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Article in Indian Journal of Horticulture · December 2015

DOI: 10.5958/0974-0112.2016.00005.0

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Indian J. Hort. 72(4), December 2015: 472-478

Rejuvenation of old and uneconomical *ber* trees and its effect on growth, yield and fruit quality under rainfed conditions of western India

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ABSTRACT

A study was conducted to rejuvenate a 33-year-old orchard of *ber* under rainfed conditions during 2011-12. Trees were headed back from ground level and newly emerged shoots were budded with early, mid and late season cultivars, *i.e.* Gola, Seb and Umran, respectively under two alley spacings, *i.e.* 6 and 12 m, keeping plant to plant spacing in both the alleys at 6 m. Tree height and stem diameter were recorded higher under closer spacing, whereas, tree spread were recorded maximum in wider spacing of *ber* alleys. Within three years of rejuvenation, trees attained good canopy and was slightly higher in 6 m × 12 m spacing in all the cultivars. Though the trees started fruiting in the same year after rejuvenation but the yield was negligible but it increased remarkably during third year. The variety Gola recorded 3.55 times higher yield (36.4 kg tree^{-1}) compared to yield level just before the process of rejuvenation. Higher percentage (80) of 'A' grade fruit was obtained in Umran followed by Gola (78%) and Seb (72%). The morphological attributes of fruit obtained from rejuvenated trees were significantly higher than non-rejuvenated trees of each cultivar. The chemical attributes, *i.e.* TSS, TSS:acid ratio and total sugars were found slightly higher in fruits from non-rejuvenated trees. Hence, rejuvenation technology helped in restoring the productivity of old, unproductive and seedling orchards in shortest possible time.

Key words: *Ber*, fruit quality, growth, rejuvenation, yield.

INTRODUCTION

The Indian *ber* or jujube (*Ziziphus mauritiana* Lam.) is one of the most ancient cultivated fruit tree grown in north Indian plains. particularly Punjab, Haryana and Rajasthan. The total area under *ber* in India is more than 80,000 ha with an annual production of 9,00,000 tonne fruits (Sharma *et al.*, 12). However, over the year, *ber* trees start giving diminished yield and smaller fruits of inferior quality after bearing normal crops of 25-30 years. Besides, a large number of seedling plantations of *Ziziphus rotundifolia* also exist in western Rajasthan and other regions. Such established and healthy trees of non-descript origin and poor genetic potential can be converted into productive ones by rejuvenation with improved and region-specific commercial cultivars.

It has been observed that the tree architecture engineering, canopy density and photosynthetic efficiency play important role in governing the fruiting potential (Lal and Mishra, 4). There are several reports on rejuvenation by pruning, canopy management, dehorning and top working in different fruit crops like mango, guava, *aonla*, litchi, peach, apple and *ber*. Rejuvenation technology with heading back of branches in mango during December at a height of 4 m from the ground level and effective after care management can give new lease of life to the unproductive orchards for another 25-30 years and make them productive and economic after four years of rejuvenation (Lal and Mishra, 4). Similarly, in guava, yield enhancement in the range of 70-90% over the unpruned trees can be recorded after first year of rejuvenation. Pathak *et al.* (10) found 40-100% success rate by top working on seedling *aonla* trees. Keeping these point in view, a study was conducted to rejuvenate a 33-year-old orchard of *ber* and study its effect on growth yield and quality under rainfed conditions.

MATERIALS AND METHODS

The present investigations were carried out at ICAR-Central Research Farm, Central Arid Zone Research Institute, Jodhpur during 2011-12 under rainfed conditions. The experimental site is situated at an elevation of 216 m from above mean sea level and lies between 26°18'N latitude and 73°04' E longitude. The environmental conditions of the site is arid in nature with very high temperature during the summer touching a maximum of 48°C, short (December to mid-February) cool and dry winters (from 4.1 to 14°C), high evaporation (3.5 to 13.5 mm day^{-1}) and generally low humidity (35 to 70%) with low annual rainfall range of 100-420 mm, mostly confined between July to September. The soil of the experimental site

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belonged to the typical Pal soil series and contains high percentage of fine and coarse sand. The pH of soil varies from 8.2 to 8.4 having average organic carbon (0.217%), available N (kg ha^{-1}), available P_2O_5 (23.8 kg ha^{-1}) and available K_2O (359 kg ha^{-1}).

Twenty two cultivars, planted at 6 m × 6 m spacing raised on *Zizyphus rotundifolia* rootstock in the year 1978 in randomized block design with three replications under rainfed conditions were used as experimental material. Non-rejuvenated five trees of cvs Gola, Seb and Umran were taken as control. Trees were headed back from the ground level in May, 2011. The cut surfaces were smeared with copper oxychloride to check the microbial infections. Out of numerous shoots emerged after 12-15 days, 1-2 shoots were kept and rest were removed periodically. Selected shoots on same plants were budded with early, mid and late season cvs Gola, Seb and Umran, respectively in the month of July under two alley spacing, *i.e*. 6 and 12 m, keeping plant to plant spacing in two alleys at 6 m. Twenty seven trees of each cultivars were kept in each spacing with nine plants in each replications. Side shoots, which emerged on the cut surfaces after budding, were removed regularly as and when they appeared, so as to promote the growth of bud sprouts. Buds sprouted within 10-15 days. Recommended doses of manures and fertilizers and uniform cultural practices were followed (Meghwal *et al.*, 5).

The observations on vegetative characters like tree height (m), stem diameter (cm), tree spread (E × W, N × S) and tree volume (m^3) were recorded from five randomly selected trees in each treatment during October every year as per procedure given by Ranganna (11). Fruit yield (kg/tree) over the years was calculated by taking all the harvested fruits on each picking at maturity, and thereafter, fruits were graded into large (>35 mm), medium (35-25 mm) and small grade (<25 mm) (Pareek and Gupta, 9) and calculated per cent contribution of A, B, and C grade fruits in total marketable yield. Yield increment (%) in rejuvenated trees compared to non-rejuvenated trees over the year were also analysed taking into account cumulative yield (average of 8.0 kg/tree) of all 22 cultivars before rejuvenation. The uniform fruits of *ber* cultivars were harvested and were then analyzed for their physico-chemical properties using 20 randomly selected fruits from the all aspects of tree during each picking. Fruit and stone size was recorded by measuring the length and breadth using digital Vernier calipers, while weight was taken using top pan digital balance. The fruit from different samples were weighed and volume was estimated by water displacement method and specific gravity was determined from the weight divided by fruit volume. The total soluble solids (TSS) were determined with Erma hand refractometer (0-32°Brix). The tritratable acidity, total sugars and ascorbic acid contents were estimated by the standard methods described by Ranganna (11). The average data of three years were subjected to statistical analysis using software packages of MS Excel and SPSS 12.0 version.

Fig. 1. Sequential steps of rejuvenation of *ber* orchard.

RESULTS AND DISCUSSION

Preliminary data was recorded on growth and yield potential, the average annual shoot growth was in the range of 0.65 to 1.2 m and canopies were not in proper shape and were full of criss-crossed and unmanaged branches. Average production for the pre-experimental period was recorded 8 kg tree^{-1} with misshapen and poor quality fruits infested with fruit fly. The data pertaining to the vegetative characters of different *ber* cultivars under two spacings are presented in Table 1. Growth characters in terms of plant height, tree spread and stem diameter were non-significantly affected by spacing in respects of cultivars in their respective year of experiment. However, in general, tree height was higher under 6 m × 6 m spacing, whereas, tree spread and stem diameter were higher under 6 m × 12 m spacing with respect to different cultivars during 3rd year after rejuvenation. Among the cultivars, tree height was maximum in cv. Seb (2.73 m), which was at par with Umran (2.71 m) under 6 m × 6 m spacing. However, tree spread was maximum in cv. Gola in 6 m × 12 m spacing, whereas, stem diameter of rejuvenated tree was maximum in cv. Seb under both the spacings in 3rd year of rejuvenation.

Based on the growth habit cvs Gola, Seb and Umran are categorized as drooping, spreading and erect growth habit, respectively (Vashishtha, 15; Meghwal *et al.*, 5) and this might be the reason for variations in growth performance because all the cultivars were budded on same rootstock under similar environmental conditions. Since *ber* bears flowers and fruits on current season's growth, therefore, tree volume may have direct impact on yield of trees. Canopy development of rejuvenated trees in terms of tree volume, depicted in Fig. 2 showed linear increase over the year of rejuvenation as age of tree increased

Table 1. Vegetative growth of rejuvenated trees over the three years.

Spacing (m × m)	Cultivar	Plant height (m)			Tree spread (m)						Stem dia. (cm)		
					E×W	N×S	E×W	N×S	E×W	N×S			
		1st year	2nd year	3rd year	1st year		2nd year		3rd year		1st year	2nd year	3rd year
6 × 6	Seb	1.55	2.12	2.73	2.04	2.25	2.66	2.58	3.88	3.56	2.58	4.4	6.15
	Gola	1.34	2.14	2.24	2.21	1.97	2.84	2.92	4.49	4.40	3.65	4.2	5.89
	Umran	1.63	2.52	2.71	2.20	1.84	3.44	3.22	3.49	3.76	2.82	3.9	5.44
	Mean	1.5	2.26	2.56	2.15	2.02	2.98	2.90	3.95	3.90	3.02	4.16	5.82
$CD_{(0.05)}$		0.14	0.33	0.26	NS	0.22	0.38	0.26	0.40	0.42	0.41	0.24	0.28
6 × 12	Seb	1.61	2.15	2.28	2.60	2.50	2.64	2.60	4.24	3.94	3.43	4.4	6.18
	Gola	0.98	1.76	2.01	2.12	2.10	2.92	2.92	4.52	4.84	2.8	4.2	5.87
	Umran	1.48	1.98	2.19	1.77	1.64	2.52	2.42	4.23	4.12	2.45	3.8	5.32
	Mean	1.35	1.96	2.16	2.16	2.08	2.69	2.64	4.33	4.3	2.89	4.13	5.79
$CD_{(0.05)}$		0.15	0.21	NS	0.28	0.27	0.30	0.23	NS	0.44	0.33	0.21	0.32

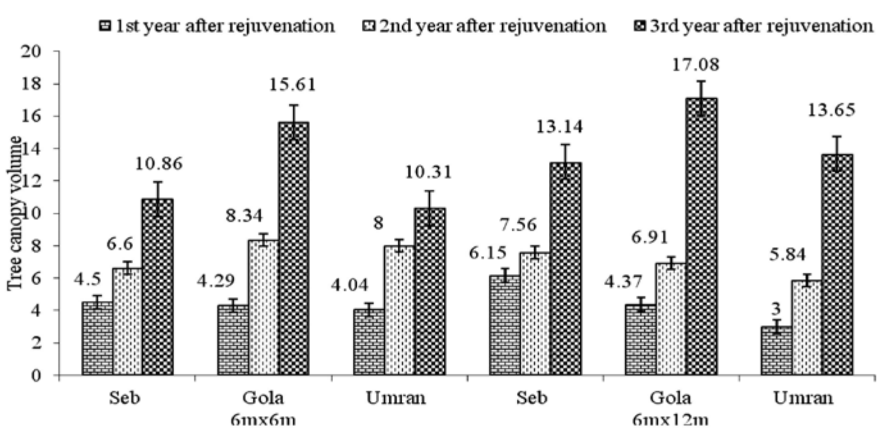

Fig. 2. Tree canopy volume (m^3) of rejuvenated *ber* cultivars.

irrespective of cultivar and spacing. Within three years of rejuvenation trees attained reasonably good canopy and it was slightly higher in 6 m × 12 m spacing in the three cultivars. Similar findings were reported by several workers on mango (Misra and Lal, 6; Sree Hari and Reddy, 14), *aonla* (Misra *et al*., 7; Pathak *et al*., 11) and other fruit crops (Kalloo *et al*., 3).

Before rejuvenation process the average fruit yield of experimental trees was recorded 8.0 kg tree^{-1}. Though the rejuvenated trees started fruiting in first year after rejuvenation but the yield was low in the range of 1.28 to 6.8 kg tree^{-1}, hence there was loss of one fruiting season but during second year of fruiting season yield was recorded higher than non-rejuvenated trees in all the cultivars except Seb under 6 × 12 m. However, the yield was remarkably improved during third year after rejuvenation and recorded highest in cv. Gola followed by Seb and Umran under both the spacings. The yield was recorded in the range of 36.4 kg tree^{-1} in Gola and minimum (23.0 kg tree^{-1}) in Umran under 6 m × 6 m spacing in third year of rejuvenation. *Ber* alley spacing had non significant effect on total yield during third year of fruiting season (Fig. 3). During first year all the cultivars showed negative trend but during second year yield increment over non-rejuvenated trees was recorded as high as 166.8% in Gola under closer spacing. However during third year of fruiting season, wider spacing of *ber* trees showed higher increment in yield than closer spacing but the difference was non significant (Fig. 4). Gola recorded 3.55 times higher yield after third year of rejuvenation followed by Seb and Umran over yield obtained from such trees before rejuvenation process.

Fruits obtained from rejuvenated and non-rejuvenated (control) trees were graded according to fruit size manually during each picking to find out the contribution (%) of different grade fruits in total marketable yield (Fig. 5). It is apparent from the Fig. 5

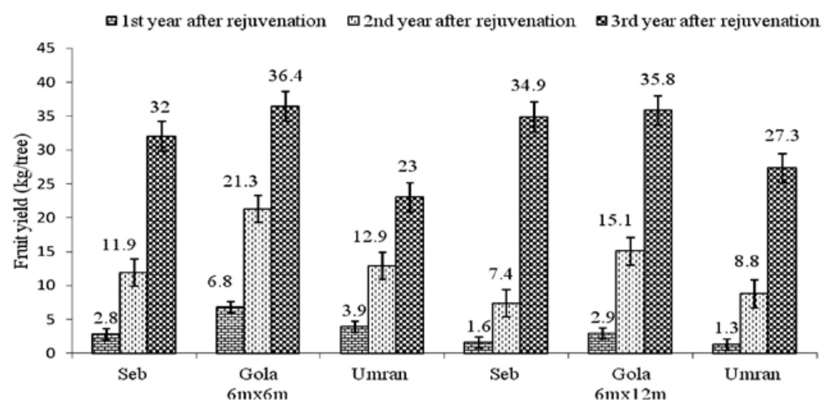

Fig. 3. Fruit yield (kg tree^{-1}) of rejuvenated *ber* trees over the years.

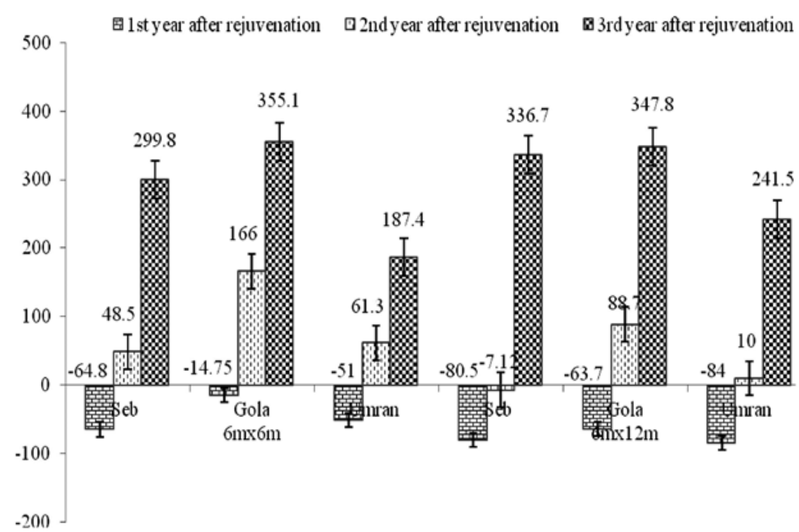

Fig. 4. Yield increment (%) in *ber* rejuvenated trees compared to non-rejuvenated trees.

that major portion of yield of rejuvenated trees was mainly contributed by 'A' grade fruits irrespective of cultivar and spacing. Out of total yield obtained 'A' grade fruit was in the range of 65 to 80 per cent, whereas, yield obtained from non-rejuvenated trees was mainly occupied by 'B' grade fruits. Among the cultivars, maximum 'A' grade fruits was found in Umran followed by Gola and Seb. Quantity of 'C' grade fruit was found meagre in rejuvenated trees in all the three cultivars; whereas, in control it was in the range of 9-20 per cent. It is obvious from the finding that rejuvenation technique not only increases the total yield but significantly improved the actual marketable yield.

The physico-chemical attributes of fruits obtained from rejuvenated and non-rejuvenated trees of each cultivar were compared and data are presented in Table 2. The morphological attributes of fruits obtained from rejuvenated trees was significantly better than fruits obtained from non-rejuvenated trees of each cultivar. Fruit weight, fruit length, stone length, pulp content and pulp: stone ratio were recorded higher in cv. Umran followed by Gola and Seb, whereas, fruit and stone diameter and stone weight was found higher in cv. Gola. Variation in physical parameters of fruits obtained from rejuvenated trees of different cultivars is only due to their genetic characters. The chemical attributes, *i.e.* TSS, TSS:acid ratio and total sugars were found slightly higher in fruits from non-rejuvenated trees in each cultivar but the differences were non-significant. However, ascorbic acid content was higher in fruits obtained from rejuvenated trees. The TSS and TSS: acid ratio were found higher in cv. Seb, whereas, acidity, total sugars and ascorbic acid contents were found higher in cv. Gola.

The variation in growth parameters among the different cultivars might be due to their genetic makeup and indigenous level of carbohydrates and other phytohormones. Rapid rate of canopy development within shorter period after rejuvenation in all the cultivars might due to fact that in aged trees, old woods goes on accumulated every year, which reduce the growth rate and production of lateral shoots (Bal *et al.*, 2; Singh and Bal, 13), while during rejuvenation all such woods are removed by heading back at ground level and rootstock portion remains dormant and all physiological processes of such trees are ceased for some time. At the same time, well established root systems of rootstock governs favourably the greater uptake of moisture and nutrient, which contributes to production of new and healthy vegetative growth, leaves and establish better source and sink relation. Higher root: shoot ratio of such trees tends to partition a greater proportion of carbon to reproductive areas (flower bud, flowers, fruit set and fruit development). Growth of new healthy shoots and luxuriant leaves tend to exhibit high photosynthetic efficiency thereby, keeping a balance between vegetative and reproductive growth (Baba *et al.*, 1), which ultimately might have resulted into increased tree canopy volume, yield and quality of fruits in rejuvenated trees. The technology also helps in maintaining the manageable tree height with open architecture and canopy of healthy shoots with outwardly growth facilitating maximum light penetration and its utilization by the plant. Capturing and conversing sunlight into the fruit biomass is an important process in fruit production. It is well established fact that better light penetration into the tree canopy improves tree growth, productivity, yield

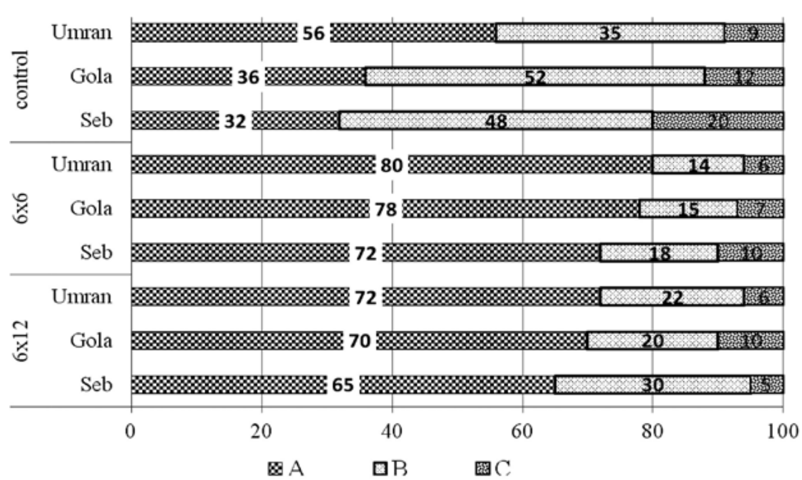

Fig. 5. Contribution of different grade fruits in total marketable yield (%) of *ber* cultivars.

Table 2. Physico-chemical attributes of fruits of different *ber* cultivars obtained from rejuvenated trees.

Character	Seb		Gola		Umran	
	Rejuvenated	Non-rejuvenated	Rejuvenated	Non-rejuvenated	Rejuvenated	Non-rejuvenated
Fruit wt. (g)	21.6	14.8	25.7	15.5	29.5	14.7
Fruit length (mm)	32.7	29.4	37.1	32.3	42.2	32.2
Fruit dia. (mm)	35.4	28.4	34.9	30.9	33.1	24.3
Pulp wt. (g)	18.7	12.3	22.8	10.6	25.9	13.7
Stone wt. (g)	1.68	1.42	2.1	1.4	1.7	0.88
Pulp: stone ratio	11.1	9.4	10.8	7.5	15.4	12.2
Stone length (mm)	19.8	17.5	19.1	15.2	21.9	20.7
Stone breadth (mm)	11.9	10.3	11.9	9.7	9.3	7.7
TSS (^{0}B)	18.0	24.6	18.5	20.5	17.5	18.0
Acidity (%)	0.36	0.32	0.42	0.46	0.40	0.39
TSS: acid ratio	52.3	72.8	44.8	45.6	44.7	46.2
Total sugars (%)	10.2	10.8	12.2	13.9	6.2	6.1
Ascorbic acid (mg/100 g pulp)	188.4	186.8	236.3	246.6	196.2	192.0

and fruit quality. Similarly, Lal and Mishra, (4), Baba *et al*. (1); Mistry and Patel, (8) and Pathak *et al*. (10) also recorded improved canopy growth, yield and fruit quality in different fruit crops after rejuvenation in similar pattern. Findings of the present study on growth, yield and fruit quality can also be corroborated with the findings of Singh and Bal, (13) and Bal *et al.* (2) in rejuvenated *ber* trees under semi-arid conditions of Punjab.

ACKNOWLEDGEMENT

The authors are highly thankful to Director, ICAR-Central Arid Zone Research Institute, Jodhpur for providing facilities.

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Received : September, 2014; Revised : October, 2015; Accepted : November, 2015