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Growth, flowering and fruiting behaviour of different blueberry (*Vaccinium* spp) genotypes under mid hill conditions of Himachal Pradesh, India

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ABSTRACT

Four southern highbush blueberry (*Vaccinium* spp.) cultivars, viz. Jewel, Misty, Gulf Coast and Sharpblue along with Austin, and Alapaha (Rabbiteye) were studied for their vegetative growth, flowering and fruiting behaviour at CSKHPKV, Palampur, Himachal Pradesh during the year 2015-16. A significant variation was observed for annual shoots/cane growth and growth pattern among these genotypes. Southern highbush cultivar Jewel produced maximum (49.05 cm) shoots/cane length with vigorous growth, closely followed by a rabbiteye cultivar cv. Austin (48.36 cm) and minimum shoot growth (39.02 cm) was observed in Alapaha. The growth rate at different interval was also recorded and it was observed maximum at D2-3 intervals in all genotypes.The results also showed significant variation with respect to various foliar characters, viz. leaf size, specific leaf area, number of flowers/cluster, corolla size (length and breadth), number of stamens/flower and color of corolla. All southern highbush blueberry cultivars were earliest to flower as compared to rabbiteye. Similarly, a significant variation was observed for number of flowers and fruits/ cluster among genotypes. Gulf Coast had maximum (8.78 flowers/cluster) number of flowers/cluster followed by Jewel (7.67 flowers/cluster) another southern highbush blueberry cultivar. The harvesting of southern highbush cultivars, viz. Misty and Gulf Coast was earliest among other genotypes and both rabbiteye blueberries the harvesting was late starting from 21 May in Alapaha and 27 May in Austin. However, the yield of individual cultivars was not recorded but cumulative yield at the end of harvesting it was observed to be 200-250 g/bush (data not presented). The southern highbush blueberries such as Jewel, Misty, Gulf Coast and Sharpblue have shown encouraging results with satisfactory growth, flowering and fruiting thus they can be grown in Himachal Pradesh and areas prevailing similar agroclimatic conditions in India.

Key words: Alapaha, Blueberry, Flowering, Fruiting, Jewel, Misty, Rabbiteye

Blueberry (*Vaccinium* spp., Family: Ericaceae) is a potential berry fruit for acidic soils; the genus includes some 450 species worldwide, just a handful of them are of economic significance. The genus *Vaccinium* is divided into five sub groups, viz. lowbush blueberries (*Vaccinium angustifolium*); highbush blueberries (*Vaccinium corymbosum* L.) native to northen America; European wild lowbush or bilberry or forest blueberry (*Vaccinium myrtillus*) is native of Europe, rabbiteye blueberry (*Vaccinium ashei* R), originated in south eastern United Sates and southern highbush, (lowchill) derived from northern highbush types crossed with several species such as *Vaccinium darrowi* and *Vaccinium ashei* are proven suitable in warm climates with low winter chill.

In India commercial blueberry production has not been reported yet except few for research purpose only (Negi *et al*. 2012). Blueberries are now becoming important commercial fruit worldwide (Strik and Yarborough 2005, Jimenez *et al*. 2005). Nutritionally, blueberries are good source of carbohydrates, vitamins, anthocyanins and several minerals, they also contain high amount of iron. In a study performed on rats showed that when they were fed diets supplemented with 2% blueberry extracts, age-related losses of behaviour (Alzheimer's disease and other) and signal transduction were delayed or even reversed, and radiation-induced losses of spatial learning and memory were reduced (Shukitt-Hale *et al*. 2007). Like other berries, blueberries, also supply bioactive compounds abundantly with high antioxidant activities, such as flavonoids (flavonols, anthocyanins and others) and phenolic acids (Schotsmans *et al*. 2007).

In Himachal Pradesh, highbush and rabbiteye cultivars, viz. Jewel, Misty, Bluecrop, Gulfcoast, Primadonna, Sharpblue, Duke, Alapaha and Springwide were introduced in Palampur in the year 2006-07. Out of these, only southern highbush blueberry cultivars such as; Jewel, Misty, Gulfcoast, Sharpblue and one rabbiteye cultivar Alapaha survived and adapted to this climate. Similarly, two rabbiteye cultivars, viz. Austin and Brightblue were transferred from National Bureau of Plant Genetic Resources, Shimla, India

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to Palampur and were planted at the same location but only Austin survived and acclimatized well to this climate and now bearing fruits. Thus an attempt was made to evaluate the blueberry production in Himachal Pradesh, India, where soil is slightly acidic and winter is cool enough to meet the chilling requirements for southern highbush and rabbiteye blueberries.

MATERIALS AND METHODS

The study was carried out at CSKHPKV, Palampur, Himachal Pradesh India, during the year 2015-16. The experimental area is located at 1239 m above mean sea level, 32° 5'55.05"N latitude and 76°32'32.94"E longitude. Area represents the mid hill zone of Himachal Pradesh, the soil is silty clay with slightly acidic with pH 6.0. The plants were planted closely in raised beds at 1.5 × 1.5 m spacing and the basin area was kept slightly raised, mulched with pine needles and barks. Only well rottened FYM at 10-20 kg/plant was applied in December and no chemical fertilizer was applied.

Four cultivars of southern highbush blueberry (*V. corymbosum* L. hybrids) namely; Misty, Gulf Coast, Jewel, Sharpblue along with two rabbiteye cultivars (*V. ashei* syn. *V. virgatum* Ait.), viz. Austin and Alapaha were studied for their growth, flowering and fruiting behavior during the year 2015-16. The plants were selected on the basis of their uniform growth and vigour, aged between 7 to 8 years.

The observations on growth parameters, periodic growth and growth rate of selected branches were recorded at different intervals starting from shoot emergence to the secession of growth at the end of growing season.

The growth rate was calculated by using formula:

$$\text{Growth rate} = \frac{Gt2 - Gt1}{Gt1} \times 100$$

where, G_{t2}= Growth at final stage, G_{t1}=Growth at initial stage.

The rate was expressed in percent increase over initial growth and percent increase over initial growth of cane/shoot was plotted against different growth intervals. Internodal length was just calculated by dividing total number of nodes by shoot length at the end of growing season and expressed in cm.

For foliar characteristics, viz. leaf size, shape index (L/D ratio), leaf area and foliar density were recorded as per standard procedures. The specific leaf area was recorded by just dividing leaf area by leaf fresh weight and expressed as cm^2/g. For flowering, observations on opening of first flower, full bloom date and duration were recorded and expressed as flowering duration. Similarly, colour of opened flowers, size of corolla, number of stamen and number of flowers per cluster were also recorded. The number of fruits per cluster were also recorded by counting number of fruits per cluster from randomly selected shoots and duration of harvesting was also recorded. Although yield of individual cultivars was not recorded but cumulative yield of the plot

Table 1 Periodic cane/shoot growth (cm) of blueberry genotypes under mid-hill conditions of Himachal Pradesh

Genotype	March, 20 (D_1)	April, 5 (D_2)	April, 21 (D_3)	May, 8 (D_4)	May, 23 (D_5)	June,10 (D_6)	July, 1 (D_7)	July, 21 (D_8)	August, 8 (D_9)	August, 28 (D_{10})	September, 15 (D_{11})	October, 5 (D_{12})	October, 21(D_{13})	November, 15 (D_{14})	Mean
Jewel	5.51	9.48	14.63	20.18	21.00	22.21	25.69	30.31	36.58	42.16	47.52	49.05	49.05	49.05	30.17
Misty	5.23	9.05	14.44	18.89	19.76	21.21	24.71	28.25	34.43	39.32	43.04	46.64	46.64	46.64	28.45
Gulf Coast	4.92	7.00	13.81	16.21	17.32	18.57	22.46	27.20	34.29	38.74	42.91	46.69	46.59	46.59	27.37
Sharpblue	4.75	6.22	11.05	14.74	15.63	17.03	20.71	25.25	32.05	36.55	42.67	48.00	48.00	48.00	26.48
Alapaha*	4.25	6.71	9.56	10.47	11.92	13.32	16.29	20.66	28.30	32.67	35.55	39.02	39.02	39.02	21.91
Austin*	4.50	6.64	12.80	14.89	16.63	17.79	22.57	28.70	34.24	39.44	44.11	48.36	48.36	48.36	27.68
Mean	4.87	7.54	12.71	15.90	17.04	18.35	22.07	26.73	33.32	38.14	42.63	46.28	46.28	46.28	
*Rabbit eye blueberry															
CD (P=0.05)	0.81														
T (Genotypes)	1.24														
D (Intervals)	NS														
T × D															

was recorded at the end of harvesting (data on yield not presented) and total yield was divided by individual plants.

The experiment was laid on randomized block design with three replications and each replication constituted one plant. The whole data obtained was analyzed by using DOS based statistical software Assex at 5 % level of significance for comparison of variance.

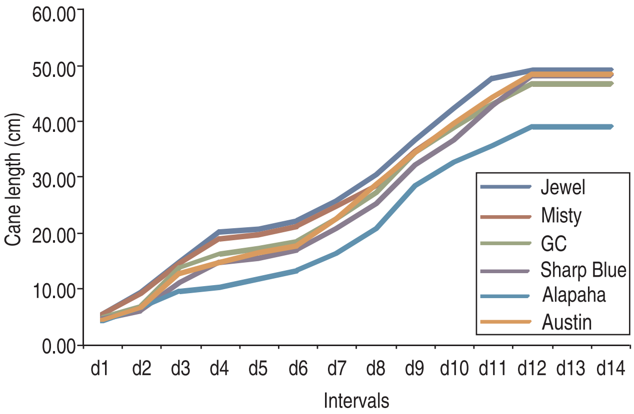

Fig 1 Annual growth pattern of different blueberry genotypes under mid-hill conditions of Himachal Pradesh.

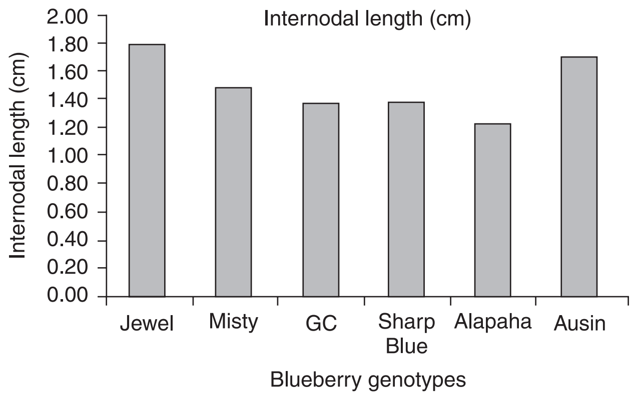

Fig 2 Internodal length of different blueberry genotypes (cm).

RESULTS AND DISCUSSION

Plant growth and leaf characteristics

The annual shoots/cane growth and periodical growth was recorded by randomly selecting 10 shoots each from each plant after bud sprout starting from first week of March and it was observed significantly influenced by the genotypes (Table 1 and Fig 1). It is clear from the table that southern highbush cultivar Jewel produced maximum (49.05 cm) shoots/cane length which was closely followed by a rabbiteye cultivar Austin (48.36 cm) and minimum shoot growth (39.02 cm) was observed in Alapaha another rabbiteye blueberry. Similarly, both genotypes, i.e. Jewel and Austin produced canes with longer internodal length (1.80 and 1.70 cm) at the end of growing season (Fig 3).These findings are in conformity with the earlier reports by Ehlenfeldt *et al*. (1995) that southern highbush cultivar Gulf Coast produced semi-upright and vigorous growth along with southern highbush cultivar Sharpblue.

The periodic shoot extension growth of blueberry genotypes also showed significant variation and the mean shoot extension growth was observed maximum (30.17 cm) in Jewel and minimum (21.91 cm) in Alapaha (Table 2). In a preliminary studiy by Francis *et al*. (2006) also reported that the southern highbush blueberry cultivar Jewel produced maximum cane length with vigorous growth when compared with other cultivars in Waimea, Hawaii. However, in photoperiodic studies on vegetative and reproductive growth of *Vaccinium darrowi* and *V. corymbosum* interspecific hybrids (Timuthi *et al*. 2003) it was concluded that if the plants were kept at similar photoperiod there were no differences in average cane length among two *Vaccinium* genotypes.

The growth rate at different interval was also studied and it was found that there was rapid increment of cane at D2-3 intervals in all genotypes and it was found that all genotypes followed sigmoidal pattern of growth curve

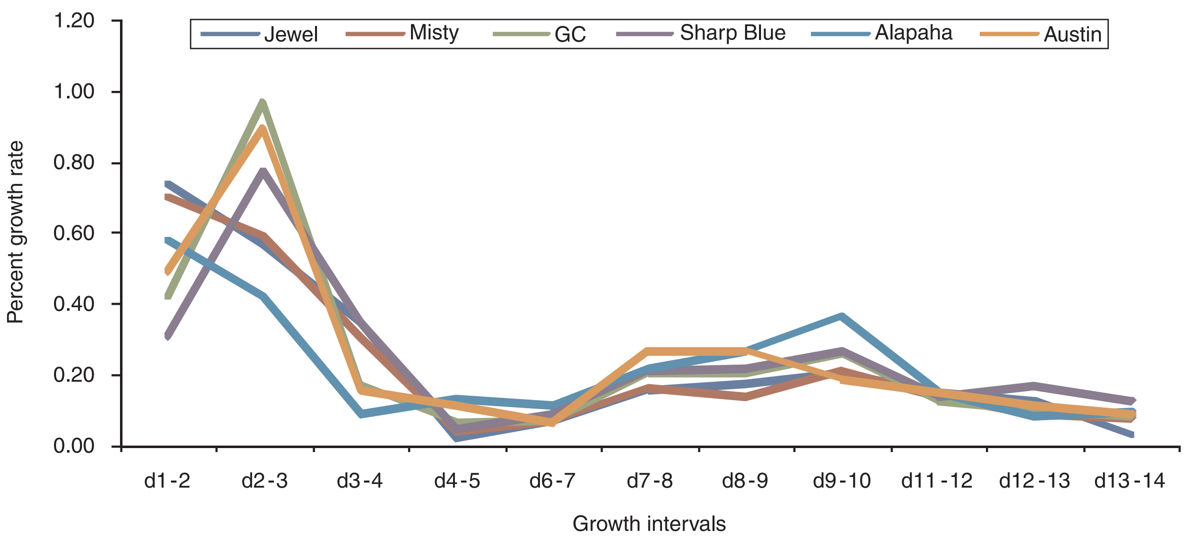

Fig 3 Periodic growth rate (%) of different blueberry genotypes under mid-hill conditions of Himachal Pradesh.

Table 2 Physical and morphological characteristics of leaves of southern highbush and rabbiteye blueberry genotypes

Genotype	Leaf shape index (L/D ratio)	Area (cm^2)	Specific leaf area (cm^2/g)	Foliar density (number of leaves/ cm shoot length)	Leaf color (blade)	Leaf lamina shape	Leaf emergence	Defoliation during dormancy
Jewel	1.67	17.75	88.68	0.84	Dark green	Ovate-elliptical	10 February	Partially
Misty	1.88	16.94	104.97	0.76	Light green	Elliptic	7 February	Partially
Gulf Coast	1.76	15.36	124.47	0.86	Light green	Elliptic	10 February	Partially
Sharpblue	2.01	17.82	100.57	0.78	Medium green	Elliptic	25 February	Partially
Alapaha*	2.08	8.76	106.60	0.95	Pinkish green	Elliptic	2 March	Fully
Austin*	2.22	18.22	97.85	0.75	Silvery green	Obovate-elliptic	15 March	Fully
SEm±	0.06	0.51	8.06	0.03				
CD (P=0.05)	0.14	1.48	17.96	0.07				

*Rabbiteye blueberry

when plotted against time (Fig 3). After this interval the rate was lowest in all genotypes up to D6-7 intervals (June 10 to July 1). The slower growth rate at these intervals might be due diversion of metabolites towards developing fruits since, these intervals coincided with rapid growth and development of fruits. After fruit harvesting (last week of April to second week of May) growth of shoots/cane started again from July onwards and lasted till the secession of growth in November by attaining maximum average cane length in cultivar Jewel and minimum in Alapaha (Table 1). These findings are in line with those of Banados and Strik (2006) who had concluded that the first phase of vegetative growth in blueberry starts at spring and second phase of growth occurred in late summer after fruit harvest while studying on manipulation of the annual growth cycle of blueberry using photoperiod.

The morphological variation was also observed in blueberry genotypes for various leaf characters and it was observed that all genotypes had simple leaf, leaf colour varied from dark green in Sharpblue to slight pinkish in Alapaha and in Austin it was observed silvery green (Table 2). Leaf lamina shape was also observed varying in blueberry genotypes and it was observed ovate elliptical in Jewel, obovate in Austin and rest of the genotypes (Misty, Gulf Coast, Sharpblue and Alapaha) had elliptical leaf shape (Table 2). In both rabbiteye blueberry genotypes there was a complete defoliation during dormancy however, all four southern highbush blueberry did not shed their leaves completely and older leaves remained intact in shoots along with newly emerged leaves in spring.

The leaf emergence was observed during early spring and it was recorded earliest in Misty (7 February) followed by Jewel, Gulf Coast and Sharpblue (all southern highbush blueberries), whereas, in both rabbiteye this event was observed slightly late and Austin was last to unfold their leaves, i.e. on 5 March (Table 2). The event of leaf emergence is controlled by genetic as well as environmental factors, in this study it was observed that all southern highbush genotypes were earliest in unfolding their leaves as compared to both rabbiteye genotypes (Table 2). These findings are in conformity with the earlier reports by Francis *et al*. (2006) that southern highbush blueberry genotypes, viz. Misty, Jewel and Sharpblue had chilling requirements of 150 to 500 hr and Misty has lowest chilling requirements of 150 hr among southern highbush genotypes so cultivar Misty was earliest to open the buds. Similarly, leaf length and breadth ratio (leaf shape index) was also found significantly different among blueberry genotypes and it was recorded maximum in rabbiteye cultivar Austin (2.22) followed by Alapaha and minimum L/D ratio was observed in Jewel (1.67). The L/D ratio is an important character for determining the leaf shape, in present investigations it was observed minimum in Jewel hence it had slight ovate-elliptical shape. In a study by Kim *et al*. (2011), revealed that blueberry plants exposed in various shade level exerted significant effects on leaf shape and L/D ratio which was more in plants exposed to high light intensity which might have increased photosynthetic activities and improved chlorophyll content. The L/D ratio ranged between 1.90 to 2.03 in northern highbush cultivar Bluecrop. However, in our study no such condition was given to the plants except different genotypes which might have exerted different leaf shape and L/D ratio.

The other foliar characteristics, viz. leaf area, specific leaf area; expressed as cm^2/g of leaf weight and foliage density were also observed significantly affected by different genotypes (Table 2). The specific leaf area is an important foliar character responsible for photosynthesis and synthesis of other pigments it was recorded maximum in Gulf Coast followed by Alapaha and Misty in descending orders. Similarly, the foliage density which was recorded by just counting number of leaves per cm of cane length and it was also found significantly varied among different blueberry genotypes. It was observed highly dense, i.e. 0.97 leaves/cm cane length in rabbiteye cultivar Alapaha, closely followed by southern highbush blueberry cultivars; Gulf Coast (0.86 leaves /cm cane length) Jewel and Sharpblue in descending order. However, foliage was sparsely dense in Austin where it was recorded 0.75 leaves per cm cane length (Table 2). The reason for higher leaf density in Alapaha in this study might be due to smaller leaf size and internodal distance as compared to other genotypes (Table 1 and Fig 2).

Table 3 Flower characteristics of southern highbush and rabbiteye blueberry genotypes

Genotype	Corolla size		Number of stamen/ flower	Number of flowers /cluster	Number of fruits / cluster	Start date of flowering	End date of flowering	Full bloom period	Color of opened flower
	Length (cm)	Breadth (cm)							
Jewel	1.13	0.75	10.33	7.67	4.78	21 January	9 March	20 February	White
Misty	1.19	0.66	9.67	5.33	4.00	18 January	2 March	16 February	White
Gulf Coast	1.09	0.78	10.33	8.78	4.89	16 January	1 March	15 February	White
Sharpblue	1.05	0.75	10.33	6.44	5.00	26 January	11 March	22 February	White
Alapaha*	0.94	0.75	9.33	5.33	3.78	20 February	11 April	10 March	Pink
Austin*	1.15	0.68	7.67	6.33	4.67	20 March	8 May	22 April	Slightly pinkish
SEm±	0.01	0.02	0.37	0.31	0.59				
CD (P=0.05)	0.03	0.04	0.84	0.88	1.33				

*Rabbiteye blueberry

Flowering and fruiting

The floral morphological and physical characters, viz. size opened flower (length and breadth), stamen number and number of flowers per cluster also differed significantly among blueberry genotypes (Table 3). It is evident from the Table 3 that maximum (1.19 cm) length of fully opened flower (corolla) was recorded in southern highbush cultivar Misty, however, the breadth was found maximum (0.78 cm) in Gulf Coast another southern highbush cultivar, similar variations for different floral traits in blueberry hybrids had also been reported earlier by Ritzinger and Paul (1999). Whereas, Alapaha, a rabbiteye blueberry genotype produced smallest flowers in terms of length and breadth among all genotypes. These floral morphological and physical characters were desirable characters which govern further pollination and aids the pollinators more amenable to pollination possibly resulting to higher fruit set in blueberries (Eck and Mainland 1971 and Lyrene 1994). However, in our study the pollination studies were not conducted, only morphological characters of different blueberry genotypes under mid-hill conditions of Himachal Pradesh were studied. The number of stamens and flowers per cluster are also other important characters of any genotypes, in this study also all genotypes significantly varied with respect to stamen number and flowers/cluster (Table 3). It is clear from the Table 3 that southern highbush blueberry cultivars had maximum number of stamens per flower and minimum was observed in Austin (7.67 stamens/flower).

Fig 4 Flowering cluster of different blueberry genotypes: A; Jewel, B; Misty, C; Gulf Coast, D; Sharpblue E; Alapaha and F; Austin.

Similarly, number of flower and fruits/cluster were also varied significantly among blueberry genotypes and maximum (8.78) number of flowers/cluster was recorded in Gulf Coast and cultivars Alapaha and Misty produced least number (5.33) of flowers/cluster (Table 3 and Fig 4). However, Sharpblue had maximum (5.00) number of fruits/ cluster statistically at par with all genotypes except Alapaha

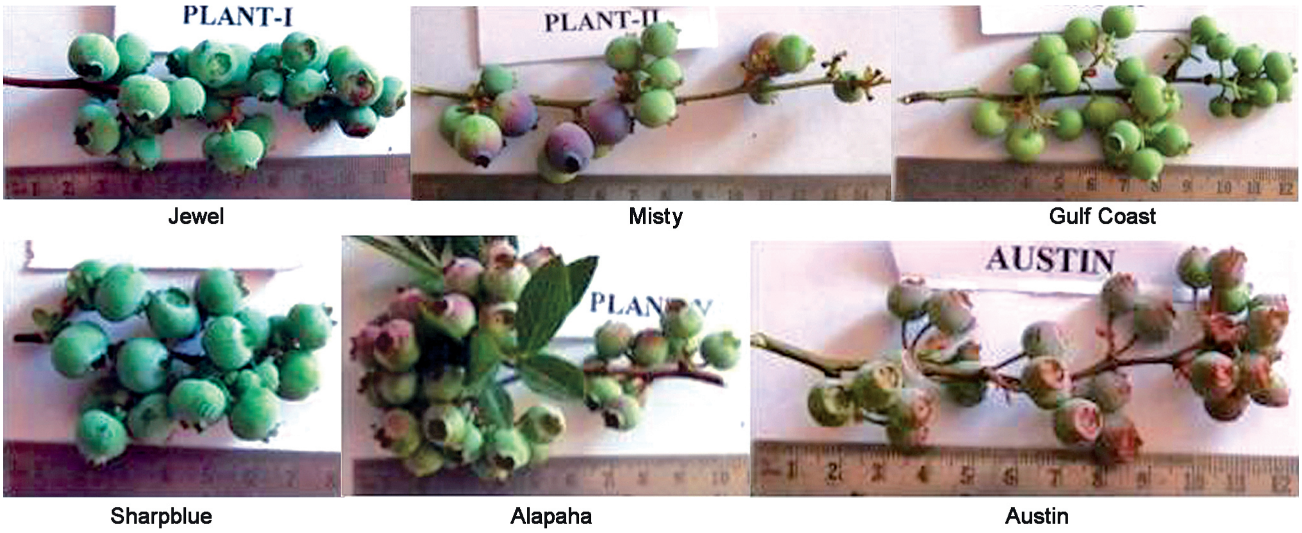

Fig 5 Fruiting cluster of blueberry genotypes.

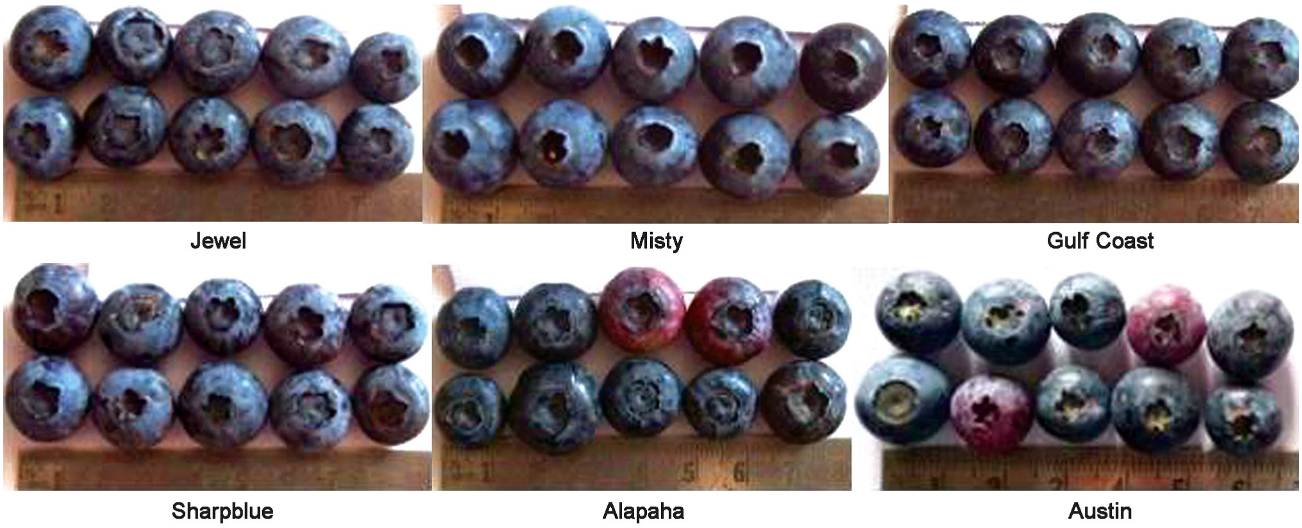

Fig 6 Berry characteristics of different blueberry genotypes.

(Table 3 and Fig 5). In a study by Zang *et al*. (2016) while investigating on the effects of gibberellic acid on plant growth attributes, return bloom and fruit quality of rabbiteye blueberry cultivars revealed that the flower number per inflorescence in cultivars Powder Blue, Garden Blue and Climax ranged from 8.6 to 9.8 but with the application of GA_3 significantly increased the flower number up to 11 per inflorescence among the rabbiteye cultivars. There was a less variation for color of opened flower or corolla among genotypes but, it was observed slight pinkish in Alapaha and pink in Austin, however, in all the southern highbush cultivars the color of flowers was white (Fig 4).

Duration of fruit harvesting was also investigated in the present study. All the four southern highbush blueberry genotypes, harvesting was started from last week of April and earliest among these genotypes were observed to be Misty and Gulf Coast (April 25 each). Among rabbiteye, Alapaha was earliest to mature as compared to Austin. The former cultivar attained 25 % maturity on 21 May, whereas, in Austin harvesting was started from May 27 onwards and ended second week of June during the year 2016. The overall harvesting duration, i.e. date of first harvesting to last picking date for all genotypes was 42 days.

The yield of individual cultivars was not recorded but the cumulative yield at the end of harvesting was observed to be 200-250 g berries/plant, which is quite low when compared to the other blueberry growing countries where average yield of blueberry ranged between 2 to 7 kg/plant (Ben *et al*. 2000). The present study was carried-out to provide a preliminary aspect on trial planting of blueberry genotypes that is still in progress and the methods employed may not be necessarily as per the recommended practices of blueberry production adopted by blueberry growing countries.

All the four southern highbush blueberry genotypes (Jewel, Misty, Gulf Coast and Sharpblue) adapted well to the prevailing agro-climatic conditions of Palampur, Himachal Pradesh. Although, both rabbiteye genotypes have also shown promising results but the time of fruit maturity in Austin was observed slightly late and at that time the incidences of fruit fly in other fruits remain very high in Palampur area. Therefore, southern highbush blueberry cultivars (mostly have less chilling requirement as compared to northern highbush blueberries) can be grown successfully.

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