, nutrient uptake, economics.

INTRODUCTION

Brinjal (*Solanum melongena* L.) is an important vegetable crop of western Rajasthan. The crop is widely grown both in rainy and summer seasons. It is often planted at the onset of rainy season. The growth and development of this crop is affected by many edaphic factors but optimum soil temperature and moisture are most crucial. Several factors control soil temperature and moisture but only soil cover and FYM incorporation can manipulate both the regimes to some extent. However, the extent of manipulations of soil cover especially with organic mulches depends on their availability in the particular region. Few studies, however, have assessed the effects of various types of soil covers on hydrothermal regimes of soil and growth and yield of brinjal grown in the sandy soils of hot arid regions (Awasthi *et al*., 4; Singh *et al*., 9). Inadequate moisture in the rhizosphere of the plant may affect the root and vegetative growth, yield and nutrient uptake potential of the crop. Further, water deficit during critical growth stages such as fruit development interferes with cell division and elongation, hence reduce fruit yield. Restricted root growth also results in reduced uptake of moisture, nutrient and low yield (Verma *et al*., 11). Thus, due to unawareness of proper soil water management techniques in sandy soils, farmers are unable to exploit the full potential of the locally grown brinjal crop. In this study, the relative efficacy of different soil water conservation practices has been assessed for regulation of hydrothermal environment of soil, improving the root growth, nutrient uptake, yield of brinjal and their economics which will improve the farm income.

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MATERIALS AND METHODS

Field trials were conducted on Typic Torripsamments (sand 86%, silt 5%, clay 8%) at the research Farm of the Central Institute for Arid Horticulture, Bikaner, Rajasthan receiving a mean annual rainfall of 250 mm. The local brinjal was transplanted in plot size of 5.0 m × 1.5 m (flat bed receiving irrigation through the furrow) during July month of 2004-2009. The region is characterized by nutrient deficient sandy soils, low organic matter, high wind velocity coupled with high evaporation rates, high temperature and solar radiation, erratic rainfall, and water deficit during plant growth period (Table 1). The soil (0-30 cm) has loamy sand texture; single grain structure; bulk density 1.58-1.60 Mg m^{-3}; soil moisture retention capacity ranged from 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^{-1}; pH (1:2.5 soil water suspension) 8.5-8.7; EC 0.16-0.21 dS m^{-1};

Table 1. Climatic features of experimental site in the western Rajasthan region over the study period 2004-2009.

Month	Temperature (°C)		RH (%)		Mean annual rainfall (mm)	Wind speed (km h^{-1}) (mm)	Evaporation (mm day^{-1})
	Max.	Min.	Max.	Min.			
January	21.14	7.20	64.75	31.50	1.44	3.34	3.33
February	28.48	9.38	65.72	29.46	19.00	3.68	5.03
March	34.66	17.58	66.80	27.34	0.92	3.82	7.63
April	39.01	21.40	48.65	49.66	13.80	8.32	10.30
May	42.58	25.00	58.40	54.21	7.48	12.49	12.66
June	41.84	27.82	55.63	50.00	15.00	13.40	11.23
July	38.65	26.61	77.00	38.61	47.80	12.37	12.80
August	36.31	25.57	80.81	36.26	31.41	10.96	9.46
September	36.46	24.47	74.20	42.24	38.70	8.10	9.20
October	35.71	17.80	69.66	41.83	7.22	5.62	7.10
November	29.97	12.21	66.21	31.24	-	3.80	4.00
December	24.87	8.36	75.60	32.81	1.92	3.42	3.00

organic C 0.030-0.033%; total N 0.0021%; available N 65-79 kg ha^{-1}; available (Olsen) P_2O_5 5.7-6.8 kg ha^{-1}; and available K_2O 360-480 kg ha^{-1}; 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^{-1}]; available Fe 5.0-5.8; Mn 4.0-4.5; Cu 0.10-0.18; and Zn 0.10-0.15 mg kg^{-1}.

The experiment was laid out in a randomized block design with four treatments of soil water conservation practices (SWCP), namely Farmyard Manure (FYM) mulch laid on the soil surface, cluster bean (*Cyamopsis tetragonoloba*) straw mulch, *bui* (*Aerva pseudotomentosa*) straw mulch, FYM incorporated and no mulch (control) each replicated thrice. All the treatments were applied after 15 days of transplanting in the month of July each year. The FYM and straw mulches were applied @ 30 and 8 t ha^{-1}, respectively. The cultural practices were carried out as per the recommendation.

Soil samples were collected from each plot (as per the irrigation interval given below) from 0-15 and 15-30 cm depths and their moisture contents were determined gravimetrically. Soil temperature (15 cm depth) was measured at 14.30 hours with Fisher brand bimetal dial thermometers. At the first fruiting stage, five plants/plot were tagged randomly from each treatment and all the growth parameters were recorded. Root growth and proliferation was monitored at harvest stage of brinjal through monoliths method. Root fresh weight was recorded immediately after collection while the root volume (RV) was recorded by water displacement method. Root length (RL) under each monolith section was measured using a modified line intercept method (Tennant, 10). Total root length was divided by the volume of monolith to compute root length density (RLD). The roots were dried in an oven at 70°C and dry matter was determined. Root weight density (RWD) was computed by dividing the root dry weight by volume of monolith. The mean root growth parameters of the depths 0-10, 10-20, and 20-30 cm, are depicted in Table 2.

Surface irrigation with a low pressure plastic pipe was applied at an interval of 3 days during August at 5, 6, 7, 10 and 15 days interval up to January to fulfill the water requirement up to 75% of field capacity. The monthly average soil water use was determined by following the method of soil moisture depletion approach. The mean soil water use in plots treated with FYM, cluster bean, *bui*, FYM incorporation and control was 648, 729, 790, 870 and 956 mm, respectively.

Fruits were harvested from second fortnight every year and data were pooled to calculate the total fruit yield. Dry matter yield was taken at the crop harvest. The plant samples were analysed for major nutrients by standard methods outlined in A.O.A.C (1). The removal of nitrogen, phosphorus and potassium by brinjal crop was calculated using the flowing formulae, Nutrient removal (kg ha^{-1}) = [% nutrient in fruits × fruit yield (kg ha^{-1}) + % nutrient in leaf × leaf yield (kg ha^{-1})]. The data were subjected to analysis of variance using INDOSTAT packages.

RESULTS AND DISCUSSION

Application of different soil water conservation practices markedly influenced the soil moisture content (Fig. 1). During the growing period soil

Table 2. Effect of soil water conservation practices on root growth parameters and fruit yield.

Treatment	Root length density (m m^{-3} × 10^3)	Root weight density (g m^{-3} × 10^3)	Root volume (m^3 m^{-3} × 10^{-3})	Ratio of root length to aerial mass (cm mg^{-1})	Root length (cm)	No. of primary root branches
FYM mulch	1.703	0.818	2.526	0.060	13800	42
Cluster bean straw mulch	0.752	0.323	1.850	0.035	6100	28
Bui straw mulch	0.539	0.234	1.390	0.034	4370	21
FYM incorporation	0.450	0.193	1.043	0.030	3650	11
Control	0.362	0.166	0.846	0.025	2937	10
CD (*P=0.05*)	0.030	0.009	0.048	0.006	115	6

moisture content (mean of monthly average) was found maximum (10.0%) under FYM mulch followed by cluster bean straw (9.0%), *bui* straw (8.2%), FYM incorporation (6.9%) and control (5.3%). The higher soil moisture content in various soil water conservation treatments might be due to reduction in soil surface evaporation and high water retentive capacity because of high organic matter content. This confirms with the results in brinjal of Singh *et al*. (9) and in ginger of Aggarwal *et al*. (2). The cluster bean straw, *bui* straw and FYM incorporation also conserved higher soil moisture in 0 - 0.15 m depth in comparison to control.

The soil temperatures in unmulched treatment at 15 cm depth were significantly higher (31°C) than mulched soil during early growth period (Fig. 2). This might be because of the interception of the sun rays and hot dry air through mulches on the soil surface (Singh *et al*. 9) and has lower content coefficient. During the active growth period, however, soil temperatures ranged from 28.5-36°C which prevailed for almost 40 days after transplanting. FYM incorporation did not have much affect on soil temperature. Mulch treatments, however, significantly (P<0.05) reduced the soil temperature up to 5.4°C during August to October months and thereby lowering the soil temperatures to the optimal range of 28.5-34.6°C (Fig. 2). Generally, the FYM mulch showed the lowest soil temperatures during early growth period followed by cluster bean straw mulch. The marked reduction in soil temperature from mulching was observed during the early period of crop growth. This shows that soil temperature under mulched plots reduced several degrees as comparison to non-mulched. Mulching, thus, reduced the amount of radiant flux reaching the soil surface and probably minimized heat loss by evaporation during the day and inversion of soil temperature gradient at night. The

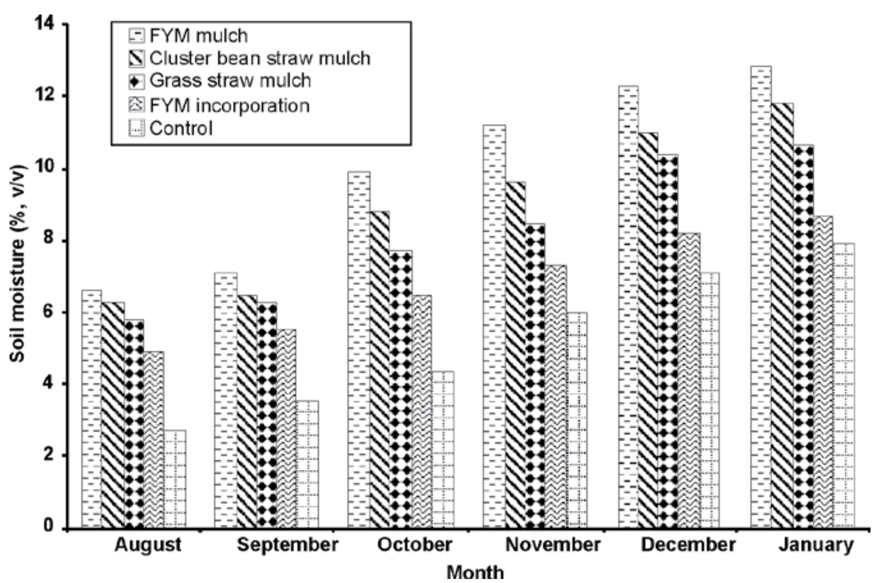

Fig. 1. Monthly average soil moisture content (% v/v) at 0-15 cm depth under different soil water conservation practices.

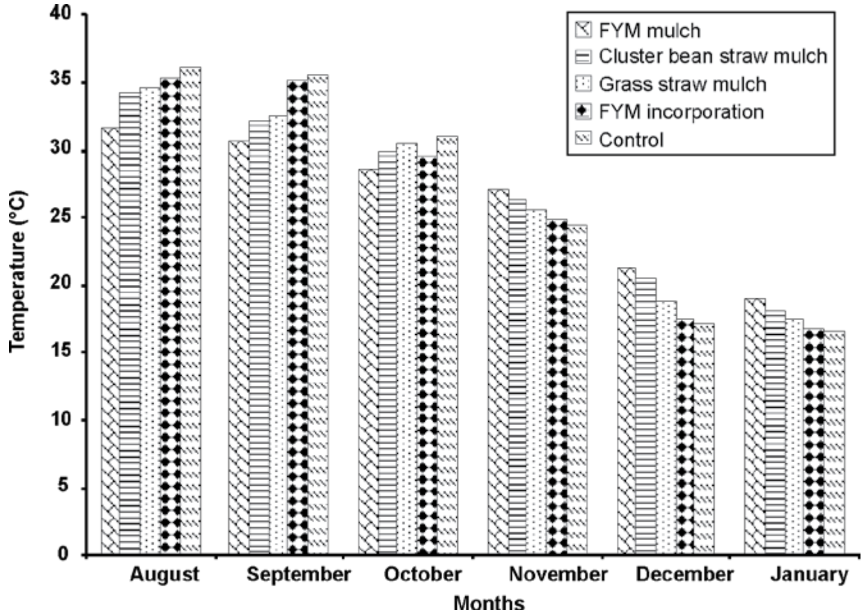

Fig. 2. Monthly average soil temperature (°C) at 0-15 cm depth under different soil water conservation practices.

lower soil temperatures of mulched plots observed in this investigation were in agreement with the results of Awasthi *et al*. (4). In general, soil temperature of the plots treated with different mulches remained remarkably higher (1.0°C) than that of control during winter season, *i.e.* November to January (Fig. 2). The maximum increase in soil temperature was recorded under FYM mulch. However, the plants treated with FYM incorporation registered slightly higher temperature (0.2 to 0.6°C) as compared to control. Similar results on increased soil temperature with the use of organic mulches have been reported by Singh *et al*. (12).

The assumption that the root distribution is mainly concentrated up to a depth of 30 cm was found correct. It has also been observed that only 1% roots mass was observed beyond 30 cm depth. Therefore, the root concentration below 30 cm depth was not taken into account. The soil moisture conservation practices significantly improved the most of the root growth parameters. However, the values of ratio of root length to aerial mass (RL/AM) obtained with FYM incorporation treatment were observed to be at par with control. The FYM mulch treatment estimated maximum values of RL/AM which increased by 140% over control and exactly two orders of magnitude higher than the FYM incorporation treatment. The results are in agreement with the findings of Verma *et al*. (11). The moderation of hydrothermal regimes under FYM mulch treatment significantly affected root growth parameters (RLD, RWD and RV) of brinjal (Table 2). It was observed that RLD, RMD and RV are higher by 370, 392 and 198%, respectively under FYM mulch treatment as compared to the control treatment. The favourable effects of different mulches in modifying the soil environment might be the reason for improved RLD, RWD and RV (Verma *et al*., 11). Besides FYM mulch treatment, other soil water conservation treatments significantly affected the root growth and recorded higher values of RLD, RWD and RV as compared to control. Mulching treatments significantly affected the root expansion (No. of primary branches) potential of the plant, whereas FYM subsurface incorporation treatment was not observed to affecting the growth potential of roots significantly. The highest root length (13800 cm) was recorded under FYM mulch treatment while the lowest under control (2933 cm). FYM mulch treatment also recorded almost four-fold increase in number of primary branches of roots than the control and FYM incorporation treatments, while same was two-fold higher than the grass straw mulch treatment. The poor root growth under un-mulched treatment may be due to unfavourable moisture levels in the soil and the sub-optimal thermal regimes. The results are in consonance with the findings of Gonzalez-Real *et al*. (6).

Plants under soil water conservation practices consisting organic mulches had a faster rate of growth compared to FYM incorporation treatment (Table 3). The highest increase in No. of leaves plant^{-1} (249), plant height (30 cm), No. of shoots plant^{-1} (24), shoot length (25 cm), plant spread (E-W) (29 cm) and plant spread (N-S) (37 cm) were recorded in FYM mulch,

Table 3. Effect of soil water conservation practices on vegetative growth of plant.

Treatment	No. of leaves plant^{-1}	Pl. height (cm)	No. of shoots plant^{-1}	Shoot length (cm)	Plant spread (E-W) (cm)	Plant spread (N-S) (cm)	Fruit yield (t ha^{-1})
FYM mulch	378	80	34	61	61	79	30
Cluster bean straw mulch	245	77	20	60	56	68	26
Bui straw mulch	228	70	20	52	53	59	21
FYM incorporation	133	70	18	46	47	57	15
Control	129	50	10	36	32	42	11
CD (*P=0.05*)	13.03	3.01	8.79	3.28	6.41	3.69	3

followed by cluster bean straw (116 Nos., 27 cm, 10 Nos., 24 cm, 24 cm and 26 cm, respectively). Mulched plants had improved the vegetative growth significantly because they were exposed to ideal hydrothermal regimes, higher water use efficiency and high nutrient supplementation in the root zone during the growth period. The FYM incorporation showed the lowest No. of leaves plant^{-1} (133), plant height (70 cm), No. of shoots plant^{-1} (18), shoot length (46 cm), plant spread (E-W) (47 cm) and plant spread (N-S) (57 cm). This may be attributed to moderate evaporation from soil surface and less buffering of temperature, which could have reduced the growth of the brinjal. The poor plant growth under control treatment may be due to unfavourable moisture levels in the soil, sub-optimal thermal regimes lower water use efficiency and nutrient uptake. Awasthi *et al.* (4) reported that plant growth is affected by inadequate soil moisture.

Soil water conservation practices registered significant increase in fruit yield by 4 t ha^{-1}(FYM incorporation), 10 t ha^{-1} (*Bui* straw mulch), 15 t ha^{-1} (cluster bean straw mulch) and 19 t ha^{-1} (FYM mulch) as compared to the control (Table 3). The fruit yield harvested by application of cluster bean straw mulch and FYM mulch were at par. It seems that buffering capacity to hydrothermal regimes under different treatments might have resulted in differential fruit yield. Among the soil water conservation practices, however, FYM incorporation was observed to produce the lowest yield, possibly because of higher soil temperature and relatively low soil moisture content throughout the crop growth period. This also indicates that soil-accumulated heat might be more related to plant growth and yield than air-accumulated heat. The results are in accordance with the findings of Ali and Talukdar (3). The effects of mulches of FYM and straw, and FYM incorporation have shown significant impacts on major plant nutrient (N, P and K) removal by fruit and straw. The nutrient removal under FYM mulch was higher by 294 kg ha^{-1} of N, 47 kg ha^{-1} of P and 264 kg ha^{-1} of K amounting to 363, 392 and 275% higher, respectively as compared to the control treatment (Fig. 3).

It was noticed that the nutrient removal by crops, in general, was significantly higher under FYM mulch over all other treatments under investigation (Fig. 3). The FYM mulch have shown higher nutrient removal

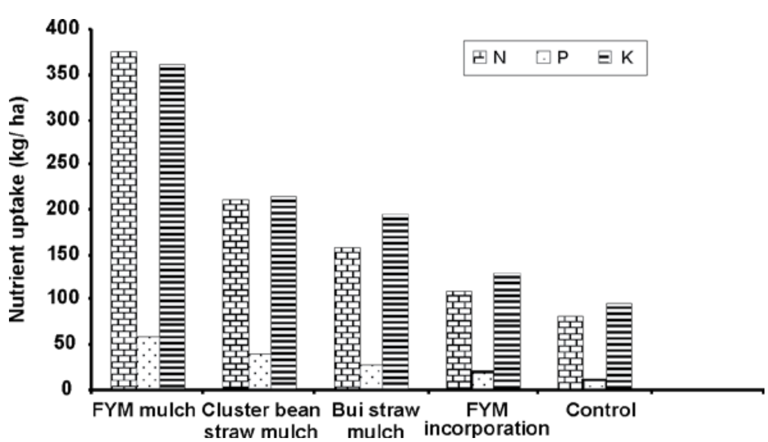

Fig. 3. Effect of soil water conservation practices on removal of nutrient elements (N, P and K) by brinjal crop.

than the other applications could be explained in light of beneficial effect of enhanced root growth, *i.e.*, higher root to shoot ratio (Kuchenbuch and Classen, 7), root density (Nambiar, 8) and root length (Fohse and Jungk, 5) which facilitated higher absorption and uptake of nutrient elements by the crop. Kuchenbuch and Classen (7) pointed out that the root to shoot ratio has a great influence on nutrient uptake and concentration (potassium uptake in their experiments) in plants: the longer the root per unit shoot weight, the higher the nutrient uptake of the plant. According to Nambiar (8), root density (root length per unit volume of soil) is the decisive factor governing nutrient uptake, particularly where nutrient concentrations in the soil solution are low or nutrients are absorbed mainly by root interception and diffusion. Studies conducted by Fohse and Jungk (5), showed that the length of root hairs, which is one factor affecting the size of the "depletion zone" surrounding the root, is also a factor for nutrient uptake in general and for phosphorus and potassium uptake in particular. The root hairs are longer in soils with low phosphorus and potassium levels, becoming shorter as concentration increase. The efficient utilization of nutrients especially under FYM and straw mulches could be expected because of more active root system, conditioned by relatively better hydrothermal regimes. Applied soil water conservation practices were proved to be economically effective and beneficial in enhancing the production potential of eggplant under hot arid ecosystem. Moreover, the pooled results revealed that maximum gross return and net returns were obtained from the FYM much treatment. However, these were drastically reduced with control. Higher benefit: cost ratio (1.91) (Table 4) for five years of application of soil water conservation practices with brinjal was also recorded with FYM mulch treatment.

In conclusion, the present study showed that FYM mulch was significantly more effective in moderating the hydrothermal regimes of soil, improving the root and vegetative growth development, fruit yield and nutrient removal potential of brinjal. On the basis of economic feasibility of applied treatments, FYM mulch was also found to be the most economical treatment. Furthermore, cluster bean straw mulch may be another option for improved physical environment of soil, root growth and yield potential of brinjal crop.

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Table 4. Effect of soil water conservation practices on gross returns, net returns and benefit: cost ratio of brinjal.

Treatment	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
FYM mulch	41,100.00	1,20,000.00	78,900.00	1.91
Cluster bean straw mulch	46,000.00	1,04,000.00	58,000.00	1.26
Bui straw mulch	38,000.00	84,000.00	46,000.00	1.21
FYM incorporation	30,000.00	60,000.00	30,000.00	1.00
Control	24,000.00	44,000.00	20,000.00	0.83
CD (P = 0.05)	2,458.78	2,664.51	1,403.70	0.13

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Received: July, 2011; Revised: November, 2012;
Accepted: March, 2013