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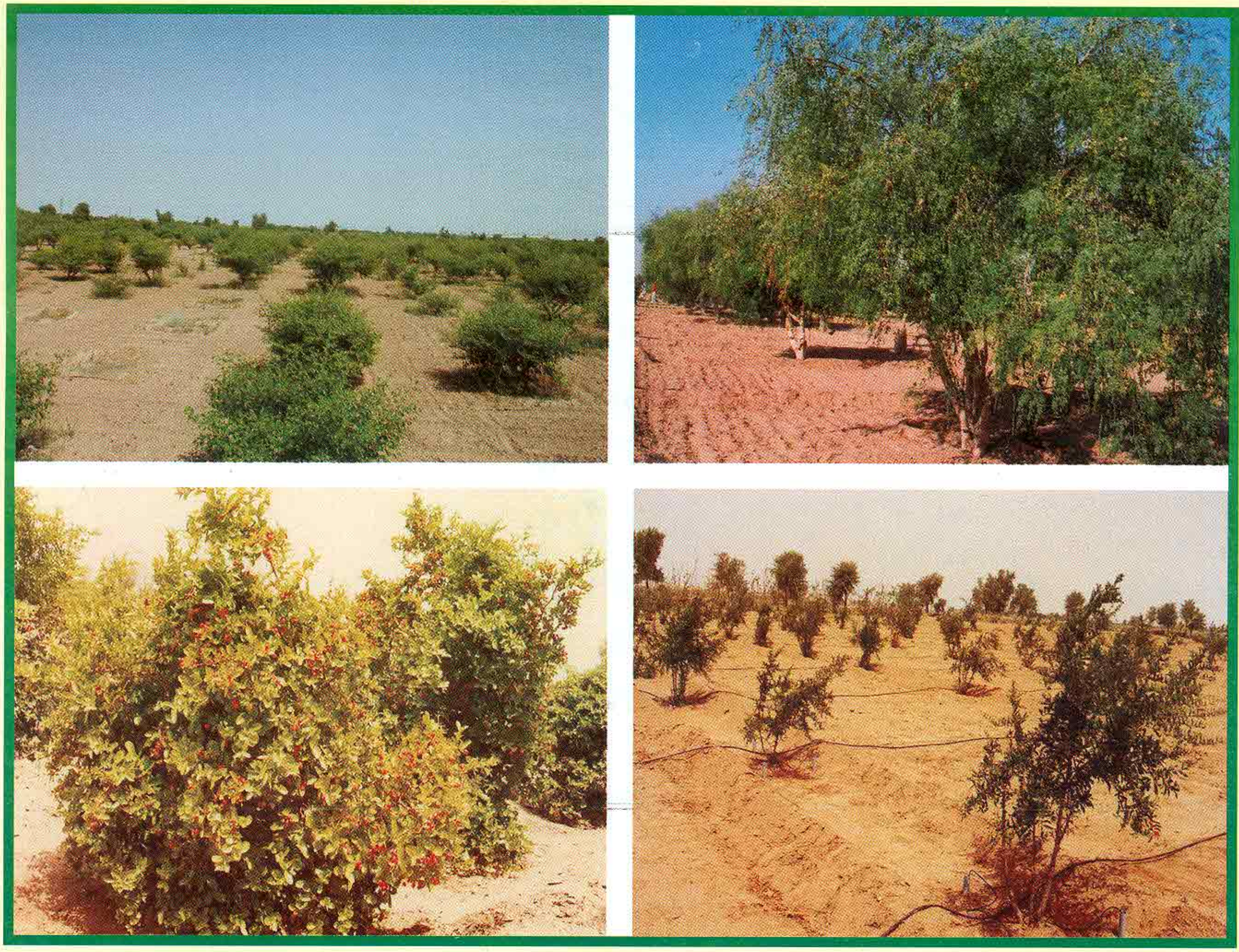
# Soil Fertility Changes Under Fruit Trees in Thar Desert Ecosystem



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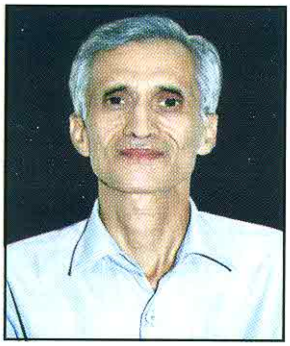

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# FOREWORD

Monitoring of changes in soil fertility under the fruit trees plantation over the period is the most important aspect for managing light textured sandy soils of hot arid regions. The sandy soils of hot arid region are characterized by poor fertility status, coarse textured, low water holding capacity and high infiltration rates. To improve the water and nutrients level in the soil; the plantation of fruit crops is the most beneficial practice as it directly adds much of organic matter to the soil through litterfall and infusion of many nutrients to the available pool of the soil. In natural forests and man-made protected plantations, cycling of nutrients is an important aspect as considerable amount of nutrients are returned through litterfall and become available for recycling. Moreover, the plantation of trees also plays a great role in improving the micro-climate of soil and thereof enhancing the nutrient reserves of the soil by reducing the loss of soil moisture through evaporation caused by high heat of radiation and high wind velocity and volatilizational loss of some nutrient elements from soil. Different tree species give rise to different soil's properties even in the same climatic conditions having similar parent material. The effect of different vegetation to enrich nutrient status depends on various factors such as leaf chemistry, behavior of nutrient, nature of soil, organic matter accumulation and decomposition, microbial activity and quantity of nutrient bearing minerals. Plantation of some tree species like ber (*Ziziphus mauritiana*), pomegranate (*Punica granatum*), drumstick (*Moringa oleifera*), karonda (*Carissa congesta*) and khejri (*Prosopis cineraria*) are considered excellent for improvement of desert soil in Western Rajasthan (India) owing to their faster growth habit, deep rooted and hardy tolerance to adverse climate and edaphic factors and assured economic returns.

These species can be grown on marginal soils having poor soil fertility status (desert soils) and are also fairly tolerant to soil moisture deficit and high soil temperature regimes. Being deciduous in nature, these fruit trees add huge amount of leaf litter into the soil and on decomposition enhances soil nutrient status. Gradual accumulation of mineral nutrients by the perennial trees through leaf fall and incorporation of these into an enlarged plant-litter-soil nutrient cycle is the mechanism responsible for soil enrichment. Information on the changes in soil properties brought by plantation of these fruit crops in dune soils of western Rajasthan would be proved beneficial in quantifying the amount of litterfall and nutrients returned thereof under different plantations and to evaluate their effect on physical and chemical properties.

In the present bulletin entitled "Soil Fertility Changes under Fruit Trees in Thar Desert Ecosystem" an attempt has been made to provide the information on changes/improvement in soil fertility status by some perennial horticultural tree species to make an easy access to students, researchers engaged in soil fertility improvement of desert soils and extension workers. I appreciate the effort made by authors for this useful contribution. I hope the readers would be benefited from this bulletin.

**1st March 2011, Bikaner**

**(S. K. Sharma)**
**Director**

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1

# INTRODUCTION

The soil fertility status, particularly the available nutrient status is an important parameter for raising arable and perennial crops. Soil fertility could be improved, but organic inputs are scarce and mineral fertilizers are often out of reach for the poor farmers of western Rajasthan. Thus, the enhancement of soil fertility assumes importance for sustained agricultural productivity in drought prone regions. It has been perceived by many researchers that the soil productivity of the sandy soils of Thar Desert ecosystem could primarily be enhanced by addition of organic matter to the soil (Aggarwal *et al.*, 1976). The natural addition of organic matter to the soil only takes place through the litterfall from the existing trees/plants which on decomposition increase the soil productivity. The litter decomposition is responsible for quick or slow improvement in sustaining soil productivity. The decomposition process is depending upon the several factors such as chemical composition of litter, soil decomposer composition and climate of the region.

Considering the edaphological conditions, the hot region is suitable for production of perennial fruit crops like ber (*Ziziphus mauritiana*), pomegranate (*Punica granatum*), drumstick (*Moringa oleifera*), karonda (*Carissa congesta*) and khejri (*Prosopis cineraria*). They are also being considered excellent for improvement of desert soil in western Rajasthan owing to their faster growth habit, tolerance to adverse climate and edaphic factors and assured economic returns. These species can be grown even on marginal soils having poor soil fertility status (desert soils) and are also fairly tolerant to soil moisture deficit, high soil temperature and frost, etc.

Being deciduous in nature, these fruit trees add huge amount of leaf litter into the soil and on decomposition may enhance soil nutrient status. The enhancement of soil nutrient status under the canopy of fruit trees may be attributed to their development of an extensive root system that enables the plant to obtain resources from a large soil volume. Since each tree species has a unique form (root, stem and crown), size, rooting structure and phenology thus shows a varied nutrient accumulation and moisture regime in different layers of soil profile. The effect of different vegetations to enrich nutrient status of soil depends on various factors such as the leaf litter chemistry (lignins, C : N ratios), behavior of nutrient, nature of soil, organic matter accumulation, microbial activity, measures of climate (evapotranspiration) and quantity of nutrient bearing minerals (Bhoumik and Totey, 1990). Litter production and nutrient return through tree litterfall vary with age of trees, spacing and other management practices (Singh *et al.*, 2007). The changes in soil physical and chemical properties through tree plantation have been reported by various workers (Singh and Raman, 1982; Aggarwal and Praveen-Kumar, 1990; Sharma and Gupta, 1997). Physical processes are important determinants of the distribution of most cations in the desert shrub lands, however, the distribution of these ions is non-random. On the surface, solar radiation and wind degrade, fragment, and redistribute litter (Gallo *et al.*, 2006). These conditions combined with limited activities of soil fauna reduce the incorporation of foliar litter into soil, thereby slowing the accumulation of soil organic C and N and accumulating the relative contributions of rhizo-deposition and biological crust production to soil C and N pools (Belnap *et al.*, 2005a). But little is known about the effect of fruit tree plantation on physico-chemical properties of soil. Keeping in view of this an effort was carried out to evaluate the effect of fruit trees on soil fertility on smallholder farms in western Rajasthan. Some vegetational parameters of study sites are given in table 1.

**Table 1. Vegetational parameters of study sites**

| Sites | Sequence | Age (Year) | Species | Av. ht. (m) | Av. girth (cm) | Canopy diameter (E-W) (m) | Canopy diameter (N-S) (m) | Plant $ha^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| I | Dune soil | - | - | - | - | - | - | - |
| II | Sole Plantation | 10 | *Ziziphus mauritiana* | 4.6 | 72.3 | 6.96 | 7.57 | 277 |
| III | Diversified Plantation | 5 | *Ziziphus mauritiana* | 3.5 | 67.0 | 4.05 | 4.35 | 156 |
| IV | Sole Plantation | 10 | *Punica granatum* | 2.3 | 30.0 | 3.93 | 4.24 | 156 |
| V | Diversified Plantation | 5 | *Moringa oleifera* | 4.8 | 88.0 | 3.90 | 3.45 | 156 |
| VI | Diversified Plantation | 5 | *Carissa congesta* | 2.1 | 35.0 | 2.70 | 2.70 | 1111 |
| VII | Diversified Plantation | 5 | *Prosopis cineraria* | 3.0 | 46.0 | 2.55 | 2.40 | 156 |

2

# BER (*Ziziphus mauritiana*)

## 2.1 Temporal changes in physical and chemical properties of soil

### 2.1.1 Bulk density and porosity

Fig. 1. Ber plantation

Bulk density of soil under all the two sites showed an increasing trend with depth (Table 2). It was observed that bulk density of initial (before plantation) soils was uniform throughout the profile and same varied from 1.58 to 1.60 Mg $m^{-3}$. The data revealed that the ber plantation could bring down the bulk density in different layers of soil satisfactorily. The reduction in bulk density of top soil layers from 1.58 to 1.37 Mg $m^{-3}$ was observed under 5 years old plantation while same was further reduced to 1.35 Mg $m^{-3}$ under 10 years old plantation (Fig. 1). At 15-30 and 30-60 cm layers, reduction in bulk density showed almost similar pattern as it was in top layer (Table 2). The reduction in bulk density

**Table 2. Temporal changes in bulk density (Mg $m^{-3}$) and porosity (%)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years | After 10 years |
|---|---|---|---|
| **Bulk density** | | | |
| 0.00-0.15 | 1.58 | 1.37 | 1.35 |
| 0.15-0.30 | 1.58 | 1.39 | 1.36 |
| 0.30-0.45 | 1.60 | 1.44 | 1.40 |
| 0.45-0.60 | 1.60 | 1.44 | 1.40 |
| **Porosity** | | | |
| 0.00-0.15 | 42.7 | 45.2 | 48 |
| 0.15-0.30 | 42.7 | 45.0 | 47 |
| 0.30-0.45 | 42.0 | 42.8 | 45 |
| 0.45-0.60 | 42.0 | 42.8 | 45 |

was mainly due to appreciable build up of organic carbon content in different soil layers.

There was an increase in total porosity as recorded in the surface soils (Table 2). In top layers, porosity increased from 42.7 to 45.2% after five year of plantation which further increased to 48.0% after 10 year of plantation. Similar trend was also observed in rest of the soil layers which may be due to the high organic carbon content (Table 4) and also higher annual litter returns by *Ziziphus mauritiana* (Table 28). Increased porosity due to plantation was also reported by Balamurugan *et al.* (2000). The increased porosity is especially important to crop development since it may have direct effect on soil aeration and can enhance root growth. The improved root growth makes it possible for the plant to absorb soil water and nutrients from the subsoil.

### 2.1.2 Moisture status

The vertical distribution of soil water content changed through the development of ber plantation (Table 3). It was found that the amount of moisture retained in the ber plantation field at field capacity and wilting point has been increased throughout the soil profile as compared to bare soil. The soil moisture content increased from 3.21% to 4.37% after 5 years of plantation and shoot up to 10.52% after 10 years of plantation in top soil. Thus, much higher available water holding capacity was observed particularly in top 30 cm soil depth. The considerable increase in moisture content under plantation may be attributed to the higher deposition of litter fall to the soil. The profile moisture content decreased with increase in depth. The five years old plantation has recorded slightly higher soil moisture content (4.11 to 4.37%) as compared to bare site (3.02 to 3.21%). The soil moisture content at filed capacity in the 10 years old orchards was much higher as compared to bare soil. This indicates that fruit (ber) plantations would be highly promising/effective only after 10 years of its plantation in case of sandy soils of hot arid regions. Ber plantation also helped to increase the water content in soil profile at wilting point and it was only 1.54% and has been increased to 2.72% after 10 years period and same trend was also observed in lower soil strata of ber plantation. It was also estimated that the available soil moisture contents also increased and it was only 1.67 to 1.80% different strata of bare soil while it has increased to 7.12 to 7.80% after 10 year period of plantation.

**Table 3. Temporal changes in soil moisture content (% w/w) at different potentials**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years | After 10 years |
|---|---|---|---|
| **Field capacity** | | | |
| 0.00-0.15 | 3.21 | 4.37 | 10.52 |
| 0.15-0.30 | 3.20 | 4.28 | 10.30 |
| 0.30-0.45 | 3.14 | 4.14 | 10.17 |
| 0.45-0.60 | 3.02 | 4.11 | 9.78 |
| **Wilting point** | | | |
| 0.00-0.15 | 1.54 | 1.85 | 2.72 |
| 0.15-0.30 | 1.46 | 1.61 | 2.68 |
| 0.30-0.45 | 1.32 | 1.60 | 2.66 |
| 0.45-0.60 | 1.22 | 1.58 | 2.66 |
| **Available moisture content** | | | |
| 0.00-0.15 | 1.67 | 2.52 | 7.80 |
| 0.15-0.30 | 1.74 | 2.61 | 7.62 |
| 0.30-0.45 | 1.82 | 2.86 | 7.51 |
| 0.45-0.60 | 1.80 | 3.03 | 7.12 |

Vegetation has a strong effect on the vertical dimension pertaining to the chemical properties of the soil profile in deserts. Concentrations of nutrients in the soils under the canopy and adjacent area of the plants are greatest at the soil surface and attenuate with depth. In contrast with mineral derived elements like P and K, plants play an obvious role in the vertical distribution of organic C and total N by controlling most of the organic additions to the soil. Redistribution by plants does not occur for soil organic carbon and may be negligible for total soil N. In the present study, changes in different chemical properties were estimated and given below.

### 2.1.3 Calcium carbonate

One of the striking features of aridity is the presence of calcium carbonate in surface soils as well as in deep substratum, distributed either uniformly throughout the depth or as an accumulative layer (Dhir, 1977). As the recorded concentrations of free $CaCO_3$ content in the bare soil and 5 years old plantations are more than 1%, thus it gives an enough proof to be treated as calcareous soils. Distribution of free calcium carbonate content in the bare soil exhibited decreasing trend with depth. However, under plantations sites no regular trend of its distribution was observed. This may be due to *in-situ* crystallization of calcite in soil groundmass (Chaudhary, 1990). In 10 years old plantation soil, subsurface horizons except surface horizon observed to be devoid of $CaCO_3$ content which might be because of its downward leaching due to cultivation process (Table 4).

**Table 4. Temporal changes in $CaCO_3$ (%) and organic carbon (%) contents**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years | After 10 years |
|---|---|---|---|
| **Calcium carbonate** | | | |
| 0.00-0.15 | 5.0 | 2.5 | 1.5 |
| 0.15-0.30 | 5.0 | 2.0 | 1.3 |
| 0.30-0.45 | 3.5 | 6.0 | 0.0 |
| 0.45-0.60 | 3.0 | 0.0 | 0.0 |
| **Organic carbon** | | | |
| 0.00-0.15 | 0.03 | 0.13 | 0.39 |
| 0.15-0.30 | 0.03 | 0.10 | 0.18 |
| 0.30-0.45 | 0.04 | 0.09 | 0.16 |
| 0.45-0.60 | 0.03 | 0.07 | 0.14 |

## 2.1.4 Organic carbon

The organic carbon varied markedly between plantation and bare soil sites. The organic carbon content was rated low at all the study sites and decreased with depth. The results are in consonance with the findings of Aggarwal *et al.* (1990). They also reported the similar status of organic carbon in soils of hot arid regions of western Rajasthan. Soil organic carbon was recorded to be higher in ber plantations compared with bare soils for the reason that plantation produced enough biomass which on decomposition might have increased the organic carbon content. The organic carbon content ranged from 0.14 to 0.39% under 10 years old plantation whereas same was ranging to the tune of 0.07 to 0.13% under 5 years old plantations. Higher content of organic carbon under plantations may also be facilitated by wetter conditions and lower temperatures which are conducive to organic matter accumulation. On bare site, no such additions of organic matter take place and thus it recorded lower organic carbon content. The above result confirms the findings of Sharma *et al.* (1993) who reported that *Z. rotundifolia* significantly improved the organic carbon status of the soil as compared to other tree combinations (table 4).

## 2.1.5 Exchangeable cations

Exchangeable calcium and magnesium was the dominant cations in soils of all the sites under study and exhibited decreasing trend with depth which might be due to higher free calcium carbonate in the soil solution. The exchangeable calcium and magnesium content under 5 years old plantation soil ranged from 4.8 to 6.5 and 0.8 to 1.6 [cmol (p+) $kg^{-1}$], respectively. The exchangeable calcium and magnesium contents under 10 years old plantations were higher by 2.9 and 0.8 [cmol (p+) $kg^{-1}$] amounting to 57 and 67% higher, respectively as compared to the bare site with the lowest 5.1 and 1.2 [cmol (p+) $kg^{-1}$] which are higher than its critical limits in soil (2 and 2.3 cmol (p+) $kg^{-1}$) (Table 5). Ten years old plantation recorded 23 and 25% higher Ca and Mg cations on the exchange complex as compared to 5 years old plantation which might be due to variation in organic matter mainly in these aspects.

**Table 5. Temporal changes in exchangeable cations [cmol (p+) $kg^{-1}$]**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years | After 10 years |
|---|---|---|---|
| **Exchangeable Ca** | | | |
| 0.00-0.15 | 5.1 | 6.5 | 8.0 |
| 0.15-0.30 | 4.6 | 5.5 | 7.5 |
| 0.30-0.45 | 4.2 | 5.1 | 7.2 |
| 0.45-0.60 | 4.1 | 4.8 | 7.0 |
| **Exchangeable Mg** | | | |
| 0.00-0.15 | 1.2 | 1.6 | 2.0 |
| 0.15-0.30 | 0.5 | 1.5 | 1.7 |
| 0.30-0.45 | 0.4 | 1.3 | 1.6 |
| 0.45-0.60 | 0.5 | 0.8 | 1.5 |

### 2.1.6 Available nitrogen, phosphorus and potassium

In a tropical country like India and particularly in arid areas, nitrogen status is rated as low, and available N status is rarely enough for normal plant growth (Aggarwal *et al.*, 1990). The available nitrogen status in surface soils of studied sites i.e., bare soil (70 kg/ha), 5 years old plantation (100 kg/ha) and 10 years old plantations (213 kg/ha) also seemed to be low (Table 6).

The available phosphorus content in bare soil varied from 5.21 to 9.16 kg/ha with a mean value of 6.86 kg/ha while the mean value of the same was slightly higher (7.5 kg/ha) under 5 years old plantation. However, the highest available P content (12.35 kg/ha) was recorded under 10 years old plantation, which was rated

**Table 6. Temporal changes in available nutrient status (kg ha$^{-1}$)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years | After 10 years |
|---|---|---|---|
| **Available N** | | | |
| 0.00-0.15 | 70 | 100 | 213 |
| 0.15-0.30 | 60 | 94 | 188 |
| 0.30-0.45 | 65 | 88 | 148 |
| 0.45-0.60 | 65 | 88 | 128 |
| **Available $P_2O_5$** | | | |
| 0.00-0.15 | 9.16 | 7.6 | 12.35 |
| 0.15-0.30 | 6.30 | 7.6 | 8.24 |
| 0.30-0.45 | 5.21 | 7.5 | 8.20 |
| 0.45-0.60 | 6.79 | 7.3 | 8.21 |
| **Available $K_2O$** | | | |
| 0.00-0.15 | 477 | 223 | 580 |
| 0.15-0.30 | 433 | 199 | 521 |
| 0.30-0.45 | 348 | 182 | 450 |
| 0.45-0.60 | 348 | 182 | 410 |

as medium level of fertility status. The higher concentrations of soil available P under canopy areas compared to bare areas indicate that more sequestration of this nutrient takes place at more moist soil areas; root uptake and subsequent litterfall may contribute to a localized soil distribution within mature stands of ber. Significant increase in available phosphorus content of the soil with tree plantation has also been reported by Sharma *et al.* (1993) and Hosur and Dasog (1995).

The available potassium content in the bare soil strata ranged from 348 to 477 kg/ha which was rated of high fertility status (Table 6). Higher values of potassium in the light textured soils are due to higher ionic activity of potassium in comparison to calcium and magnesium in soil solution and presence of micaceous minerals (Sharma and Mishra, 1989). The immediate availability of the potassium is related to intensity factor, reserve of non-exchangeable potassium to the quantity factor and replenishment capacity to the potassium buffering capacity (Beckett, 1964). This pattern of distribution of K in the surface and subsurface soils seems to be closely associated with the distribution of organic carbon in different layers of soil which indicates positive effect of plantations on fertility attributes of the soil. Five years young orchards recorded lower quantities of available K content as compared to control. The results are quite expected as the plants in the younger stage consume nutrients more for their development and return less.

3

# POMEGRANATE (*Punica granatum*)

## 3.1 Temporal changes in physical and chemical properties of soil

### 3.1.1 Bulk density and porosity

Improvement in bulk density and porosity of soils under pomegranate (Fig 2) were more or less similar to that of the soil under ber plantation. Moreover, the bulk density under the pomegranate plantation (1.40 Mg $m^{-3}$) was much lower in comparison to that of the soil in the control (1.58 Mg $m^{-3}$) (Table 7). Bulk density at the plantation site increased with depth, and ranged from 1.40 to 1.44 Mg $m^{-3}$. This decrease in bulk density might be due to the organic matter addition, increased concentration of roots which lead to loosening of soil and the greater soil faunal activity.

Fig. 2. Pomegranate plantation

Table 7. Temporal changes in bulk density (Mg $m^{-3}$) and porosity (%)

| Soil depth (m) | Before plantation (Initial soil) | After 10 years |
|---|---|---|
| **Bulk density** | | |
| 0.00-0.15 | 1.58 | 1.40 |
| 0.15-0.30 | 1.58 | 1.42 |
| 0.30-0.45 | 1.60 | 1.42 |
| 0.45-0.60 | 1.60 | 1.44 |
| **Porosity** | | |
| 0.00-0.15 | 42.7 | 46 |
| 0.15-0.30 | 42.7 | 45 |
| 0.30-0.45 | 42.0 | 45 |
| 0.45-0.60 | 42.0 | 44 |

### 3.1.2 Moisture status

Pertaining to the distribution pattern of other physical properties like porosity, moisture content at field capacity, wilting point and available water content, a general decreasing trend was noted in their contents with increase in depth of the soil. Pomegranate improved the soil moisture retention status both at field capacity and wilting point of the soil (Table 8) and this may be attributed to lower bulk density and higher organic matter content. Although, the distribution pattern of available water content was similar throughout the profile but same was found two fold higher compared to the control. The increase in porosity (Table 7) and organic matter addition (Table 9) may be the reasons for increasing the available water content of the soil.

**Table 8. Temporal changes in soil moisture content (% w/w) at different potentials**

| Soil depth (m) | Before plantation (Initial soil) | After 10 years |
|---|---|---|
| **Field capacity** | | |
| 0.00-0.15 | 3.21 | 7.30 |
| 0.15-0.30 | 3.20 | 7.05 |
| 0.30-0.45 | 3.14 | 7.00 |
| 0.45-0.60 | 3.02 | 6.85 |
| **Wilting point** | | |
| 0.00-0.15 | 1.54 | 2.40 |
| 0.15-0.30 | 1.46 | 2.30 |
| 0.30-0.45 | 1.32 | 2.20 |
| 0.45-0.60 | 1.22 | 2.00 |
| **Available moisture content** | | |
| 0.00-0.15 | 1.67 | 4.90 |
| 0.15-0.30 | 1.74 | 4.75 |
| 0.30-0.45 | 1.82 | 4.80 |
| 0.45-0.60 | 1.80 | 4.85 |

### 3.1.3 Calcium carbonate

The free $CaCO_3$ content ranges between 3.0 and 5.0%, whereas same ranges between 0.0 to 1.0% at the plantation sites. Soil of both the sites recorded maximum $CaCO_3$ content in the surface layer and the same was found to be decreased with depth. Under the plantation site surface layer exhibited calcareous reaction while underlying sub-soils were devoid of free calcium carbonate contents may be due to leaching of $CaCO_3$ along with irrigation water in the lower horizons.

### 3.1.4 Organic carbon

Maximum organic carbon content was recorded in the surface (0.25%) and subsurface soils (0.08%) under the canopy area of pomegranate. The improvement in organic carbon content could take place due to high rate of litter fall, and its incorporation into the soil. Application of FYM around the basin and their protection from erosion below the canopy area may be the probable reasons for higher organic carbon content than the bare spaces (Table 9).

**Table 9. Temporal changes in $CaCO_3$ (%) and organic carbon (%) contents**

| Soil depth (m) | Before plantation (Initial soil) | After 10 years |
|---|---|---|
| **$CaCO_3$** | | |
| 0.00-0.15 | 5.0 | 1.0 |
| 0.15-0.30 | 5.0 | 1.0 |
| 0.30-0.45 | 3.5 | 0.0 |
| 0.45-0.60 | 3.0 | 0.0 |
| **Organic carbon** | | |
| 0.00-0.15 | 0.03 | 0.25 |
| 0.15-0.30 | 0.03 | 0.08 |
| 0.30-0.45 | 0.04 | 0.06 |
| 0.45-0.60 | 0.03 | 0.05 |

### 3.1.5 Exchangeable cations

Plantation sites recorded the available Ca content in the range of 4.6 to 6.8 [cmol (p+) $kg^{-1}$]. It was also observed that overall exchangeable calcium content recorded at both the sites throughout the soil strata was found to be at par. However, surface soil at plantation sites registered appreciably higher Ca content than the bare sites which might be ascribed to higher organic matter content, upward uptake of Ca with the soil solution from the lower horizons and their accumulation in the same soil layer. While regarding Mg distribution in the soil strata, plantation site [1.4 to 2.0 cmol (p+) $kg^{-1}$] has shown substantially higher content compared to the bare site (0.4 to 0.2 cmol (p+) $kg^{-1}$). Except the surface layer, the plantation site showed uniform distribution of Mg in the subsoil layers (Table 10).

**Table 10. Temporal changes in exchangeable cations [cmol (p+) $kg^{-1}$]**

| Soil depth (m) | Before plantation (Initial soil) | After 10 years |
|---|---|---|
| **Exchangeable Ca** | | |
| 0.00-0.15 | 5.1 | 6.8 |
| 0.15-0.30 | 4.6 | 5.2 |
| 0.30-0.45 | 4.2 | 4.8 |
| 0.45-0.60 | 4.1 | 4.6 |
| **Exchangeable Mg** | | |
| 0.00-0.15 | 1.2 | 2.0 |
| 0.15-0.30 | 0.5 | 1.5 |
| 0.30-0.45 | 0.4 | 1.5 |
| 0.45-0.60 | 0.5 | 1.4 |

### 3.1.6 Available nitrogen, phosphorus and potassium

Pomegranate plantation also consisted of substantially higher available nitrogen content throughout the soil strata as compared to the bare soil. The available nitrogen content under the plantation soil strata varied from 100 to 180 kg/ha and the same has been depicted decreasing trend with increase in depth of soil.

**Table 11. Temporal changes in available nutrient status (kg $ha^{-1}$)**

| Soil depth (m) | Before plantation (Initial soil) | After 10 years |
|---|---|---|
| **Available N** | | |
| 0.00-0.15 | 70 | 180 |
| 0.15-0.30 | 60 | 134 |
| 0.30-0.45 | 65 | 116 |
| 0.45-0.60 | 65 | 100 |
| **Available $P_2O_5$** | | |
| 0.00-0.15 | 9.16 | 10.67 |
| 0.15-0.30 | 6.30 | 7.46 |
| 0.30-0.45 | 5.21 | 7.08 |
| 0.45-0.60 | 6.79 | 6.98 |
| **Available. $K_2O$** | | |
| 0.00-0.15 | 477 | 515 |
| 0.15-0.30 | 433 | 475 |
| 0.30-0.45 | 348 | 430 |
| 0.45-0.60 | 348 | 393 |

Level of Phosphorus concentration was found to be slightly higher below the canopy area rather than bare areas. As compared to bare areas, phosphorus content below the canopy area of pomegranate in surface and subsurface soil increased by 34.7 and 34.8%, respectively (Table 11).

Soils under pomegranate trees have recorded 8 to 24% higher available potassium content over the bare sites. The available K content in soil strata under plantation has shown a poor potential activity in the maintenance of fertility status of soil. Therefore, the nutrient status of the soils was very little changed by the fruit tree plantation. Thus soils belong to the order Entisols and near calcareous pH are well adopted for the plantation of the arid fruit crop.

4

# DRUMSTICK (*Moringa oleifera*)

## 4.1 Temporal changes in physical and chemical properties of soil

### 4.1.1 Bulk density and porosity

Reduction in bulk density of soil at all the depths under both the sites was noticed as compared to control site (no plantation), however, the change was not substantial. Under drumstick plantation (Fig 3), accumulation of litter and humus on soil surface reduced the bulk density reaching 1.40 Mg $m^{-3}$ while the lowest bulk density in sub-layers was about 1.41 Mg $m^{-3}$ (Table 12). The decrease in bulk density may be attributed to increased interaction between soil and plant roots, addition of organic matter, increased concentration of roots which lead to loosening of soil and the greater soil faunal activity (Balamurugan *et al.*, 2000). Change of bulk density may affect soil porosity. Therefore, as a result of little decrease in bulk

Fig. 3. Drumstick plantation

**Table 12. Temporal changes in bulk density (Mg $m^{-3}$) and porosity (%)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Bulk density** | | |
| 0.00-0.15 | 1.58 | 1.40 |
| 0.15-0.30 | 1.58 | 1.41 |
| 0.30-0.45 | 1.60 | 1.45 |
| 0.45-0.60 | 1.60 | 1.45 |
| **Porosity** | | |
| 0.00-0.15 | 42.7 | 44.7 |
| 0.15-0.30 | 42.7 | 44.4 |
| 0.30-0.45 | 42.0 | 42.7 |
| 0.45-0.60 | 42.0 | 42.7 |

density of soil, 2 to 5% increase in porosity of soils under plantations was recorded. The influence of plantation on the physical properties was obviously due to the differential organic matter addition, root densities, root length and soil faunal activity.

### 4.1.2 Moisture status

Results showed that moisture content in the surface soils at field capacity was the lowest for bare site (3.21%) and highest (4.12%) for drumstick (Table 13). Similar kind of improvement in other soil moisture constants (wilting point and available water content) was also observed due to the young plantation. The effect is ascribed to increased porosity of soil due to higher availability of organic carbon obtained from higher annual return of leaf litter. The result is in agreement with the findings of Sharma (2005) who reported that a matured (10 years old) *Prosopis cineraria* exhibited maximum water storage under the tree canopy as compared to open spaces. Hence, all the soil physical properties have been shown to depend largely on carbon balance (Quiroga *et al.*, 1998).

**Table 13. Temporal changes in soil moisture content at different potentials**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Field capacity** | | |
| 0.00-0.15 | 3.21 | 4.12 |
| 0.15-0.30 | 3.20 | 4.05 |
| 0.30-0.45 | 3.14 | 3.97 |
| 0.45-0.60 | 3.02 | 3.92 |
| **Wilting point** | | |
| 0.00-0.15 | 1.54 | 2.00 |
| 0.15-0.30 | 1.46 | 1.89 |
| 0.30-0.45 | 1.32 | 1.57 |
| 0.45-0.60 | 1.22 | 1.40 |
| **Available water content** | | |
| 0.00-0.15 | 1.67 | 2.12 |
| 0.15-0.30 | 1.74 | 2.16 |
| 0.30-0.45 | 1.82 | 2.40 |
| 0.45-0.60 | 1.80 | 2.52 |

### 4.1.3 Calcium carbonate

Measured calcium carbonate values in the soil horizons for the two profiles varied from 0.0 to 5.0%; $CaCO_3$ values were lowest or negligible in two lowermost horizons under the plantation sites (0.0%) (Table 14). This suggests the benefit of fruit plantation in increasing the productivity of sandy soils because higher calcium carbonate content inhibits the uptake of most of the essential micronutrient for the plants.

**Table 14. Temporal changes in $CaCO_3$ (%) and organic carbon (%) contents**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **$CaCO_3$** | | |
| 0.00-0.15 | 5.0 | 0.5 |
| 0.15-0.30 | 5.0 | 1.0 |
| 0.30-0.45 | 3.5 | 0.0 |
| 0.45-0.60 | 3.0 | 0.0 |
| **Organic carbon** | | |
| 0.00-0.15 | 0.03 | 0.10 |
| 0.15-0.30 | 0.03 | 0.08 |
| 0.30-0.45 | 0.04 | 0.08 |
| 0.45-0.60 | 0.03 | 0.05 |

### 4.1.4 Organic carbon

Measured organic C values in the soil horizons for the two profiles varied from 0.03 to 0.04% and 0.05 to 0.10% at bare soil and plantation sites (Table 14), respectively. This may be due to favourable soil temperature and moisture conditions in the soil. Organic C values were found to be the highest in first two soil layers in the plantation sites where the leaf litter addition and overall root biomass was maximum. This is in accordance with the findings of Sharma *et al.* (1993) and Sharma *et al.* (1994). Organic carbon content underneath the canopy of the plantations, in general, decreased with depth. The differences between the four depths point to a strong stratification/accumulation of soil organic carbon at 0-15 and 15-30 cm soil depths, where the below surface carbon contents (particularly, 30-45 and 45-60 cm depths) under the plantation accounted for 25 to 60% of surface carbon. Similar results were reported by Franzluebbers (2002) who found generally higher stratification ratios for organic carbon under hot and low organic matter environments.

### 4.1.5 Exchangeable cations

The exchangeable cations viz. calcium and magnesium were recorded to be lower under the plantations sites compared to control site. This might be due to a part of absorbed nutrients retained in the plant systems for making their tissues because of the young nature of plantations. Calcium was the most dominant exchangeable cation (3.8 to 4.5 cmol (p+) $kg^{-1}$) followed by magnesium [0.6 to 0.9 cmol (p+) $kg^{-1}$] (table 15). While analyzing the sandy soils of western Rajasthan, Dhir *et al.* (1991) found the similar results. Calcium in general was the highest in the surface horizons for all the studied soils. This might be attributed to calcium addition at the surface by wind also (Khresat *et al.*, 1998). Exchangeable magnesium showed light differences between the surface and subsurface horizons. This suggests that the extractable cations, though small tend to accumulate in the upper soil layers. Marion *et al.* (2008) also showed the higher concentration of essential nutrients likes N, K, Ca and Mg beneath the plant canopy near the surface soils. Total bases recorded under the fruit tree were at par with the values recorded in control. These results are quite expected as the plants in the younger stage consume nutrients more for their development and return less (Nath *et al.*, 1988).

**Table 15. Temporal changes in exchangeable cations [cmol (p+) $kg^{-1}$]**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Exchangeable Ca** | | |
| 0.00-0.15 | 5.1 | 4.5 |
| 0.15-0.30 | 4.6 | 4.5 |
| 0.30-0.45 | 4.2 | 4.0 |
| 0.45-0.60 | 4.1 | 3.8 |
| **Exchangeable Mg** | | |
| 0.00-0.15 | 1.2 | 0.9 |
| 0.15-0.30 | 0.5 | 0.7 |
| 0.30-0.45 | 0.4 | 0.6 |
| 0.45-0.60 | 0.5 | 0.7 |

### 4.1.6 Available nitrogen, phosphorus and potassium

The soil available nitrogen is also concentrated in the top 30 cm under the plantation sites. The available N in the open spaces of study sites ranged from 60 to 70 kg/ha whereas under vegetation varied from 80 to 94 kg $ha^{-1}$, respectively (Table 16). The results related to available nutrient status of bare soils are in agreement with the values reported by Sharma (2005). Many studies on soil nutrient status have shown that soils under trees are richer in nutrients compared with soil from without tree area (Sharma and Gupta, 2001). They stated that leaf litter is related more closely with N-cycling as nitrogen is bound up in organic molecules.

Aggarwal and Praveen-Kumar (1990) and Sharma (2005) also reported that available N content in soil under *Prosopis cineraria* and *Acacia albida* was considerably higher than that of the bare field.

The concentration of available phosphorus in bare field ranged from 5.21 to 9.16 kg/ha which agreed with the values reported by Dhir (1990) in soils of western Rajasthan. Available phosphorus content was recorded to be decreased in soil under the plantations (6.0 to 7.3 kg/ha) compared to control site (Table 16). Thus, the result revealed that in case of soil enrichment by young plantation, the parent material determines more significantly the fraction of available P rather than the amount of litter fall received to the soil surface and characteristics of litter material. The content of available phosphorus showed a decreasing pattern with depth; however, surface layers registered the highest content of available phosphorus under plantation sites including control. Only marginal decrease in nutrient status after 5 years of plantation suggests the sustainability of the system. It has been observed that the cited arid fruit tree species require very little mineral nutrient input and are able to thrive best on sandy soils of poor nutrient regimes.

**Table 16. Temporal changes in available nutrient status (kg $ha^{-1}$)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Available N** | | |
| 0.00-0.15 | 70 | 94 |
| 0.15-0.30 | 60 | 90 |
| 0.30-0.45 | 65 | 80 |
| 0.45-0.60 | 65 | 80 |
| **Available $P_2O_5$** | | |
| 0.00-0.15 | 9.16 | 7.3 |
| 0.15-0.30 | 6.30 | 6.3 |
| 0.30-0.45 | 5.21 | 6.3 |
| 0.45-0.60 | 6.79 | 6.0 |
| **Available $K_2O$** | | |
| 0.00-0.15 | 477 | 468 |
| 0.15-0.30 | 433 | 430 |
| 0.30-0.45 | 348 | 336 |
| 0.45-0.60 | 348 | 330 |

The results depict that in spite of young nature of plants the contents of K seems to be at par with the control site which may be due to constant replenishment of K by the plant roots and addition of substantial amount of leaf litter to the soil mass.

5

# KARONDA (*Carissa congesta*)

## 5.1 Temporal changes in physical and chemical properties of soil

### 5.1.1 Bulk density and porosity

Soil bulk density at the plantation site (Fig 4) showed very similar values and the average was 1.47 Mg $m^{-3}$ while porosity varied from 42.1 to 42.9% which is also very close to the values obtained for bare soil. Table 17 showed the marked homogeneity of the soil physical characteristics along the soil profile may be because of less vegetative growth and young nature of plantation.

Fig. 4. Karonda plantation

Table 17. Temporal changes in bulk density (Mg $m^{-3}$) and porosity (%)

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Bulk density** | | |
| 0.00-0.15 | 1.58 | 1.45 |
| 0.15-0.30 | 1.58 | 1.47 |
| 0.30-0.45 | 1.60 | 1.48 |
| 0.45-0.60 | 1.60 | 1.48 |
| **Porosity** | | |
| 0.00-0.15 | 42.7 | 42.9 |
| 0.15-0.30 | 42.7 | 42.7 |
| 0.30-0.45 | 42.0 | 42.1 |
| 0.45-0.60 | 42.0 | 42.1 |

### 5.1.2 Moisture status

The soil moisture content of different soil layers at field capacity were found uniform and at par to the values under bare soil: about 3.64% (w/w) throughout the soil strata. The maximum soil moisture values at field capacity varied between 3.21% w/w at bare site and 3.67% w/w at plantation site (Table 18). The water content at wilting point was also observed to be followed the similar trend of water content at field capacity. The sandy soils being homogeneous in physical characteristics consisted of uniform available soil moisture content (i.e. from 1.96 to 2.18% w/w) in the different soil layers.

**Table 18. Temporal changes in soil moisture contents at different potentials**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Field capacity** | | |
| 0.00-0.15 | 3.21 | 3.67 |
| 0.15-0.30 | 3.20 | 3.64 |
| 0.30-0.45 | 3.14 | 3.64 |
| 0.45-0.60 | 3.02 | 3.63 |
| **Wilting point** | | |
| 0.00-0.15 | 1.54 | 1.71 |
| 0.15-0.30 | 1.46 | 1.48 |
| 0.30-0.45 | 1.32 | 1.46 |
| 0.45-0.60 | 1.22 | 1.46 |
| **Available moisture content** | | |
| 0.00-0.15 | 1.67 | 1.96 |
| 0.15-0.30 | 1.74 | 2.16 |
| 0.30-0.45 | 1.82 | 2.18 |
| 0.45-0.60 | 1.80 | 2.17 |

### 5.1.3 Calcium carbonate

Calcium carbonate contents throughout the soil strata were found to be consistently lower under the plantation sites than the bare soil sites (Table 19), which were indicative of differences in long-term soil moisture dynamics, with deeper moisture percolation in the soils under the plantation.

**Table 19. Temporal changes in $CaCO_3$ (%) and organic carbon (%) contents**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| $CaCO_3$ | | |
| 0.00-0.15 | 5.0 | 3.5 |
| 0.15-0.30 | 5.0 | 2.1 |
| 0.30-0.45 | 3.5 | 1.5 |
| 0.45-0.60 | 3.0 | 1.0 |
| Organic carbon | | |
| 0.00-0.15 | 0.03 | 0.06 |
| 0.15-0.30 | 0.03 | 0.05 |
| 0.30-0.45 | 0.04 | 0.05 |
| 0.45-0.60 | 0.03 | 0.04 |

### 5.1.4 Organic carbon

The mean values of organic carbon content varied from 0.03% in bare soil to 0.05% (Table 19) in soils under karonda plantation. However, no substantial crop induced change was recorded at the surface layer of karonda plantations, which might be due to lower canopy growth and subsequently less addition of biomass in the surface soils.

### 5.1.5 Exchangeable cations

Young karonda plantation was not observed to be effective in increasing the essential nutrient content (Ca) of soil due to its young nature. However, the overall

**Table 20. Temporal changes in exchangeable cations [cmol (p+) $kg^{-1}$]**

| Soil depth (m) | Bare soil | After 5 years |
|---|---|---|
| **Exchangeable Ca** | | |
| 0.00-0.15 | 5.1 | 3.9 |
| 0.15-0.30 | 4.6 | 3.6 |
| 0.30-0.45 | 4.2 | 3.5 |
| 0.45-0.60 | 4.1 | 3.5 |
| **Exchangeable Mg** | | |
| 0.00-0.15 | 1.2 | 0.9 |
| 0.15-0.30 | 0.5 | 0.6 |
| 0.30-0.45 | 0.4 | 0.7 |
| 0.45-0.60 | 0.5 | 0.7 |

mean Mg content concentrated in the soil strata of young plantation was found to be at par with the mean calcium content under bare soil strata (Table 20).

### 5.1.6 Available nitrogen, phosphorus and potassium

The amount of available N varied from 80 to 86 kg/ha in the profiles studied and the surface soils contained relatively higher amounts (Table 21). In general, its content decreased with depth. At all the depths the soil available N content was not observed to be much greater under karonda plantation compared to bare soil, possibly suggesting that less N storage from comparatively lesser litter input.

**Table 21. Temporal changes in available nutrient status (kg $ha^{-1}$)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Available N** | | |
| 0.00-0.15 | 70 | 86 |
| 0.15-0.30 | 60 | 82 |
| 0.30-0.45 | 65 | 80 |
| 0.45-0.60 | 65 | 80 |
| **Available $P_2O_5$** | | |
| 0.00-0.15 | 9.16 | 8.2 |
| 0.15-0.30 | 6.30 | 8.0 |
| 0.30-0.45 | 5.21 | 8.0 |
| 0.45-0.60 | 6.79 | 7.3 |
| **Available $K_2O$** | | |
| 0.00-0.15 | 477 | 301 |
| 0.15-0.30 | 433 | 288 |
| 0.30-0.45 | 348 | 253 |
| 0.45-0.60 | 348 | 270 |

In spite of the young nature and less contribution of nutrient (P) through the litterfall the karonda plantation has registered slightly higher P content in the soil strata which may be attributed to major contribution solely made by the added FYM to the soil.

The available K content in the open spaces (control) of study sites ranged from 348 to 477 kg/ha, whereas, the same in the sites under plantation ranged from 253 to 301 kg/ha in the soil strata, respectively (Table 21). No improvement in soil available K content had taken place in karonda plantation.

6

# KHEJRI (*Prosopis cineraria*)

## 6.1 Temporal changes in physical and chemical properties of soil

### 6.1.1 Bulk density and porosity

Data in table 22 indicate that with increasing depth there is a gradual increase in bulk density whereas just reverse trend i.e. decreasing pattern noted in case of porosity of soil. But the less porosity of soils under plantation site is rather conspicuous and is due to mechanical compaction of lower soil surfaces through movement of heavy machine (tractor) and very less canopy development.

**Table 22. Temporal changes in bulk density (Mg m$^{-3}$) and porosity (%)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Bulk density** | | |
| 0.00-0.15 | 1.58 | 1.46 |
| 0.15-0.30 | 1.58 | 1.46 |
| 0.30-0.45 | 1.60 | 1.49 |
| 0.45-0.60 | 1.60 | 1.50 |
| **Porosity** | | |
| 0.00-0.15 | 42.7 | 42.0 |
| 0.15-0.30 | 42.7 | 41.8 |
| 0.30-0.45 | 42.0 | 41.3 |
| 0.45-0.60 | 42.0 | 40.5 |

### 6.1.2 Moisture status

Moisture contents at the field capacity and wilting point were found to be consistently higher in the plantation sites (Fig 5) than in the bare sites (Table 23), suggesting the compaction of soil layers due to movement of heavy machines,


Fig. 5. Khejri plantation

hence, the available water content showed an increasing trend with depth in both the sites under study.

**Table 23. Temporal changes in soil moisture content (%) at different potentials**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Field capacity** | | |
| 0.00-0.15 | 3.21 | 3.60 |
| 0.15-0.30 | 3.20 | 3.60 |
| 0.30-0.45 | 3.14 | 3.57 |
| 0.45-0.60 | 3.02 | 3.55 |
| **Wilting point** | | |
| 0.00-0.15 | 1.54 | 1.61 |
| 0.15-0.30 | 1.46 | 1.50 |
| 0.30-0.45 | 1.32 | 1.36 |
| 0.45-0.60 | 1.22 | 1.22 |
| **Available moisture content** | | |
| 0.00-0.15 | 1.67 | 1.99 |
| 0.15-0.30 | 1.74 | 2.10 |
| 0.30-0.45 | 1.82 | 2.21 |
| 0.45-0.60 | 1.80 | 2.33 |

## 6.1.3 Calcium carbonate

Plantation site showed substantially lower calcium carbonate content compared to the bare site. The free calcium carbonate under the plantation ranged from 1.0 to 1.6% in the top 0-30 cm and the two lowermost soil layers were devoid of calcium carbonate content (Table 24). The subsurface soil layer which was just below the surface layer contained maximum calcium carbonate.

## 6.1.4 Organic carbon

The organic carbon content under the plantation was almost similar to the bare soil with mean values of 0.03% and 0.04% of plantation soil (Table 24). And the values obtained from different soil strata revealed that organic carbon occurred in narrow range and it was distributed almost evenly along the vertical soil strata. Thus the results have brought out that the young plantation soils of western Rajasthan were not rich in organic carbon. This may be because of constant management of cultural practices.

**Table 24. Temporal changes in $CaCO_3$ (%) and organic carbon (%) content**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **$CaCO_3$** | | |
| 0.00-0.15 | 5.0 | 1.0 |
| 0.15-0.30 | 5.0 | 1.6 |
| 0.30-0.45 | 3.5 | 0.0 |
| 0.45-0.60 | 3.0 | 0.0 |
| **Organic carbon** | | |
| 0.00-0.15 | 0.03 | 0.05 |
| 0.15-0.30 | 0.03 | 0.05 |
| 0.30-0.45 | 0.04 | 0.04 |
| 0.45-0.60 | 0.03 | 0.04 |

## 6.1.5 Exchangeable cations

Similar to the pattern of other available nutrient content in the young plantation sites, a substantial decrease in exchangeable Ca contents was also recorded (Table 25). Thus plantation has exhibited negative balance on availability status of calcium nutrient in the soil strata. The probable reason is that the calcium accumulates in greater quantities in the foliage than the other cations and also does not go out of the foliage just before leaf fall as large portions of other elements do (Banerjee and Badola, 1980). However, the concentration of Mg in the soil strata seems to be slightly higher than the bare soil strata (Table 25) which are indicative of intervention of cultural practices at the plantation sites.

**Table 25. Temporal changes in exchangeable cations [cmol (p+) $kg^{-1}$]**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Exchangeable Ca** | | |
| 0.00-0.15 | 5.1 | 3.6 |
| 0.15-0.30 | 4.6 | 3.0 |
| 0.30-0.45 | 4.2 | 3.0 |
| 0.45-0.60 | 4.1 | 2.8 |
| **Exchangeable Mg** | | |
| 0.00-0.15 | 1.2 | 1.6 |
| 0.15-0.30 | 0.5 | 1.4 |
| 0.30-0.45 | 0.4 | 1.4 |
| 0.45-0.60 | 0.5 | 0.6 |

### 6.1.6 Available nitrogen, phosphorus and potassium

Mean values for N under the plantation sites (71 kg/ha) were found to be more or less similar to their mean concentrations in bare soils (65 kg/ha) (Table 26). The khejri plantation also showed lower concentrations of K as compared to bare soil which may be due to higher uptake of nutrients rather than contribution to soil mass through litter fall. All these nutrients showed in general a decreasing trend with depth.

**Table 26. Temporal changes in available nutrient status (kg $ha^{-1}$)**

| Soil depth (m) | Before plantation (Initial soil) | After 5 years |
|---|---|---|
| **Available N** | | |
| 0.00-0.15 | 70 | 75 |
| 0.15-0.30 | 60 | 70 |
| 0.30-0.45 | 65 | 70 |
| 0.45-0.60 | 65 | 69 |
| **Available $P_2O_5$** | | |
| 0.00-0.15 | 9.16 | 9.0 |
| 0.15-0.30 | 6.30 | 8.5 |
| 0.30-0.45 | 5.21 | 8.6 |
| 0.45-0.60 | 6.79 | 8.5 |
| **Available $K_2O$** | | |
| 0.00-0.15 | 477 | 312 |
| 0.15-0.30 | 433 | 300 |
| 0.30-0.45 | 348 | 294 |
| 0.45-0.60 | 348 | 300 |

Khejri plantation being the lowest vegetative growth registered slightly higher available phosphorus content in the soil strata may be due to addition of external nutrient input for getting higher productivity and speedy establishment of plantation and thus balancing the fertility status of the soil.

Available potassium is typically lower in the areas under plantation (294 to 312 kg/ha) than in the bare soil (348 to 477 kg/ha). The soil available potassium content is also much more concentrated in the top 15 cm both in plantation and bare soil areas with the average K content being lower under plantation (Table 26).

7

# CORRELATION

Correlation analysis of soil chemical elements with organic carbon and bulk density has been carried out but in case of the elements viz. $Mg^{2+}$ the level of significance was not very high (Table 27). Simple correlation coefficients of $Mg^{2+}$, available N and P contents of soils under ber plantations with organic carbon are significant at a level of 0.1-5.0%, likewise correlation coefficients of N, P and K contents under drumstick and karonda with organic carbon are significant at a level of 1.0-5.0%. In most of the cases positive relation exists between organic carbons vs. nutrients. Correlation study of organic carbon under khejri plantation with all the nutrients revealed that the levels of significance are not satisfactory at all. Most of the correlations between bulk density and nutrients are negatively correlated except magnesium which depicts positive correlationship under all the plantations. This indicated that soil chemical properties were gradually improved under the plantation process. However, under ber plantation the positive correlation exists with most of the nutrients and the level of significance are highly satisfactory. Among the chemical properties, increase of organic carbon was the most internal and fundamental factor leading to such a change. Numerous studies suggest a strong correlation between available forms of nutrients with organic matter (Singh *et al.*, 1987).

**Table 27. Correlation analysis of nutrient content in the soil with organic carbon and bulk density under the young plantation**

| | Ber | Drumstick | Karonda | Khejri |
|---|---|---|---|---|
| Organic carbon vs | 'r' | 'r' | 'r' | 'r' |
| Calcium | 0.887 | 0.740 | 0.542 | 0.443 (NS) |
| Magnesium | 0.834 | 0.445 | 0.313 (NS) | 0.505 |
| Available N | 0.820 | 0.753 | 0.615 | 0.432 (NS) |
| Available P | 0.771 | 0.758 | 0.682 | 0.227 (NS) |
| Available K | 0.864 | 0.696 | 0.373 (NS) | 0.192 (NS) |
| Bulk density vs | | | | |
| Organic carbon | -0.854 | -0.683 | -0.306 (NS) | -0.645 |
| Calcium | -0.880 | -0.900 | -0.625 | -0.625 |
| Magnesium | -0.754 | -0.645 | -0.322 (NS) | -0.708 |
| Available N | -0.920 | -0.930 | -0.735 | -0.560 |
| Available P | -0.675 | -0.708 | -0.392 (NS) | -0.446 |
| Available K | -0.899 | -0.669 | -0.659 | -0.352 (NS) |

NS : Not significant

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# NUTRIENT DYNAMICS

Litterfall from ber plantation (Fig 6) varied appreciably between two different tree ages and the litter production increased with advancement of plantation age (Table 28). So the litterfall mass accumulation exhibited a positive relationship with canopy diameter. Thus, total litter fall (Table 28) was substantially higher under ber (577 kg $ha^{-1}$) (Fig. 6) than in drumstick (237 kg $ha^{-1}$) (Fig. 7), karonda (125 kg $ha^{-1}$) and khejri (60 kg $ha^{-1}$) plantations. In case of old plantations i.e. ber and pomegranate on an average 1734.0 and 425.0 kg/ha, respectively of leaf litter fall measured every year.

**Fig. 6. Litter from ber**

**Fig. 7. Litter from drumstick**

The amount of nutrients returned through litterfall varies depending upon the age and growth of trees, quantity of litterfall addition and concentration of nutrients in litterfall (Mohsin *et al.*, 1996). Among the various nutrients, return of nitrogen, potassium and calcium were higher under all the young and old species. The phosphorus and magnesium returns were considerably lower. Similar results were reported in different plantations by Jha and Dimri (1991) and Prasad *et al.* (1991).The nutrient returns by the young species followed the order K > N > Ca in *Z. mauritiana* and *M. oleifera*; N > Ca > K and Ca > N > K in *C. congesta,* and *P. cineraria,*

**Table 28. Litter production and nutrient returns under the young fruit tree species**

| Young Species | Litter yield (kg ha$^{-1}$) | Litter nutrients (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| | | N | P | K | Ca | Mg |
| Ber | 577 | 7.61 | 0.52 | 8.20 | 5.77 | 2.02 |
| Drumstick | 237 | 5.07 | 0.95 | 6.35 | 3.00 | 0.60 |
| Karonda | 125 | 1.82 | 0.10 | 1.25 | 1.45 | 0.63 |
| Khejri | 60 | 1.17 | 0.07 | 0.57 | 1.26 | 0.24 |
| Old Species | | | | | | |
| Ber | 1734 | 30.34 | 2.25 | 26.70 | 13.52 | 7.80 |
| Pomegranate | 425 | 6.37 | 0.68 | 5.95 | 3.27 | - |

respectively (Table 28). In all the tree plantations studied, less nutrients were returned in *P. cineraria* plantation which is attributed to lower litter fall and small size of leaf owing to less vegetative growth.

# 9 FUTURE THRUST

1. Screening/Investigation of microbes dominating the microbial population in the rhizosphere of the fruit plants and involved in transformation of nutrients from unavailable forms to available forms.

2. Complete leaf and root chemistry needs to be worked out to formulate a model of nutrient dynamics in fruit plantation.

3. Carbon sequestration study needs to be studied in detail.

4. Spatial and temporal changes in physical and chemical properties of sandy soils due to fruit plantation should be worked out in detail.

5. Horticultural tree crops productivity should be studied for different crops.

6. Both horizontal and vertical distribution of nutrients form the main trunk of the fruit trees needs to be assessed critically.

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# CONCLUSION

From the study, it can be inferred that both soil physical and chemical properties are improved under all the three plantations except karonda and khejri. However, the results indicated much variation in available water holding capacity of soils under different fruit tree plantation. Nutrient contents in young plantation sites were found lower in general as compared to initial soil, whereas, old plantation sites showed the greater improvement in soil nutrient status. The high average organic carbon and available nitrogen may be related to greater return of nitrogen and carbon through litter fall in plantation areas. Moreover, it has been amply observed that these species of fruit crop require very little mineral content and are able to thrive best on sandy soils of poor nutrient regimes. It can also be inferred here that control (bare) site had resulted in loss of soil nutrients through leaching and wind erosion *inter-alia* no replenishment of nutrients was made through litter fall. Therefore, it could be concluded that among the fruit tree plantations, the growth of ber contributes much to soil fertility improvement. The process of fertility improvement although is very low in arid regions; but satisfactory increase in soil organic carbon content may be helpful in improving the productivity potential of sandy soils. However, looking to the present needs in the field of soil nutrient dynamics, the thrust areas explained above may be considered useful in planning for future research work.

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