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Vikalp
Department of Horticulture, Maharana Pratap Horticultural University, Karnal, Haryana, India

Mukesh Kumar
Regional Research Station, Bawal (Rewari), CCS HAU, Hisar, Haryana, India

JR Sharma
Department of Horticulture, CCS HAU, Hisar, Haryana, India

Mukesh Bishnoi
Department of Horticulture, CCS HAU, Hisar, Haryana, India

Swati Rani
Department of Bio and Nano Technology, GJUST, Hisar, Haryana, India

Arjoo
Department of Horticulture, Maharana Pratap Horticultural University, Karnal, Haryana, India

Corresponding Author:
Vikalp
Department of Horticulture, Maharana Pratap Horticultural University, Karnal, Haryana, India

Evaluation of Ber (*Ziziphus mauritiana* Lamk.) germplasm under semi-arid conditions of Haryana

Vikalp, Mukesh Kumar, JR Sharma, Mukesh Bishnoi, Swati Rani and Arjoo

Abstract
The present study was conducted to characterize the ber (*Ziziphus mauritiana* Lamk.) germplasm for their growth attributes under the semi-arid condition. The evaluated germplasm had significant variability for the observed parameters. Erect growth habit was observed in three germplasm, *viz.* Bawal Ber 4, Bawal Ber 10 and Bawal Ber 11; however, spreading type of growth habit was observed in four germplasm, *viz.* Bawal Ber 9, BS 1, BS 2 and BS 3, while semi-erect growth habit was observed in most of the germplasm. Germplasm could be classified based on shoot surface, *viz.* smooth and tomentose. The main characters for classification of germplasm was the leaf shape, *viz.* oval, obovate, cordate and ovate; fruit shape; stone shape. Leaves of Bawal Ber 1 to 5, Bawal Ber 9, Bawal Ber 10, Bawal Ber 11 and BS 3 were observed oval in shape; leaves of Bawal Ber 6 to 8 were obovate; leaves of BS 1 and BS 2 were cordate in shape, and; leaves of Bawal Ber 12 were ovate. Further different germplasm showed considerable variation in leaf pubescence on the lower side *i.e.*, densely tomentose, sparsely tomentose and smooth. Germplasm could also be classified based on the branch thorniness, *viz.* less, medium and high. Different germplasm of ber showed a considerable variation in thorn shape, fruit weight, stone weight, yield. The thorns of Bawal Ber 12 were all curved, while the thorns of all the rest of the germplasm were observed as alternate curved. The germplasm also showed considerable variation and classified on the basis of fruit length, fruit width, fruit weight, stone weight, fruit set percent, fruit maturity group, yield *etc.*

Keywords: Jujube, erect, thorns, yield, cordate

Introduction
Ber (*Ziziphus mauritiana* Lamk.) is an important cultivated species belongs to family Rhamnaceae, which includes about 50 genera and 600 species. The genus *Ziziphus* contains about 40 species occurring in tropical and subtropical regions of the world (Pareek, 2001) [18]. It is known to be indigenous to the geographical region of India to South-Western China and Malaya (Vavilov, 1951) [28]. Ber (*Ziziphus mauritiana* Lamk.) is one of the important species commercially cultivated for its nutritious fruits. Beside consumed as fresh fruit, it has been also used in other processed forms such as dried, candies, pulp, jam and beverages. According to studies by Azam-Ali *et al.* (2006) [3] and Krishna *et al.* (2014) [11], berries have higher concentrations of protein, phosphorus, calcium, carotene, and vitamin C than apples and oranges, respectively, in terms of these nutrients. Additionally, it has plenty of antioxidants (Krishna and Parashar, 2013) [9]. Some of the most prevalent phenolics found in ber include p-coumaric acid, ferulic acid, caffeic acid and p-hydroxybenzoic acid (Bakhshi, 1974; Koley *et al.*, 2011) [4, 8]. Its leaves contain 5.6% digestible crude protein and 49.7% of all nutrients that are digestible. It's nutritive value and cheaper availability makes it 'poor man's fruit'.
There are more than 125 cultivars of ber fruit has been reported in India (Pareek, 2001) [18], most of them are results of selection. So far, very limited systematic efforts have been made to characterize the variability existing in ber germplasm across the country. Besides there is great ambiguity in classification or naming of these cultivars, due to numerous variants within each group and regional naming, such as, Gola cultivar has got many variants such as Kala Gola, Kakrola Gola, Gurgaon Gola, Gurgaon Gola-I, II *etc.* For plant varieties to be protected in India under the Protection of Plant Varieties and Farmer's Right Act, 2001 (PPV&FR Act), distinctness, uniformity and stability (DUS) testing must be conducted. The act contains provisions for comparing one's variety with varieties of common knowledge regarding some pertinent characteristics specified in the Draft National Test Guidelines for DUS testing of ber (Anonymous, 2013) [1].

The goal of the current study was to evaluate 15 different germplasm based on physical and growth characteristics in order to determine how unique each variety was compared to the other kinds that were available in India.

Materials and Methods

A total of 15 ber germplasm *viz.* Bawal Ber 1, Bawal Ber 2, Bawal Ber 3, Bawal Ber 4, Bawal Ber 5, Bawal Ber 6, Bawal Ber 7, Bawal Ber 8, Bawal Ber 9, Bawal Ber 10, Bawal Ber 11, Bawal Ber 12, BS 1, BS 2 and BS 3 were evaluated at Regional Research Station, Bawal (Rewari) of CCS HAU, Hisar (Haryana) in a randomized block design (RBD) with three replication of the same plant (3 samples taken from different directions of the plant) during the year 2019-2020. The spacing adopted was 8 × 8 m.

The experimental location, Bawal is situated at an altitude of 266 m above mean sea level with coordinates of 28º 10´ N latitude and 76º 50´ E longitude in Southern zone of Haryana. The average of total rainfall received is 456 mm; however, the total rainfall received during April 2019 to March 2020 (experimental period) was 644 mm. About 80-85 per cent of total annual rainfall is received during monsoon season and little showers of rainfall are received from December to February.

The parameters were recorded at specific stage as per standard DUS testing guidelines of PPV&FRA (Anonymous, 2016). Parameters like growth habit, shoot surface, leaf shape, thorn shape *etc.* were recorded after three to four months of pruning when canopy attained the characteristic shape according to specific germplasm and has no sign of active growth. Similarly, observation on thorns were also recorded in the middle of tertiary branches. Immature fruit characters were recorded when fruit has not attained its full size and specifically green in colour. Other fruit and stone characters were recorded when the fruit becomes mature and ready to harvest.

Results and Discussion

Among the 15 germplasm, considerable variations were recorded for various morphological and physical characters. The characteristics of different ber germplasm under study are presented in Table 1 and Table 2. The growth parameters *i.e.*, growth habit, leaf length, leaf breadth, leaf pubescence and leaf shape are helpful in the identification of the genotypes. Similar reports of variability are available from Raja (2004) [21], Saran (2005) [23], Dalal and Beniwal (2014) [5], Krishna *et al.* (2016) [10], Meena *et. al.* (2019) [13] and Singh *et. al.* (2019) [26] in ber.

Out of the fifteen germplasm, majority of them had semi-erect growth, while Bawal Ber 9, BS 1, BS 2 and BS 3 had spreading growth and Bawal Ber 4, Bawal Ber 10 and Bawal Ber 11 had erect growth habit (Table 2). These findings are in agreement with those of Raja (2004) [21] and Krishna *et al.* (2016) [10] in ber. The tree growth habit might be the varietal/germplasm characteristic because the variation in tree shape of ber under different agro-climatic conditions remained the same (Singh, 2018) [24].

Among the studied germplasm, plant height varied from 4.20 m to 8.00 m (Table 1). According to Dubey *et al.* (2002) [6], the capacity of the plant's root zone to absorb additional nutritional matter may be what causes the variance in plant height of guava. It could result from the unique growth characteristics of several genotypes or from the genetic structure of the plant. Singh and Misra (2002) [25] also reported the variation in plant height of ber, it varied from 3.75 m to 5.75 m. Tree spread (average of N-S and E-W) was observed maximum (7.95 m) in BS 2 and minimum in Bawal Ber 12 (4.25 m) and the trunk girth was recorded minimum (57 cm) in Bawal Ber 4; however, it was maximum (171 cm) in Bawal Ber 7 (Table 1). Godi *et al*. (2016) [7] also reported the variations in tree spread and trunk girth in different ber cultivars. The selection of cultivar must be based on the performance of germplasm/ variety under particular condition because the same cultivars behave differently with a change in agro-climatic conditions (Parveen, 2019) [19].

Shoot surface of different germplasm varied significantly and found that the Bawal Ber 4, Bawal Ber 6, Bawal Ber 7, Bawal Ber 10, Bawal Ber 11, BS 1 and BS 2 (Table 2) had smooth shoot surface and the rest of all germplasm had tomentose shoot surface. The variation in shoot surface among the different germplasm might be due to inherent characteristics of the particular germplasm. These types of variations in shoot surface of ber were also observed by Krishna *et al.* (2016) [10]. The differences in leaf shape, leaf pubescence and leaf size (leaf length and breadth) were due to inherent characteristics of the ber genotypes. The fruit-bearing capacity of a plant is very much influenced by the variation in these attributes. Significant variability was observed in different genotypes of ber for growth habit, leaf length, leaf width and leaf shape. The variation in leaf shape was observed in different germplasm *i.e.*, oval, obovate, cordate, ovate (Plate 1) and leaf base varied as cordate, round, oblique and acute (Table 2). Different shapes of leaves are shown in Plate 1. Similar variability in leaf shape of ber was also reported earlier by Nehra *et al*. (1984) [16], Raja (2004) [21], Saran (2005) [23] and Razi *et al.* (2013) [22].

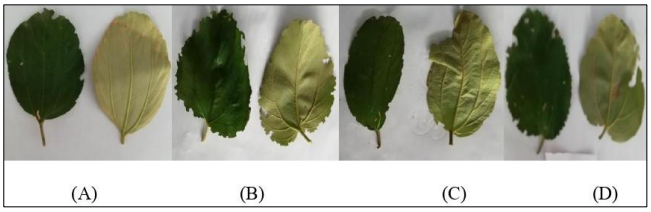

Plate 1: Leaf shape: (A) Oval (B) Obovate (C) Cordate (D) Ovate

Leaf curving was found (present) in the majority of the germplasm except, Bawal Ber 11, BS 2 and BS 3. Nicotra *et al.* (2011) [17] reported that the variation in leaf shapes of angiosperms is associated with variation in other leaf traits due to different climatic factors. Krishna *et al.* (2016) [10] also reported the same types of variations in leaf curving and leaf pubescence on the lower side on 24 varieties of ber. The variation in leaf curving, leaf pubescence on lower side among different germplasm might be due to any genetic features of particular germplasm.

The maximum leaf length was recorded in BS 3 (8.08 cm) and minimum in BS 2 (5.44 cm). Likewise, the maximum leaf width was observed in Bawal Ber 2 (6.44 cm) and minimum in BS 1 (4.27 cm) (Table 1). Similar results in the leaf size were also observed by Nehra *et al.* (1984) [16], Singh and Misra (2002) [25], Raja (2004) [21] and Saran (2005) [23] on different varieties/ germplasm of ber. The difference in leaf size for length, breadth and leaf area was due to inherent characteristics of the genotypes. Nagar *et al.* (2018) [15] reported that the variation in leaf length, leaf width among the

germplasm of bael might be due to improved photosynthetic efficiency and thus ultimate growth potential of the plant.

Bawal Ber 1 and BS 3 had observed less thorniness, while all the remaining germplasm had medium branch thorniness. Thorns in all the germplasm were observed as alternate curved, except Bawal Ber 12, which had all curved thorns. The thorn persistence: caducous was present in BS 1, BS 2 and BS 3, while the thorn persistence in another germplasm was observed as absent (Table 2). These types of variation in ber cultivars for thorns persistence present/ absent were also recorded by Krishna *et al.* (2016) [10]. The variation in branch thorniness and thorn shape might be due to some genetic factors of the germplasm (Tatari *et al.*, 2016) [27].

Among different germplasm fruit length, fruit width and fruit weight varied significantly. The fruit weight is an important criterion for the selection of new promising cultivar. The fruits of higher weight had more size also. This may be due to fruits remained on the plant for a longer time to attain maturity/ ripening. The increase in fruit weight of some germplasm of ber might be due to more uptakes of nutrients, water and also due to the translocation of photosynthates from source to sink (Patel *et al.*, 1977) [20]. Climatic factors and inherent characters of germplasm may be the other probable reason for these variations (Saran, 2005) [23]. Higher fruit weight is also the preferred character for germplasm selection. Maximum stone weight (2.21 g) was recorded in Bawal Ber 10, while minimum (1.29 g) was recorded in Bawal Ber 1. The specific gravity among different germplasm varied significantly and it ranged from 0.96 to 1.33 (Table 1). The variability in specific gravity might be due to a decrease in moisture concentration, increase in ash content or an increase in fresh weight during ripening (Kumar *et al.*, 2016) [12].

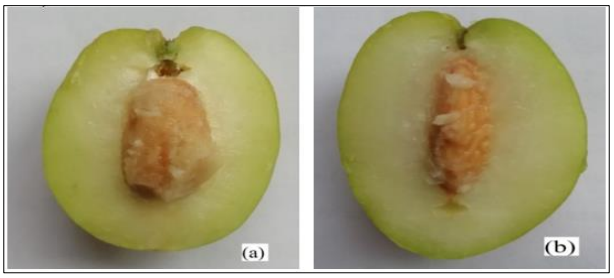

Plate 2: Pulp cavity (a) Stem end (b) Stylar end

The data on the pulp cavity at the stem end of different ber germplasm varied as pulp cavity at stem end present or absent. The pulp cavity at stem end was present in Bawal Ber 2, Bawal Ber 7, Bawal Ber 8, Bawal Ber 9 and Bawal Ber 12 (Table 2 and Plate 2a). The pulp cavity at the stylar end was present in Bawal Ber 2, Bawal Ber 5 to 7, Bawal Ber 10 and Bawal Ber 12 (Table 2 and Plate 2b). The highest fruit set percentage (19.92) was recorded in Bawal Ber 8, which was statistically at par with Bawal Ber 9, whereas the lowest fruit set percentage (11.99) was recorded in Bawal Ber 1 (Table 2). Nagar (2016) [14] reported that the variation in fruit set per cent among the various varieties of bael might be due to their inherent characters. Sometimes fruit.

Table 1: Fruit and stone morphological characteristics of ber germplasm under semi-arid conditions of Haryana

Germplasm	Plant height (m)	Trunk girth (cm)	Tree spread (m)	Leaf blade length (cm)	Leaf blade width (cm)	Average leaf fresh weight (g)	Average leaf dry weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Specific gravity (at harvesting stage)	Pulp weight (g)	Stone weight (g)	Stone length (mm)	Stone width (mm)	Stone: pulp ratio	Average seed weight (mg)
Bawal Ber 1	5.25	72	5.45	7.35	6.17	0.92	0.20	3.30	2.43	13.13	1.23	11.83	1.29	15	8	0.109	352
Bawal Ber 2	5.40	150	6.60	7.18	6.44	0.98	0.22	3.97	2.50	17.60	1.19	15.94	1.66	18	8	0.104	431
Bawal Ber 3	5.75	95	7.00	7.33	5.14	0.86	0.18	3.90	2.50	17.90	1.02	16.21	1.69	19	9	0.104	574
Bawal Ber 4	4.50	57	5.20	6.15	5.32	0.66	0.14	3.60	2.33	14.10	1.10	12.75	1.35	21	9	0.105	483
Bawal Ber 5	6.20	140	7.60	6.36	5.69	0.89	0.19	4.07	2.43	18.73	1.08	16.96	1.77	20	10	0.104	464
Bawal Ber 6	5.45	135	6.55	7.36	6.09	0.83	0.17	4.17	2.63	19.13	1.15	17.30	1.83	22	9	0.105	590
Bawal Ber 7	6.35	171	7.85	6.61	5.49	0.91	0.18	4.27	2.67	19.27	1.09	17.41	1.86	23	10	0.106	504
Bawal Ber 8	5.35	125	6.00	7.93	5.31	0.74	0.15	3.97	2.37	17.10	0.99	15.37	1.73	19	8	0.112	535
Bawal Ber 9	4.20	85	5.80	8.07	6.09	0.88	0.17	4.97	2.90	22.17	1.26	20.13	2.04	23	10	0.101	448
Bawal Ber 10	5.80	110	6.00	7.83	4.99	0.76	0.16	4.43	3.03	24.57	1.26	22.36	2.21	27	11	0.098	575
Bawal Ber 11	5.40	115	6.45	6.15	4.43	0.61	0.14	4.03	2.43	17.13	1.33	15.38	1.75	18	10	0.113	477
Bawal Ber 12	5.10	94	4.25	5.76	5.24	0.56	0.13	4.23	2.77	19.40	0.98	17.52	1.88	23	11	0.107	429
BS 1	5.10	120	6.70	6.08	4.27	0.48	0.10	3.37	2.47	13.17	0.96	11.88	1.30	19	8	0.108	356
BS 2	5.75	120	7.95	5.44	4.50	0.44	0.11	3.33	2.37	12.90	1.25	11.55	1.35	17	9	0.116	551
BS 3	8.00	155	7.75	8.08	4.72	0.78	0.18	4.53	2.63	20.97	1.26	19.12	1.85	23	9	0.096	353
Range	4.20-8.00	57-171	4.25-7.95	5.44-8.08	4.27-6.44	0.44-0.98	0.10-0.22	3.30-4.97	2.33-3.03	12.90-24.57	0.96-1.33	11.55-22.36	1.29-2.21	15-27	8-11	0.096-0.116	352-590
CD(p= 0.05)	--	--	1.66	0.27	0.26	0.03	0.01	0.30	0.18	0.84	0.23	0.80	0.25	1.8	1.5	NS	22

Table 2: Growth, leaf and fruit morphological and physical characteristics of ber germplasm

Germplasm	Growth Habit	Shoot Surface	Branch thorniness	Thorn shape	Thorns persistence: Caducous	Leaf Shape	Leaf Base	Leaf Curving	Leaf: Pubescence on lower side	Pulp cavity: Stem end	Pulp cavity: Stylar end	Pulp texture	Fruit cracking	Fruit maturity group	Fruit set (%)	Peak time of harvest	Yield (kg/plant)
Bawal Ber 1	1	5	6	8	10	12	15	11	19	10	10	7	10	23	11.99	22-29 Feb	80
Bawal Ber 2	1	5	7	8	10	12	16	11	20	11	11	21	10	23	12.32	21 Feb-1 Mar	85
Bawal Ber 3	1	5	7	8	10	12	15	11	20	10	10	7	10	23	14.81	22 Feb-4 Mar	85
Bawal Ber 4	2	4	7	8	10	12	16	11	4	10	10	7	10	24	12.28	12-20 March	60
Bawal Ber 5	1	5	7	8	10	12	16	11	20	10	11	7	10	23	17.02	21 Feb-5 Mar	66
Bawal Ber 6	1	4	7	8	10	13	16	11	20	10	11	21	10	23	14.86	19 Feb-3 Mar	82
Bawal Ber 7	1	4	7	8	10	13	16	11	20	11	11	21	10	23	15.63	20 Feb-4 Mar	83
Bawal Ber 8	1	5	7	8	10	13	17	11	19	11	10	7	10	24	19.92	15-25 March	80
Bawal Ber 9	3	5	7	8	10	12	16	11	19	11	10	21	10	24	19.21	14-25 March	67
Bawal Ber 10	2	4	7	8	10	12	16	11	20	10	11	7	10	23	15.70	28 Feb-10 Mar	85
Bawal Ber 11	2	4	7	8	10	12	16	10	4	10	10	7	10	24	16.11	16-23 March	87
Bawal Ber 12	1	5	7	9	10	12	18	11	4	11	11	21	11	22	18.31	5-16 Feb	80
BS 1	3	4	7	8	11	15	16	10	4	10	10	7	10	23	15.42	27 Feb-8 Mar	65
BS 2	3	4	7	8	11	15	16	11	4	10	10	7	10	23	16.20	26 Feb-7 Mar	67
BS 3	3	5	6	8	11	12	17	10	20	10	10	7	10	24	14.13	13-22 March	100
Range	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11.99-19.92	5 Feb-25 Mar	60-100
CD(p= 0.05)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.04	--	--

Numbers used in Table 2 coded for paramerters are given below:
1= Semi-erect, 2= Erect, 3=Spreading, 4= Smooth, 5= Tomentose, 6= Less, 7=Medium, 8= Alternate curved, 9= All curved, 10= Absent, 11= Present, 12= Oval, 13= Obovate, 14= Ovate, 15= Cordate, 16= Round, 17= Oblique, 18= Acute, 19= Densely tomentose, 20= Sparsely tomentose, 21= Soft, 22= Early, 23= Mid, 24= Late

Set per cent may vary due to agronomic practices and local environmental conditions. On a fully grown tree, fruit cracking may be due to some nutritional deficiency, temperature fluctuation or soil moisture imbalances.

The period of 50 per cent fruit maturity was observed earliest in Bawal Ber 12 (5-16 February), followed by Bawal Ber 6 (19 February to 3 March) and late in Bawal Ber 8 (15-25 March). This may be due to the requirement of environmental/ physiological conditions of particular germplasm during fruiting. The fruits of Bawal Ber 12 were observed in early maturity group; the fruits of Bawal Ber 1 to 3, Bawal Ber 5 to 7, Bawal Ber 10, BS 1 and BS 2 were observed in mid maturity group and the fruits of Bawal Ber 4, Bawal Ber 8, Bawal Ber 9, Bawal Ber 11 and BS 3 were found in late maturity group. The maximum yield (100 kg/plant) was observed in BS 3, while the minimum yield (60 kg/plant) was observed in Bawal Ber 4 (Table 2).

According to the findings of the study, the highest fruit length, width, fruit weight, pulp weight, stone length, stone width and stone weight was found in Bawal Ber 10 followed by Bawal Ber 9. The maximum plant height, leaf length, leaf width and yield was found in BS 3 followed by Bawal Ber 11. Highest fruit set percentage was found in Bawal Ber 8. These parameters help the plant to accumulate the maximum number of photosynthates and ultimately increases the yield of the plant. So, overall Bawal Ber 8 was found superior in fruit length, fruit width, fruit weight, fruit set percentage, yield, followed by Bawal Ber 9, Bawal Ber 10 and BS 3, while in terms of early fruit maturity, Bawal Ber 12 found earliest.

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