Journal of Horticultural Science and Technology 3(3): 75-82 (2020)
ISSN: 2617-3220 (Print), 2664-9489 (Online)
https://doi.org/10.46653/jhst20030375

Original Research

Effect of Different Pruning Levels on Improving Fruit Yield and Quality of Indian Jujube (*Ziziphus mauritiana* Lamk.) Cultivars

Muhammad Azhar Bashir[a], Muhammad Ikhlaq[a], Ammara Noreen[a]*, Kashif Shabir[a], Naheed Akhtar[b] and Faheem Altaf[b]

[a] Horticultural Research Station, Bahawalpur, Pakistan
[b] Horticultural Research Sub-Station, Dera Ghazi Khan, Pakistan

ABSTRACT

Indian jujube (*Ziziphus mauritiana* Lamk.) is a drought tolerant fruit crop and well adapted to sub-tropical to tropical climates. Seasonal pruning in jujube is essential to sustain the plants as productive with quality fruits because flowers and fruits are borne on young shoots of current season's growth. This experiment was initiated and accomplished during 2016-18 to assess appropriate extent of pruning in various cultivars of Indian jujube with regard to productivity and fruit quality. Four cultivars of jujube i.e., Dehli Sufaid, Pak White, Umran and Alu Bukhara were subjected to four pruning levels i.e. no pruning, 25%, 50% and 75% pruning by removing unproductive, over-crowded secondary and tertiary branches leaving 3/4 (light), 1/2 (medium) and 1/4 (severe pruning) portion of branch intact with main limb, respectively. Experiment was laid out in randomized complete block design with three replications and statistically analysed in 2-factors factorial way. Pak White initiated new growth earlier (39 days), produced maximum branches per plant (77), shoots (15), panicles (63) and fruits (90) per branch, heavier (38 g) and bulky fruits (44 cm^3), with minimum fruit drop (13%), higher yield (184 kg) per plant and fruits carrying the maximum pulp ratio (90%), total soluble solids (16 °Brix), vitamin C content (121 mg /100 g pulp) and total sugars (5.7%). Fifty percent pruning level proved more judicious in all jujube cultivars. Pak White performed the best when subjected to 50% pruning level for all the parameters under study as calculated by interaction between two factors.

Keywords: Fruit quality, jujube cultivars, productivity, pruning intensity, *Ziziphus mauritiana*.

Article History: *Received 18 August 2020; Revised 28 September 2020; Accepted 29 September 2020; Published 30 September 2020.*

INTRODUCTION

Indian jujube (*Ziziphus mauritiana* Lamk.), locally called as "Ber", belongs to the family *Rhamnaceae* and considered as the fruit of poor people. Other commercially important species of the family is *Ziziphus jujuba* Mill., usually called as Chinese jujube or Chinese date. The Indian jujube (*Z. mauritiana*) differs from the Chinese jujube (*Ziziphus jujuba* Mill.) in having leaves which are woolly beneath instead of smooth. The fruits of Indian jujube are smaller in size and not so sweet in taste. *Ziziphus* species vary widely in height, from a bushy shrub 1.5 - 2-meter-tall to a tree 10 - 12 meter height, erect or wide-spreading crown with gracefully drooping thorny branches, zigzag branch-lets, thornless or set with short, sharp straight or hooked stipular spines and has trunk 40 cm or more in diameter. Edible fruit is of variable shape and size that can be oval, obovate, oblong, or round, 1-3.5 cm wide and 2.5-6.5 cm long depending on the species and cultivar. Fruit flesh is white or creamy and crispy, when slightly unripe the fruit is a bit juicy with a pleasant aroma. The fruit's skin is smooth, glossy, thin but tight. The fruit is also cheap source of most of the nutrients (richer in vitamin C, protein, sugars, antioxidants & carotene) and minerals (potassium, phosphorus, calcium, magnesium, and iron). Fruit is consumed in fresh form as well as dried or used in juice, squashes, pickles, jams, marmalades, and candies. Indian jujube is a hardy plant that can tolerate a wide range of climate, soil, and saline water. It is one of the most important fruits suitable for arid and semi-arid regions of Pakistan.

Jujubes are grown in about 50 countries. China shares more than 90% of the world production where it developed rapidly during last 30 years and its production reached from 0.38 million tonnes (1980) to 7 million tonnes (2015). Maximum of this produce is consumed locally, and some part is exported as processed product (Johnstone, 2018). China, India, Australia, and Syria are major jujube producing countries. In Pakistan, production of jujube remained 22.17 thousand tonnes over an area of 4.37 thousand hectares. Sindh province contributed largest share (83.66%) in area under its cultivation (3.66 thousand hectares) and maximum share (65.84%) in fruit production (14.60 thousand tonnes). The Punjab province shared 34.16% in jujube fruit production (7.57 thousand tonnes) over an area of 0.72 thousand hectares (16.34% share in area). Major jujube growing area of Sindh province belongs to Hyderabad and Khairpur Divisions. In Punjab province, it is grown in Bahawalpur, Multan, Faisalabad, Lahore, Sargodha and

* Corresponding author
E-mail: ammaranoreen91@gmail.com (A. Noreen)
J. Hortic. Sci. Technol. © 2020 Pakistan Society for Horticultural Science

Rawalpindi divisions. Bahawalpur division of Punjab province shares the maximum area (42.5%) under jujube plantation with the maximum share (51.8%) in its production of the Punjab province (Anonymous, 2019).

In Southern Punjab (Pakistan), Indian jujube tree sheds its leaves after harvesting and goes to dormancy. New leaves sprout in rainy season. Flowering starts during fall (September-October) and fruit setting during fall-winter (October-November). Fruit ripening starts during winter (January-February) and maturity and harvesting continued during spring (February-April). Phenology and productivity of Indian jujube depend on many factors such as climate, weather, topography, soil, precipitation, cultivar, and cultural practices specially pruning. In Indian jujube, pruning is very vital just from planting to bearing and later years since bearing. Pre-bearing pruning is done to shape strong structure so that the tree may carry fruit load and facilitate light and air distribution properly. Later, pruning is carried out annually to perpetuate tree vigour, to boost productivity and fruit quality parameters as Indian jujube trees bear fruits on current year's flushes induced by pruning (Meghwal et al., 2017). Intensity and time of pruning may change growth, flowering, fruit set, drop, retention, ripening, maturity, productivity and quality characteristics of fruit (Raut and Diware, 2005; Boora and Singh, 2007; Gupta and Gill, 2015; Sharif et al., 2016; Gola et al., 2018). Slight to medium pruning intensity may enhance fruit production and quality in Indian jujube, while over pruning delays fruit maturity due to excessive vegetative growth (Kumar et al., 2014).

Raut and Diware (2005) removed Indian jujube shoots of various diameters declaring 1 cm as light, 2 cm as moderate and 3 cm as severe pruned. Number of shoots significantly increased from moderate pruning as compared to severe and light pruning. Gupta and Gill (2015) pruned secondary branches of Indian jujube cv. 'Umran' at 4, 6, 8, 10 and 12 bud levels and control (without pruning). They found that fruit yield decreased with increase in intensity of pruning. Fruit weight, size, pulp content, pulp stone ratio and TSS content touched the maximum at 8th bud level, followed by trees pruned at 10th bud level and the minimum were in control. Sharif et al. (2016) reported that pruning of Indian jujube cultivar 'Alu Bukhara' during mid of May, end of May and mid of June by keeping same level (by removing 50% branch length) affected growth, flowering, yield and quality parameters. Early pruning (mid of May) produced maximum limbs per tree (23), early blooming with minimum days to flowering (65 days), heaviest fruit (32.5 g), biggest fruit size (38.5 mm^2) with highest yield (208 kg/tree), TSS (16.6%), sugar (6.25%) and ascorbic acid (132.6 mg/100 g) contents. However, late pruning (mid of June) resulted into minimum values of fruit and yield parameters, but with increased fruit acidity, and delayed blooming and fruiting. Kumar (2002) applied 0 (control), 25, 50 and 75% pruning intensities to Indian jujube cultivars 'Ponda Safeda', 'Banarasi Karaka' and 'Gola' to explore optimum pruning intensity suited to vegetative growth and yield of these cultivars under semi-arid climate. Significant variation in production and growth of primary, secondary, and tertiary branches was observed. Maximum primary branches (4.45) were obtained by 25% pruning, while more number of secondary (6.70) and tertiary branches (6.12) by 50% pruning. 'Ponda Safeda' led in fruit yield (28.94 kg/tree) and maximum yield (25.92 kg/tree) remained with 50% pruning intensity, followed by 75% pruning in all the cultivars. Kumar et al. (2016) achieved the highest number of shoots per branch (6.5 shoots), number of fruits (5408/tree) and maximum yield (109.21 kg/plant) by applying 50% pruning to Indian jujube cv. 'Gola'. They also noted maximum fruit length (3.35 cm), fruit width (3.25 cm), fruit volume (20.50 cm^3), TSS (14.52%), Vitamin C (44.53 mg/100 g pulp), total sugar (7.43%) and minimum acidity (0.29%) under the same level of pruning. Pruning severity up to 70% was assessed as supra-optimal for Gola cultivar. Thus, there seems almost a consensus among various researchers that moderate pruning is best suited to get high yield with good quality Indian jujube fruit. However, information on optimized pruning level for local cultivars is still scanty. So, there is need to standardize uniform pruning practice in Indian jujube plants under a specific climate of a region. Moreover, cultivar specific pruning should also be standardized since the growth habit of different cultivars may vary. The cultivars may also be grouped according to growth habit in reference to pruning intensity. Therefore, it is utmost need to assess the extent of pruning in a specific cultivar. The current investigations were carried out to explore the best suitable level of pruning as well as response of promising Indian jujube cultivars to the pruning levels applied, ultimately improving productivity and quality of these cultivars under appropriate pruning levels.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Orchard of Horticultural Research Station, Bahawalpur (altitude 214 m, longitude 71.64°E, latitude 39.38°N) during 2016-2018. From climate perspective, the area lies under semi-arid and subtropical region. Forty eight plants spaced at 6.5 × 6.5 m in square system, uniform in age (17-20 year old), canopy and health of four cultivars of Indian jujube viz. S_1 = Dehli Sufaid, S_2 = Pak White, S_3 = Umran and S_4 = Alu Bukhara (1st factor with 4 cultivars) were subjected to four pruning levels (2nd factor) viz. L_1 = 0 (no pruning), L_2 = 25% (light pruning), L_3 = 50% (medium pruning), L_4 = 75% (severe pruning) by removing unproductive, over-crowded secondary and tertiary branches of the tree leaving 3/4 (25% pruning), 1/2 (50% pruning), 1/4 (75% pruning) portion of branch intact with main limb. Ten branches per limb from previous year growth were tagged for data recording. However, all previous year growth of the plants was removed according to the treatments except control during mid of May each year. All experimental plants received the same inputs and package of cultural practices except pruning treatments. The data on different parameters were recorded through methods and formulae given below.

Time to initiate new growth

The pruned branches were observed vigilantly during the experimental period. The count of days started from the date of pruning to the date of appearance of shoot buds.

Number of branches per plant

All primary and secondary branches appearing from pruned limbs were summed up for a tree under a pruning treatment and

averaged over replications.

Number of shoots per branch

Number of shoots per (secondary) branch were counted from tagged branches under a single treatment and averaged over replications.

Number of panicles per branch

Number of panicles per (secondary) branch were counted from tagged branches under each pruning treatment and averaged over replications.

Number of fruits per branch

Number of fruits per (secondary) branch were counted from tagged branches under each pruning treatment and averaged over replications.

Single fruit weight

It was calculated by a Digital balance (SF-400A, China) by weighing 10 fruits as a single sample from each treatment then taking their average.

Single fruit volume

Volume for three spherical shaped cultivars (Dehli Sufaid, Pak White and Alu Bukhara) was measured by applying formula: $V = 4/3\ \pi r^3$, whereas for cylindrical shaped cultivar (Umran) by using formula: $V = 2\ \pi r^3$. Here V = volume, $\pi = 22/7$ or 3.143, and r = radius.

Yield per plant

It was recorded from winter crop during the month of March by summing up all the pickings of each tree and averaged over number of plants per treatment per replication.

Fruit drop

It was estimated by using the given formula.

$$\text{Fruit drop (\%)} = \frac{\text{Number of fruits dropped}}{\text{Total number of fruits}} \times 100$$

Marketable yield per plant

It was recorded by subtracting total weight of dropped low quality fruits by a tree from overall yield per plant.

Pulp to seed ratio

It was estimated by applying the following formula.

$$\text{Pulp to seed ratio (\%)} = \frac{\text{Single fruit pulp weight}}{\text{Single fruit weight}} \times 100$$

Total soluble solids

The TSS was recorded by a Refractometer (BX-1 Atago, Japan).

Vitamin C

Vitamin C was determined by diluting 10 mL of pulp extract with 0.4% oxalic acid solution and titrating 5 mL of filtered aliquot against 2, 6-dichlorophenol indophenol dye till light pink colour end point (Saleem et al., 2008).

Fruit acidity

Fruit acidity was measured from fruit pulp extract by a Pocket Brix-Acidity Meter (Atago, Japan).

Total Sugars

Total sugars (including reducing and non-reducing sugars) were measured from fruit pulp extract using the already described method (Shafiq et al., 2011).

The experiment was laid out in randomized complete block design (RCBD) with 3 replications summing up to 48 plants (4 × 4 × 3). The statistical analysis was conducted in 2-factor factorial RCBD. Two-year data were pooled and subjected to Fischer's Analysis of Variance technique using statistical software Statistix 8.1 and mean differences were compared by Duncan's Multiple Range test (DMRT) at $\alpha = 0.05$ (Steel et al., 1997).

RESULTS AND DISCUSSION

Time to initiate new growth

Pak White initiated new growth earlier after 39.30 days, while Umran was slower to initiate new growth and took 47.03 days after pruning treatment application. Un-pruned plants also initiated new growth earlier (34.94 days) than the plants under pruning treatments (Table 1). This might be due to reason that pruning does not compensate for the portion removed by pruning as under severe pruning (Meghwal et al., 2017). So, already sustained branches in un-pruned plants initiated growth earlier, while pruned plants took a time to initiate a new growth. Pak White when left un-pruned it initiated new growth the earliest after 31.60 days, while the plants pruned at 75% level initiated new growth most slowly and took 56.45 days, as evident from 2 factors interaction (Table 1).

Number of branches per plant

Pak White produced the maximum (77.16), while Umran gave the minimum number of branches (67.69). Plants pruned at 50% level produced more number of branches (80.34) than the other pruning treatments, with lower number (64.79 branches) in un-pruned plants. Pak White when pruned at 50% level of pruning, produced the maximum number of branches (85.90), followed by Dehli Sufaid (80.45 branches) and Alu Bukhara (79.15 branches) for the same level of pruning (Table 1). The results are in line with the findings of Pandey et al. (1998) who reported significantly higher number of secondary and tertiary branches under 50% pruning intensity. Similarly, Kumar (2002) revealed significant variations in growth of branches under the effect of 25% and 50% pruning intensity but obtained maximum number of branches under 50% pruning severity applied to various Indian jujube cultivars. However, Kumar et al. (2002) found significantly higher number of branches in light pruned (20 cm

Table 1: Phenological parameters of various Indian jujube cultivars as affected by different pruning levels.

Factors	Time to initiate new growth (days)	No. of branches per plant	No. of shoots per branch	No. of panicles per branch	No. of fruits per branch
Cultivars					
S_1 = Dehli Sufaid	44.36 a	72.17 a	10.97 b	57.65 b	83.70 b
S_2 = Pak White	39.30 b	77.16 a	15.41 a	63.24 a	90.25 a
S_3 = Umran	47.03 a	67.69 b	11.48 b	50.09 c	72.40 c
S_4 = Alu Bukhara	45.79 a	70.24 a	11.79 b	49.71 c	71.22 c
Pruning Levels					
L_1 = 0%	34.94 d	64.79 c	10.63 b	44.31 c	67.60 c
L_2 = 25%	40.30 c	72.06 b	12.58 b	52.00 b	78.96 b
L_3 = 50%	48.23 b	80.34 a	14.42 a	67.44 a	95.94 a
L_4 = 75%	53.20 a	70.08 b	11.95 b	56.98 b	75.08 b
Interaction					
$S_1 \times L_1$	35.05 ij	65.25 fg	9.50 e	45.05 jkl	71.20 f
$S_1 \times L_2$	40.15 fghi	72.45 bcdef	10.90 de	53.80 efghi	86.55 cde
$S_1 \times L_3$	48.95 bcd	80.45 ab	12.85 bcde	71.35 b	100.30 ab
$S_1 \times L_4$	53.30 ab	70.50 def	10.60 de	60.50 cde	76.75 ef
$S_2 \times L_1$	31.60 j	69.00 defg	13.25 bcd	50.35 fghij	77.80 def
$S_2 \times L_2$	36.07 hij	76.95 bcd	15.70 ab	58.95 cde	90.95 bc
$S_2 \times L_3$	42.35 efg	85.90 a	17.65 a	78.85 a	109.20 a
$S_2 \times L_4$	47.20 cde	76.80 bcd	15.05 ab	64.80 bc	83.05 cde
$S_3 \times L_1$	37.20 ghi	60.90 g	10.40 de	41.35 kl	61.95 g
$S_3 \times L_2$	43.55 def	67.45 efg	11.80 cde	48.80 ghij	69.65 fg
$S_3 \times L_3$	52.30 abc	75.85 bcde	13.25 bcd	56.20 defg	86.65 cd
$S_3 \times L_4$	55.05 a	66.55 fg	10.45 de	54.00 efgh	71.35 f
$S_4 \times L_1$	35.90 ij	64.00 fg	9.35 e	40.45 l	59.45 g
$S_4 \times L_2$	41.45 fgh	71.35 cdef	11.90 cde	46.40 ijkl	68.65 fg
$S_4 \times L_3$	49.30 bc	79.15 abc	13.90 bcd	63.35 cd	87.60 cd
$S_4 \times L_4$	56.45 a	66.45 fg	12.00 bcde	48.60 hijk	69.15 fg

Means sharing similar letter(s) in a group under each parameter are non-significant at α=0.05 (DMR test).

removal of secondary branches from the top) plants compared to medium pruned (40 cm removal of secondary branches) and severe pruned (60 cm removal of secondary branches) plants of three Indian jujube cultivars.

Number of shoots per branch

Pak White had more (15.41 shoots), while Dehli Sufaid had lesser number of shoots (10.97) and the latter stood at par with other two cultivars. Fifty percent pruning was the most effective as the maximum number of shoots (14.42) appeared in this treatment. It might be due to more number of branches produced in response to 50% pruning in previous parameter and the same branches had more number of shoots per branch. Pak White cultivar was the best responsive to fifty percent pruning as it produced the maximum shoots per branch (17.65), but stood at par when the same cultivar pruned either up to 25% (15.70 shoots) or 75% (15.05 shoots) as apparent from Table 1. The results are supported by previous findings that the growth in terms of number of shoots was highest with moderate pruning (Dhaliwal and Sandhu, 1984; Raut and Diware, 2005; Kumar et al., 2016). However, the results are not supporting the findings of Khan and Hossain (1992) who obtained the highest number of side shoots per branch with severe pruning in cv. Narikeli. The reason could be better response of this cultivar to severe pruning compared to light, medium and no pruning.

Number of panicles per branch

Among the cultivars, Pak White had the maximum panicles (63.24), and all the cultivars produced the maximum panicles (67.47) under 50% pruning level. Two factors interaction indicated that the highest number of panicles per branch (78.85) was obtained by Pak White cultivar pruned at 50% level (Table 1). It may be due to emergence of more number of vegetative shoots and fruiting buds under optimal (50%) pruning level (Baloda et al., 2019).

Number of fruits per branch

Each fruit bearing branch of Pak White bore higher number of fruits (90.25) compared with other cultivars. Under 50% pruning level, all the cultivars bore the maximum number of fruits (95.94). The highest number of fruits per branch (109.20) was produced in Pak White when pruned up to 50% level (Table 1). As more number of branches per tree emerged under 50% pruning, so the same branches produced more number of shoots and panicles which consequently increased number of fruits under the optimal pruning intensity. Similarly, Kumar et al. (2016) recorded maximum number of fruits by employing 50% pruning in cv. Gola.

Single fruit weight

Pak White cultivar had heavier fruit (38.29 g) that stood statistically at par with fruit weight of Dehli Sufaid (33.65 g). Umran had lighter fruit weight (23.25 g) and it remained at par with fruit weight of Alu Bukhara cultivar (27.48 g). All cultivars bore heavier fruits (35.73 g) when pruning was done up to 50% level. The heaviest fruits (44.65 g) were borne on branches of

Pak White cultivar in response to 50% pruning level, followed by Dehli Sufaid also in response to 50% pruning (40.20 g) and Pak White in response to 75% pruning (37.50 g). All three treatment combinations were statistically similar to each other (Table 2). The results are in agreement with the findings of Kumar et al. (2016) who recorded improved fruit weight under 50% pruning in cv. Gola. It could be due to increased fruit size under more open canopy and light penetration in response to such optimal pruning intensity (Baloda et al., 2019).

Single fruit volume

Pak White cultivar had voluminous fruits (43.57 cm^3) that stood statistically at par with fruit volume of Dehli Sufaid (39.24 cm^3); Umran had lesser fruit volume (26.02 cm^3) and it remained at par with fruit volume of Alu Bukhara cultivar (31.90 cm^3). All the cultivars bore more bulky fruits (40.20 cm^3) when pruning was done up to 50% level. The bulkiest fruits (48.80 cm^3) were produced by Pak White cultivar under 50% pruning level, followed by Pak White receiving 75% pruning (45.85 cm^3), Dehli Sufaid in response to 50% pruning (43.50 cm^3) and 75% pruning (41.10 cm^3). All these four interactions were statistically at par with each other (Table 2). Trend of fruit volume was the same as for the fruit weight under various pruning intensities. Same reasons are applicable to fruit volume as attributed to fruit weight.

Yield per plant

Pak White produced significantly higher yield (184.28 kg per plant) among the cultivars; yields of other three cultivars remained statistically at par. Under 50% pruning level, all cultivars produced better yield (188.70 kg), followed by 25% pruning (170.48 kg), and these two pruning levels were statistically similar. Pruning up to 75% produced lower yield (157.65 kg) than that of 25% or 50% pruning. Pak White when pruned up to 50% level produced the best yield per plant (205 kg), which was significantly different from other treatment combinations. Dehli Sufaid under 50% pruning level (188.15 kg), Pak White under 25% pruning level (186.15 kg), Alu Bukhara (184.05 kg) and Umran (177.60 kg) under 50% pruning levels were at par statistically as apparent from interactions (Table 2). Fruit yield decreased as pruning intensity increased from 50% to 75% coinciding with the previous findings (Bajwa et al., 1987; Gupta and Gill, 2015; Kumar et al., 2016). The highest yield under 50% pruning could be due to better fruit weight, size and volume and greater number of fruits under the same level of pruning.

Fruit drop

All cultivars were statistically non-significant with respect to fruit drop. However, pruning levels affected this parameter. The minimum fruit drop (11.10%) was recorded in unpruned plants, followed by 25% pruned ones (12.81%), both remained statistically similar in effect. Fruit drop percentage increased to maximum (16.58%) at 75% pruning, followed by 50% pruning (14.47%). These two pruning levels were statistically at par. Fruit drop percentage seems to be directly proportional to

Table 2: Fruit and yield parameters of various Indian jujube cultivars as affected by different pruning levels.

Factors	Fruit weight (g)	Fruit volume (cm^3)	Yield per plant (kg)	Fruit drop (%)	Marketable yield/plant (kg)
Cultivars					
S_1 = Dehli Sufaid	33.65 a	39.24 a	169.02 b	13.40 a	146.55 b
S_2 = Pak White	38.29 a	43.57 a	184.28 a	13.28 a	159.79 a
S_3 = Umran	23.25 b	26.02 b	160.97 b	13.72 a	138.85 c
S_4 = Alu Bukhara	27.48 b	31.90 b	166.02 b	14.56 a	142.86 b
Pruning Levels					
L_1 = 0%	27.38 b	31.67 c	163.45 b	11.10 b	146.41 b
L_2 = 25%	28.65 b	32.61 c	170.48 ab	12.81 b	148.66 b
L_3 = 50%	35.73 a	40.20 a	188.70 a	14.47 a	161.44 a
L_4 = 75%	30.04 ab	36.23 b	157.65 b	16.58 a	131.54 c
Interaction					
$S_1 \times L_1$	30.15 defg	35.65c	165.74 def	11.10 ef	147.39 cd
$S_1 \times L_2$	30.95 cdef	36.70 c	175.85 bcd	12.54 def	150.97 bcd
$S_1 \times L_3$	40.20 ab	43.50 abc	188.15 b	13.25 cde	163.23 ab
$S_1 \times L_4$	33.30 bcde	41.10 abc	149.60 g	16.71 ab	124.62 f
$S_2 \times L_1$	35.20 bcde	39.70 bcd	172.60 cde	10.94 f	156.61 bc
$S_2 \times L_2$	35.80 bcd	39.90 bcd	186.15 b	12.69 def	162.52 ab
$S_2 \times L_3$	44.65 a	48.80 a	205.00 a	13.98 cde	176.34 a
$S_2 \times L_4$	37.50 abc	45.85 ab	170.10 cde	15.51 bcd	143.72 cde
$S_3 \times L_1$	19.95 j	22.50 h	154.80 fg	10.57 f	138.45 def
$S_3 \times L_2$	22.15 ij	24.10 gh	159.05 efg	13.37cde	137.78 def
$S_3 \times L_3$	28.35 efghi	31.60 efg	177.60 bcd	14.64 bcd	151.61 bcd
$S_3 \times L_4$	22.55 ij	25.85 fgh	152.65 fg	16.31 abc	127.55 f
$S_4 \times L_1$	24.20 hij	28.85 efgh	157.40 efg	11.82 ef	143.20 cde
$S_4 \times L_2$	25.70 ghjik	29.75 efgh	164.10 defg	12.63 def	143.38 cde
$S_4 \times L_3$	33.20 bcde	36.90 cde	184.05 bc	16.11 abc	154.58 bc
$S_4 \times L_4$	26.80fghij	32.10 def	158.50 efg	17.50 a	130.29 ef

Table 3: Fruit quality parameters of various Indian jujube cultivars as affected by different pruning levels.

Factors	Pulp to seed ratio (%)	Total soluble solids (°Brix)	Vitamin C (mg/100 g pulp)	Fruit acidity (%)	Total sugars (%)
Cultivars					
S_1 = Dehli Sufaid	89.53 a	15.61 a	116.75 b	0.14 b	5.22a
S_2 = Pak White	90.33 a	15.93 a	121.00 a	0.15 b	5.70 a
S_3 = Umran	85.29 b	13.90 b	103.32 c	0.19 a	4.47b
S_4 = Alu Bukhara	84.69 b	14.83 b	123.31 a	0.22 a	4.24b
Pruning Levels					
L_1 = 0%	87.64 b	13.68 b	115.94 b	0.20 a	4.65b
L_2 = 25%	87.55 b	15.50 b	113.06 b	0.21 a	4.73b
L_3 = 50%	91.33 a	17.53 a	120.21 a	0.22 a	5.64a
L_4 = 75%	83.33 c	13.57 b	115.15 b	0.22 a	4.81b
Interaction					
$S_1 \times L_1$	89.25 b	15.45 b	116.40 cd	0.15 d	4.25c
$S_1 \times L_2$	90.95 ab	15.50 b	116.50 cd	0.15 d	5.11b
$S_1 \times L_3$	93.00 ab	17.30 a	118.65 c	0.15 d	6.40a
$S_1 \times L_4$	83.90 cd	14.20 bc	115.45 cd	0.14 d	5.20b
$S_2 \times L_1$	90.00 b	14.00 bcd	122.85 b	0.14 d	5.10b
$S_2 \times L_2$	90.70 ab	16.50 b	111.65 de	0.15 d	5.35b
$S_2 \times L_3$	95.40 a	17.95 a	127.20 a	0.15 d	6.70a
$S_2 \times L_4$	89.10 b	14.25 bc	122.10 b	0.16cd	5.55b
$S_3 \times L_1$	86.45 bc	12.15 d	102.50 e	0.18 c	4.00d
$S_3 \times L_2$	83.50 cd	13.70 cd	102.00 e	0.19 bc	4.25cd
$S_3 \times L_3$	89.45 b	17.10 a	107.15 e	0.21 b	4.55c
$S_3 \times L_4$	81.75 d	12.65 d	101.60 e	0.22 ab	4.65c
$S_4 \times L_1$	83.35 cd	13.10 cd	122.00 b	0.23 ab	4.05d
$S_4 \times L_2$	85.75 bc	16.30 b	122.10 b	0.24 a	4.25cd
$S_4 \times L_3$	89.50 b	16.75 b	127.85 a	0.24 a	4.50c
$S_4 \times L_4$	80.15 d	13.15 cd	121.30 bc	0.24 a	4.15d

pruning intensity. The lowest fruit drop was recorded in Umran (10.57%), followed by in Pak White (10.94%), Dehli Sufaid (11.10%) and Alu Bukhara (11.82%) when left un-pruned; followed by Dehli Sufaid (12.54%), Alu Bukhara (12.63%) and Pak White (12.69%) at 25% pruning level. All these treatment combinations showed statistically same effect on fruit drop percentage. The maximum fruit drop (17.50%) was recorded in Alu Bukhara cultivar when pruned up to 75%, followed by Dehli Sufaid (16.71%) and Umran (16.31%) also under 75% pruning level and Alu Bukhara (16.11%) under 50% level of pruning. All these four interactions were statistically at par with each other (Table 2). The possible reason of lowest fruit drop in un-pruned plants could be the total growth attained by un-pruned plants was more than that of pruned plants irrespective of type and severity of pruning (Meghwal et al., 2017); this potential growth might restrict the fruit drop in un-pruned plants.

Marketable yield per plant

The maximum marketable yield per tree was obtained in Pak White cultivar (159.79 kg) and the minimum in Umran (138.85 kg). Marketable yields of Dehli Sufaid (146.55 kg) and Alu Bukhara (142.86 kg) were statistically similar. As for as pruning levels are concerned, the higher yield (161.44 kg) was under 50% pruning level and the lower one (131.54 kg) under 75% pruning level. Pruning up to 25% (148.66 kg) or leaving the plants unpruned (146.41 kg) had similar effect on the parameter. Previously, Gill and Ball (2006) reported significant reduction in fruit yield in response to increased pruning intensity confirming the results obtained from current study. The highest significant marketable yield (176.34 kg) was obtained by Pak White when pruned up to 50% level, followed by Dehli Sufaid under 50% pruning level (163.23 kg) and Pak White under 25% pruning level (162.52 kg). All the three treatment combinations were statistically at par with each other (Table 2). Medium pruning of 50% produced the highest marketable yield in all the cultivars conforming to the results of previous researchers (Bajwa et al., 1987; Kumar et al., 2016). Decrease in fruit yield with 75% pruning might be due to reduction in number of shoots and number of panicles under the same level of pruning.

Pulp to seed ratio

Fruits of Pak White cultivar had better pulp to seed ratio (90.33%) and it shared statistical similarity with Dehli Sufaid (89.53%). All the four cultivars showed the maximum pulp to seed ratio (91.33%) under 50% level of pruning and the minimum (83.33%) under 75% pruning level. The highest pulp to seed ratio (95.40%) was found in Pak White when subjected to 50% level of pruning, followed by Dehli Sufaid (93%) also under 50% pruning level, and Dehli Sufaid (90.95%) and Pak White (90.70%) under 25% pruning level. These four interactions were statistically non-significant among themselves (Table 3). The factors which involved in enhancing fruit size, fruit weight and volume under various pruning levels could be attributed in improving pulp content of the fruit that ultimately improved pulp to seed ratio.

Total soluble solids

Pak White (15.93 ˚Brix) and Dehli Sufaid (15.61 ˚Brix) cultivars were similar, while Alu Bukhara (14.83 ˚Brix) and Umran (13.90 ˚Brix) cultivars were also statistically similar with each other for the parameter. Total soluble solids went up to the maximum (17.53 ˚Brix) under 50% pruning in all the cultivars. However, the other pruning levels did not change the TSS value significantly. The highest TSS (17.95 ˚Brix) was in fruits of Pak White cultivar from the trees pruned up to 50%, followed by in fruits of Dehli Sufaid (17.30 ˚Brix) and Umran (17.10 ˚Brix) under same level of pruning. Three interactions were statistically non-significant in comparison to each other (Table 3). Ahmad et al. (2006) reported maximum TSS in pruned Kinnow plants as compared to un-pruned plants. Severely pruned plants have less TSS compared to moderate pruning; the reason could be more use of metabolites for vegetative growth in severely pruned plants (Baloda et al., 2019).

Vitamin C content

Fruits of Alu Bukhara cultivar led in Vitamin C content with 123.31 milligrams per 100 grams of pulp, Pak White ranked 2nd with 121 mg per 100 g of pulp. Both cultivars were similar for vitamin C content. Fifty percent pruning increased vitamin C content significantly (120.21 mg/100 g pulp); the other pruning levels remained statistically at par. The vitamin C content culminated to the maximum (127.85 mg/100 g pulp) in fruits of Alu Bukhara, then fruits of Pak White (127.20 mg/100 g pulp) picked from trees pruned up to 50%, both being statistically non-significant with each other (Table 3). The results endorsed the findings of Kumar et al. (2016) who reported increased ascorbic acid content under 50% pruning compared to 25%, 75% and control.

Fruit acidity

Fruits of Dehli Sufaid cultivar had the minimum (0.14%) acidity, followed by those of Pak White cultivar (0.15%), both being statistically similar. Fruits of Alu Bukhara cultivar had the maximum acidity (0.22%), followed by those of Umran cultivar (0.19%), both cultivars were statistically similar for the parameter. All cultivars remained non-significant under each of the pruning levels (Table 3). It is in conformity with the findings of Gupta and Gill (2015) that pruning intensities has no effect on fruit acidity of Indian jujube. Dehli Sufaid and Pak White cultivars showed acidity range 0.14-0.16% in response to four pruning levels, the respective interaction were statistically at par. The maximum acidity (0.24%) was observed in fruits of Alu Bukhara cultivar in response to 25%-75% pruning level, followed by the same cultivar (0.23%) when kept unpruned and in Umran cultivar (0.22%) when pruned to 75% level. Latter all five interactions were statistically similar with each other (Table 3).

Total sugars

Fruits of Pak White were sweater (5.70%) followed by those of Dehli Sufaid (5.22%) with higher total sugar content; both being statistically similar. Fruits of Alu Bukhara (4.24%) and Umran (4.47%) were less sweet due to low total sugar content and were also statistically similar. Fifty percent pruning level significantly enhanced total sugars content up to the maximum (5.64%), other pruning levels remained at par for this parameter. Pak White when pruned to 50% level, resulted in the maximum total sugars content (6.70%), followed by Dehli Sufaid (6.40%) under same level of pruning, both were statistically similar in effect. Pak White and Dehli Sufaid both when pruned either up to 25% or 75%, the resultant total sugars in fruits went more than 5% and the respective interactions were at par with each other (Table 3). The highest total sugar content under 50% pruning might be due to more assimilation of photosynthates (CHO-rich compounds) and metabolites in the fruits that were produced in more open canopy area under the judicious level of pruning (Kumar et al., 2016).

CONCLUSION

Indian jujube cultivars responded variably to different levels of pruning. Fifty percent pruning by removing unproductive, over-crowded secondary and tertiary branches leaving 1/2 portion of branch intact with main limb, proved the best pruning intensity as it improved vegetative, yield and quality parameters to the maximum in all the promising Indian jujube cultivars under trial. Further pruning (75%) resulted in reduced yield and would be un-necessary. However, pruning is better option than no pruning.

REFERENCES

Ahmad, S., Chatha, Z.A., Nasir, M.A., Aziz, A., Virk, N.A. and Khan, A.R. 2006. Effect of pruning on yield and quality of Kinnow fruit. *Journal of Agriculture and Social Sciences,* 2(1): 51-53.

Anonymous. 2019. Fruit, Vegetables & Condiments Statistics of Pakistan 2017-18. Economic Wing, Ministry of National Food Security and Research, Government of Pakistan, Islamabad, pp. 1-6.

Bajwa, G.S., Sandhu, H.S. and Bal, J.S. 1987. Effect of different pruning intensities on growth, yield, and quality of ber (*Ziziphus mauritiana* Lam.). *Haryana Journal of Horticultural Sciences,* 16(3 & 4): 209-213.

Baloda, S., Sehrawat, S.K., Sharma, J.R., Singh, S. and Beniwal, R.S. 2019. Effect of different levels of rejuvenal pruning on tree canopy, yield and quality of ber (Chapter 17). In: Behl, R.K, Singh, M., Ibenthal, A. and Merbach, W. (eds.). Emerging Technologies towards Agriculture, Food and Environment. Agrobios International, Jodhpur, India, pp. 241-247.

Boora, R.S. and Singh, H. 2007. Effect of pruning time and severity of on yield and fruit quality in ber (*Ziziphus mauritiana* L) cv. Sanaur-2. *Haryana Journal of Horticultural Sciences,* 36(1 & 2): 60-63.

Dhaliwal, G.S. and Sandhu, I.P.S. 1984. Effect of pruning on vegetative growth, flowering and fruit set in ber (*Ziziphus mauritiana* Lamk.) cv. Umran. *Haryana Journal of Horticultural Sciences,* 11(3 & 4): 208-212.

Gill, K.S. and Ball, J.S. 2006. Influence of pruning severity and time on yield and fruit quality of ber cv. Umran. *Indian Journal of Horticulture,* 63(2): 162-165.

Gola, A.Q., Jakhro, M.I., Tareen, A.K., Mastoi, M.S. and Khosa, M.A. 2018. Influence of pruning on fruits productionof jujube *Ziziphus mauritiana* Lam. *Pure and Applied Biology*, 7(4): 1261-1267.

Gupta, N. and Gill, M.S. 2015. Effect of intensity of pruning on yield and fruit quality of ber (*Ziziphus mauritiana* L) cv. Umran. *International Journal of Agriculture, Environment and Biotechnology,* 8(1): 69-73.

Johnstone, R. 2018. Jujubes in Western Australia – a growing industry. WA Jujube Growers Association Inc., Department of Primary Industries and Regional Development, Government of Western Australia.

Khan, M.S.I. and Hossain, A.K.M.A. 1992. Effect of pruning on growth, yield and quality of ber. Acta Horticulturae, 321: 684-690.

Kumar, A., Pratap, B. and Vishwakarma, G. 2016. Effect of pruning intensity on growth, yield and fruit quality characteristics of ber (*Ziziphus mauritiana* Lamk.) cv. Gola. Progressive Horticulture, 48(2): 148-153.

Kumar, D. 2002. Effect of pruning intensity on vegetative growth and yield of Indian jujube (*Ziziphus mauritiana*) under semi-arid condition. *Indian Journal of Agricultural Sciences,* 72(11): 659-660.

Kumar, H., Katiyar, P.N., Singh, A.K. and Rajkumar, B.V. 2014. Effect of different pruning severity on growth and yield of ber Indian jujube (*Ziziphus mauritiana* Lamk.) cv. Banarsi Karaka. International Journal of Current Microbiology and Applied Sciences, 3(5): 935-940.

Kumar, S., Ram, S.N. and Baig, M.J. 2002. Effect of pruning levels on yield and quality of ber (*Ziziphus mauritiana* L.) cultivars. *Range Management and Agroforestry,* 23(1): 59-62.

Meghwal, P.R., Singh, A. and Singh, M. 2017. Pruning in Indian jujube (*Ziziphus mauritiana* Lam.): a review. *Annals of Arid Zone,* 56(3 & 4): 107-115.

Pandey, R.C., Pathak, R.A. and Singh, I.S. 1998. Effect of pruning intensity on vegetative and reproductive growth in ber (*Ziziphus mauritiana*). Indian Journal of Horticulture, 55(4): 306-313.

Raut, V.U. and Diware, D.V. 2005. Effect of pruning time and severity on growth and development of ber (*Ziziphus mauritiana* Lam.). *Journal of Soils and Crops,* 15(1): 60-63.

Saleem, B.A., Malik, A.U., Pervez, M.A., Khan, A.S. and Khan, M.N. 2008. Spring application of growth regulators affects fruit quality of 'Blood Red' sweet orange. *Pakistan Journal of Botany,* 40(3): 1013-1023.

Shafiq, M., Khan, A.S., Malik, A.U., Shahid, M., Rajwana, I.A., Saleem, B.A., Amin, M. and Ahmad, I. 2011. Influence of pollen source and pollination frequency on fruit drop, yield and quality of date palm (*Phoenix dactylifera* L.) cv. Dhakki. *Pakistan Journal of Botany,* 43(2): 831-839.

Sharif. N., Ishfaq, M., Javaid, M.A. and Bashir, M.A. 2016. Effects of different pruning times on growth and yield of ber (*Zizyphus mauritiana* Lamk), cv. "Alu-Bukhara". *Journal of Agricultural Research,* 54(2): 251- 259.

Steel, R.G.D., Torrie, J.H. and Dickey, D.A. 1997. Principles and Procedures of Statistics: A Biometrical Approach (3rd Ed.). McGraw Hill Book Co. Inc., New York, pp. 400-428.