Indian J. Hort. 67(Special Issue), November 2010: 138-142

Effect of *ber* and pomegranate plantation on soil nutrient status of typic torripsamments

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ABSTRACT

A study was conducted in arid region of western Rajasthan to determine the cumulative effect of leaf litter of ber (*Ziziphus mauritiana*) and pomegranate (*Punica granatum*) plantations on the changes of soil nutrients below the tree canopy and their interspaces at surface (0-15 cm) and sub-surface (15-60 cm) depth. The results of the study showed that both the fruit species exerted gain in the nutrient contents in the soil below the canopy area and their interspaces. The beneficial effect of *Ziziphus mauritiana* in improving the soil nutrient status was however, more pronounced. Ten year after plantation of ber and pomegranate, organic carbon below the canopy increased from 0.03 to 0.39% and 0.03 to 0.25% in ber and pomegranate, respectively. Available P increased from 9.16 to 12.35; 9.16 to 10.67 kg ha^{-1} and exchangeable cations [cmol (p+)/kg] (Ca^{2+} 5.1 to 8.0; 5.1 to 6.8, Mg^{2+} 1.2 to 2.0; 1.2 to 2.0 and K^+ 0.3 to 2.3; 0.3 to 1.9) under the canopy area of ber and pomegranate which entails the benefits of plantations in the development of dune soils. Gain in nutrient content between the interspace although was lower than the canopy area but was higher than control. Nutrient returns through litterfall followed the order N > K > Ca > P.

Key words: Nutrient budget, dune soils, litterfall, hot arid areas, ber, pomegranate.

INTRODUCTION

Arid lands which occupy nearly 12.5% of the total geographical area of the country have various limitations of which soil fertility is one of them. However, strength such as ample sunshine, abundant solar energy, low incidence of pest and diseases makes the region suitable for production of perennial fruit crops like ber and pomegranate. These fruit trees posse's xeric characters, high "bound water" in the tissues, reduced leaf area and deep tap root system and complete maximal vegetative growth and reproductive phase during the period of maximum water availability, (Pareek, 12). Being deciduous in nature these fruit trees add huge amount of leaf litter into the soil and on decomposition enhances soil nutrient status. It is an established fact that tree vegetation as well as type of litter produced under different plant communities causes certain differences in the chemical characteristics of soil (Gedda, 5). 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 (Sharma and Gupta, 15; Sharma and Bhandari, 14). The status of nutrients at different depths is also related to growth and development characteristics of plantations (Singh and Raman, 17; Mamgain *et al*., 10) because vegetation reacts with sub-aerial environment and exerts its independent influence on soil properties. The amount and kind of organic and inorganic fertilizers applied also influence the nutrient status of the soil.

Information on the changes in soil properties brought by plantations of these fruit crops in dune soils of western Rajasthan is lacking. Therefore, this study was undertaken to prepare a comparative nutrient budget under the canopy and inter spaces of ber and pomegranate plantation. Nutrient budget so prepared will be an index for assessing the capacity of the plantations for monitoring soil nutrients.

MATERIALS AND METHODS

The study was undertaken in orchards of ber *(Ziziphus mauritiana* L.*)* and pomegranate *(Punica granatum)* planted during the year 1996 at a spacing of 6 m x 6 m and 5 m x 5 m, respectively at Central Institute for Arid Horticulture, Bikaner which is located between 27° 11' to 29° 3' N latitude and 71° 54' to 74° 12' E longitude. The study area is characterized by high temperatures during summer (45 to 50°C) and low freezing temperature in winter (-0.5 to -1.5°C), high wind velocity during summer (20 to 30 km/hr), low precipitation 250 mm and high potential evapo-

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transpiration (1200 to 1700 mm/year). The soil characteristic of the experimental site at the time of establishment of ber and pomegranate plantation (1996) was loamy sand in texture with low moisture storage capacity (115 mm/m), pH (8.6), EC (0.16 dS m^{-1}), low in organic carbon (0.03%), low in available phosphorus (5.00 kg ha^{-1}) and high in available potassium (290 kg ha^{-1}). Taxonomically these soils are classified as "Typic Torripsamments". Sixteen trees were randomly selected for the study during the year 2007. A quadrate of 0.25 m x 0.25 m was used to excavate a volume of top (0-15 cm) and subsurface (15-60 cm) soils from each sub habitat (below canopy and inter spaces) of the 16 sample trees. A total of 16 (trees) x 4 (sub habitats) x 2 (depths of soil) = 128 soil samples were taken and analysed for organic carbon, available phosphorous and exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) following standard laboratory procedures (Jackson, 8). In order to compare the nutrient status under different plantations, weighted mean values of 0-15 and 15-60 cm soil depths were calculated. The plant samples were analysed for major nutrients by standard methods outlined by A.O.A.C. (1). The nutrient return through litterfall was calculated as nutrient removal (kg/ha) = (% nutrient in leaf-litter x dry weight of leaf-litter (kg ha^{-1}).

RESULTS AND DISCUSSION

Nutrients content in the surface and sub-surface soils including the balance sheet of nutrients in terms of loss/gain over control (dune soils), between the interspaces and under the canopy of the plantation are presented in Table 1.

Organic carbon contents were recorded to be higher under the canopy of both the ber and pomegranate plantation as compared to their interspaces and control. Maximum organic carbon content was recorded below the surface (0.39%) and subsurface (0.16%) canopy area of *ber*. Organic carbon ten year after plantation below the canopy of pomegranate increased from 0.03 to 0.25% and 0.03 to 0.08% in surface and sub-surface soils, respectively, while in the interspaces it increased from 0.03 to 0.10% and 0.03 to 0.04% per cent, respectively as compared to its initial status (0.03%) analysed at the time of plantation (1996). The improvement in organic carbon content may be attributed 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 was the probable reason for higher organic carbon content than the inter spaces. The above result confirm the findings of Sharma *et al*. (16) who reported that *Z. rotundifolia* significantly improved the organic carbon

Table 1. Balance sheet of nutrients at different plantations.

Horizon	Control	*Ber* plantations		Pomegranate plantations	
		Under canopy	Interspaces	Under canopy	Interspaces
Organic carbon (%)					
Surface	0.03	0.39 (+0.36)	0.15 (+0.12)	0.25 (+0.22)	0.10 (+0.07)
Sub-surface	0.03	0.16 (+0.13)	0.06 (+0.03)	0.08 (+0.05)	0.04 (+0.01)
Available phosphorus (kg/ha)					
Surface	9.16	12.35 (+3.19)	10.43 (+1.27)	10.67 (+1.51)	9.34 (+0.18)
Sub-surface	6.10	8.22 (+2.12)	7.0 (+0.9)	7.46 (+1.36)	6.35 (+0.25)
Exchangeable Ca [cmol (p+)/kg]					
Surface	5.1	8.0 (+2.9)	7.6 (+2.5)	4.6 (+0.3)	4.5 (+0.2)
Sub-surface	4.3	4.0 (-0.3)	4.6 (+0.3)		
Exchangeable Mg [cmol (p+)/kg]					
Surface	1.2	2.0 (+0.8)	1.5 (+0.3)	2.0 (+0.8)	1.3 (+0.1)
Sub-surface	0.5	1.6 (+1.1)	1.0 (+0.5)	1.5 (+1.0)	0.8 (+0.3)
Exchangeable Na [cmol (p+)/kg]					
Surface	1.6	0.5 (-1.1)	0.7 (-0.9)	0.4 (-1.2)	1.0 (-0.6)
Sub-surface	0.5	0.4 (-0.1)	0.8 (+0.3)	0.8 (+0.3)	1.3 (+0.8)
Exchangeable K [cmol (p+)/kg]					
Surface	0.3	2.3 (+2.0)	1.1 (+0.8)	1.9 (+1.6)	0.8 (+0.5)
Sub-surface	0.1	1.5 (+1.4)	0.4 (+0.3)	1.5 (+1.4)	0.2 (+0.1)
Total Exchangeable Cations [cmol (p+)/kg]					
Surface	8.2	12.8 (+4.6)	10.9 (+2.7)	11.1 (+2.9)	8.7 (+0.5)
Sub-surface	5.4	7.5 (+2.1)	6.8 (+1.4)	8.4 (+3.0)	6.8 (+1.4)

*Figures in parenthesis indicate loss (-) or gain (+) over control status of the soil as compared to other tree combinations. Belsky (2) indicated that higher moisture concentrations and cooler temperatures in the shade of trees encourage higher decomposition rates of accumulated organic matter and lead to higher soil organic carbon concentrations underneath the canopy than between the canopies. Comparatively lower organic carbon content in the interspaces may be attributed to lower spread of litter fall, low soil moisture content, high soil temperature and removal of leaf litter through wind. Status of organic carbon content in surface and sub-surface soils of different plantations sites seems to be dependent on nature of existing plant types which supports the view of Feral *et al*. (4) and Prasad *et al.* (13) who have reported that different plant species return plant litter in different amount.

Level of Phosphorus concentration was found to be higher below the canopy area of both the fruit species rather than their interspaces. As compared to control, phosphorus content below the canopy area of *ber* in surface and subsurface soil increased by 34.7 and 34.8%, respectively, while an increase of 16.5 and 22% was recorded in surface and sub-surface below the canopy plantations of pomegranate. As regards the phosphorus content in the interspaces of *ber* and pomegranate, analysis revealed that it increased by 14 and 15% on the surface and sub-subsurface of *ber* and by 2 and 4% in surface and subsurface of pomegranate, respectively (Table 1). Higher P content under the canopy area of *Z. mauritiana* may be ascribed to the addition of relatively more litter under *ber* orchard than pomegranate through defoliation which ultimately adds more plant nutrients to the soil. Significant increase in available phosphorus content of the soil with tree plantation has also been reported by Sharma *et al*. (16) and Hosur and Dasog (7).

The results of the exchangeable cation variables of the soils excavated from the four soil sub-habitats of *ber* and pomegranate below the canopy area and their interspaces exhibited substantial difference in K content of the soil. Higher K content was recorded in the surface soils below the canopy of *ber* plantation which however, declined in the inter space with increasing depth. 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. Similar results of increased K with plantation of veld trees have been reported by Bhoumik and Totey (3).

The other measured exchangeable cations (Ca^{2+}, $Mg^{2+}$and Na^{+}) differ markedly between the various sub-habitats. Higher concentrations of Ca and Mg were recorded below the canopy area of *ber* followed by pomegranate which declined linearly towards the un-canopied area (interspace). This is in close conformity with the findings of Hagos and Smit (6) who reported that the highest concentration of these exchangeable cations was recorded close to the stem of the *Acacia mellifera* subsp. *detinens* grown on nutrient poor sandy soil and declined linearly towards the open, un-canopied area.

Nutrient contents (except exchangeable Na^{+}) in surface soil of control was found lower in all cases, indicating positive values for plantation sites and in turn, showed the improved soil nutrient status. It can be inferred here that open area (control site) had resulted in loss of soil nutrients through leaching and wind erosion *inter-alia* no replenishment of nutrients was made through litter fall and addition of FYM/fertilizers. Lower negative values of sodium under all the plantations may be related to the luxury consumption of this metal by plant roots from surface horizons. Higher amount of exchangeable Na^{+} at interspaces of pomegranate plantation might be due to the nature of litters (Prasad *et al.,* 13) and specific spatial distribution of nutrients (Hagos and Smit, 6).

The overall effect of both the plantations on magnitude of enrichment of soil nutrient status was more pronounced in surface soil than in the subsurface soil. *Ber* plantations proved to be more effective in improving the soil nutrient status than the pomegranate

Table 2. Vegetational parameters and nutrient contribution of tree species.

Species	Average height (m)	Average girth (cm)	Canopy diameter (E-W) (m)	Canopy diameter (N-S) (m)	Plant ha^{-1} (Nos.)
Ber	4.6	72.3	6.96	7.57	277
Pomegranate	2.3	30.0	3.93	4.24	156
Litter production and nutrient return under the fruit trees					
Species	Litter yield(kg ha^{-1})	Nutrient element return (kg ha^{-1})			
		N	P	K	Ca
Ber	1734	30.34	2.25	26.70	13.52
Pomegranate	425	6.37	0.68	5.95	3.27

plantations, relatively because of more canopy area in *ber* than pomegranate. Smit and Swart (18) also reported that structural difference in leaves of microphyllous and broad leafed trees present possible source of difference in the amount of leaves reaching to the soil under the canopies, the latter being more subject to further dispersion by wind.

Some vegetational characters, litter production and nutrient contribution through litter fall are given in table 2. Total litter fall was substantially higher under *ber* (1734 kg ha^{-1}) than in pomegranate (425 kg ha^{-1}) plantations (Table 2). The amount of nutrients returned through litter fall varies depending upon the growth of trees, quantity of litter fall addition, size of the leaf, concentration of nutrients in litter fall and leaf chemistry (Mohsin *et al*., 11). Among the various nutrients, return of nitrogen and potassium were higher under both the tree species. The phosphorus and calcium returns were considerably lower (Table 2). Nutrient returns by both the tree species followed the order N > K > Ca > P. Similar results were reported in different plantations by Jha and Dimri (9).

Balance sheet of nutrients (Table 1) calculated for plantations over control (dune soils) also indicated that both uptake and return of exchangeable cations by the *ber* plantation were much higher than the pomegranate plantation. Moreover, growth characteristics and nutrient contribution pattern of both the tree species revealed that *ber* was the major contributor to the improvement of fertility status of soil. Therefore, from the present study it may be concluded that nutrient status of the soils remarkably increased after plantations of ten years age in case of *Z. mauritiana* and *P. granatum.*

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Received: April, 2008; Revised: March, 2010
Accepted: August, 2010