CHARACTERIZATION OF BIRD OF PARADISE (*Strelitzia reginae* L.) FOR MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS

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By

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Affectionately Dedicated to

My Parents,

My Brother & My Sisters

UNIVERSITY OF HORTICULTURAL SCIENCES BAGALKOT
DEPARTMENT OF FLORICULTURE AND LANDSCAPE ARCHITECTURE
COLLEGE OF HORTICULTURE, BENGALURU

CERTIFICATE

This is to certify that the thesis entitled **"CHARACTERIZATION OF BIRD OF PARADISE (*Strelitzia reginae* L.) FOR MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS"** submitted by **Ms. SHILPA, K. N., ID No. UHS15PGM653** in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (Horticulture)** in **FLORICULTURE AND LANDSCAPE ARCHITECTURE**, to the University of Horticultural Sciences, Bagalkot, is a *bonafide* record of research work carried out by her during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Bengaluru
Date: August, 2017

(ANURADHA SANE)
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BENGALURU **(SHILPA, K. N.)**
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CHARACTERIZATION OF BIRD OF PARADISE (*Strelitzia reginae* L.) FOR MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS

ABSTRACT

An endeavor was made during 2015-16 to characterize 21 genotypes of Bird of Paradise (*Strelitzia reginae* L.) for various morphological and physiological traits under open field condition at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru, Karnataka. Among growth parameters, genotype BOP 41 recorded higher plant height (166.3 cm), fans per plant (29.67), leaves per plant (389) and plant spread (NS-279.67 cm, EW-275.33 cm) indicating the vigor of plant. Genotype BOP 33 exhibited higher leaf lamina length (40.51 cm), lamina breadth (13.67 cm), leaf length (124.18 cm) with higher specific leaf area (311.92 cm^2 g^{-1}). Among flower quality parameters BOP 45 recorded higher spike length (149.43 cm) and stalk length (128.66 cm), whereas maximum fresh weight (140.09 g), spathe diameter (23.09 mm), spike diameter (16.33 mm) with longer vase life (10 days) was recorded in genotype BOP 33. Genotype BOP 41 found superior with respect to spike yield per plant (41.33). Among physiological parameters, genotype BOP 45 recorded higher leaf wax content (0.62 mg cm^{-2}) with relative water content (94.91%). Whereas transpiration rate (6.61 m mol m^{-2} s^{-1}), photosynthesis rate (7.33 µ mol CO_2 $m^{-2}s^{-1}$) with stomatal conductance (0.11 mol m^{-2} s^{-1}) and total chlorophyll content (2.63 mol m^{-2} s^{-1}) was higher in genotype BOP 16 and stomata number was maximum (40.80 mm^{-2}) in genotype BOP 31. With respect to flower color pigment maximum anthocyanin content was found in genotype BOP 22 (124.65 mg $100g^{-1}$), while genotype BOP 6 recorded maximum carotenoid content (22.31 mg $100g^{-1}$) indicating bright colored flower production. The genotypes expressing better morphology can be used as a trait specific germplasm in breeding programme. The results of physiological parameters *viz*., leaf wax, stomatal density and transpiration rate will be useful for breeders to identify BOP genotypes with better drought tolerance.

SHILPA, K. N.
Student

ANURADHA SANE
Major Advisor

ಬರ್ಡ್ ಆಫ್ ಪ್ಯಾರಡೈಸನ (ಸ್ಟ್ರೆಲಿಟ್ಜಿಯಾ ರೆಜಿನೀ ಎಲ್.) ಸ್ವರೂಪ ಮತ್ತು ಶಾರೀರಿಕ ಲಕ್ಷಣಗಳ ವಿವರಣೆ

ಪ್ರಬಂಧದ ಸಾರಂಶ

ಬರ್ಡ್ ಆಫ್ ಪ್ಯಾರಡೈಸನ 21 ಜೀನೋಟೈಪ್ ವಿಧಗಳ ಸ್ವರೂಪ ಮತ್ತು ಶಾರೀರಿಕ ಲಕ್ಷಣಗಳ ವಿವರಣೆಯನ್ನು ತಿಳಿಯಲು 2015-16 ರಲ್ಲಿ ಭಾರತೀಯ ತೋಟಗಾರಿಕಾ ಸಂಶೋಧನಾ ಸಂಸ್ಥೆ, ಹೆಸರಘಟ್ಟ, ಬೆಂಗಳೂರಿನಲ್ಲಿ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ಕೈಗೊಳ್ಳಲಾಯಿತು. ವಿವಿಧ ಬೆಳವಣಿಗೆಯ ಗುಣಲಕ್ಷಣಗಳ ಪೈಕಿ ಜೀನೋಟೈಪ್ BOP-41 ರಲ್ಲಿ ಹೆಚ್ಚಿನ ಗಿಡದ ಎತ್ತರ (166.30 ಸೆಂ.ಮೀ), ಪ್ರತೀ ಸಸ್ಯsದ ಕಂದು (29.37), ಸಸ್ಯಗಳ ಎಲೆಗಳು (389) ಮತ್ತು ಸಸ್ಯದ ಹರಡುವಿಕೆಯ (ಉ.ದ-279.67 ಸೆಂ.ಮೀ, ಪ.ಪೂ-275.33 ಸೆಂ.ಮೀ) ಹೆಚ್ಚಾಗಿದ್ದು ಇದು ಗಿಡದ ಚಟುವಟಿಕೆಯನ್ನು ಸೂಚಿಸುತ್ತದೆ. ಜೀನೋಟೈಪ್ BOP-33 ರಲ್ಲಿ ಹೆಚ್ಚಿನ ಎಲೆಯ ಪತ್ರದ ಉದ್ದ (40.51 ಸೆಂ.ಮೀ), ಪತ್ರದ ವಿಸ್ತಾರ (13.67 ಸೆಂ.ಮೀ), ಎಲೆಯ ಉದ್ದ (124.18 ಸೆಂ.ಮೀ) ಮತ್ತು ಹೆಚ್ಚಿನ ನಿರ್ದಿಷ್ಟ ಎಲೆಯ ಪ್ರದೇಶ (311.92 ಚ ಸೆಂ.ಮೀ) ದಾಖಲಾಗಿದೆ. ಹೂವಿನ ಉತ್ಕೃಷ್ಟ ಗುಣಲಕ್ಷಣಗಳಾದ ಶೀರ್ಷಿಕೆಯ ಉದ್ದ (149.43 ಸೆಂ.ಮೀ) ಮತ್ತು ಕಾಂಡದ ಉದ್ದ (128.66 ಸೆಂ.ಮೀ) ಜೀನೋಟೈಪ್ BOP-45 ರಲ್ಲಿ ಅತ್ಯಧಿಕವಾಗಿದೆ. ಆದರೆ ಹೂವಿನ ತಾಜ ತೂಕ (140.09 ಗ್ರಾಂ.), ಪುಷ್ಪ ಗುಚ್ಚದ ವ್ಯಾಸ (23.09 ಮಿ.ಮೀ.), ಶೀರ್ಷಿಕೆಯ ವ್ಯಾಸ (16.33 ಮಿ.ಮೀ.) ಮತ್ತು ಹೂದಾನಿ ಬಾಳಿಕೆಯ ಅವಧಿ (10 ದಿನಗಳು) ಜೀನೋಟೈಪ್ BOP -33 ರಲ್ಲಿ ಹೆಚ್ಚಾಗಿದೆ. ಹೂವಿನ ಇಳುವರಿ ಜೀನೋಟೈಪ್ BOP-41 (41.33 ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ) ರಲ್ಲಿ ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿದೆ. ಶಾರೀರಿಕ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಸಂಬಂಧಿಸಿದಂತೆ ಜೀನೋಟೈಪ್ BOP -45 ರಲ್ಲಿ ಹೆಚ್ಚಿನ ಎಲೆಗಳ ಮೇಣದ ಅಂಶದೊಂದಿಗೆ (0.62 ಮಿ.ಗ್ರಾ./ಸೆಂ.ಮೀ) ಹೆಚ್ಚಿನ ಗರಿಷ್ಠ ಸಂಬಂಧಿತ ನೀರಿನ ಅಂಶವು (94.91 ಶೇ.) ಕಂಡುಬಂದಿದೆ. ಬಾಷ್ಪೀಕರಣ ದರ (6.61 ಮಿ.ಮೋಲ್/ಚ.ಮಿ/ಸೆ.), ದ್ಯುತಿಸಂಶ್ಲೇಷಣೆ (7.33 ಮೋಲ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್/ಚ.ಮಿ/ಸೆ.) ಜೊತೆಗೆ ರಂಧ್ರಗಳ ವಾಹಕತೆ (0.11 ಮಿ.ಮೋಲ್/ಚ.ಮಿ/ಸೆ.) ಮತ್ತು ಪತ್ರ ಹರಿತ್ತಿನ ಅಂಶ (2.63 ಮೋಲ್/ಚ.ಮಿ/ಸೆ.) ಜೀನೋಟೈಪ್ BOP-16 ರಲ್ಲಿ ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿದೆ. ಅತೀ ಹೆಚ್ಚು ರಂಧ್ರಗಳ ಸಂಖ್ಯೆ (40.80 ಮಿ.ಚ.ಮೀ) ಜೀನೋಟೈಪ್ BOP-31 ರಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಹೂವಿನ ವರ್ಣದ್ರವ್ಯಕ್ಕೆ ಸಂಬಂಧಿಸಿಂದಂತೆ ಅತೀ ಹೆಚ್ಚು ಆಂಥೋಸೈನಿನ್ ಅಂಶವು BOP -22 ರಲ್ಲಿ (124.65 ಮಿಗ್ರಾಂ./100ಗ್ರಾಂ.) ದಾಖಲಾಗಿದ್ದು ಇದು ಪ್ರಕಾಶಮಾನವಾದ ಬಣ್ಣದ ಹೂವಿನ ಬಿಡುವಿಕೆಯನ್ನು ಸೂಚಿಸುತ್ತದೆ. ಉತ್ತಮ ಸ್ವರೂಪ ಗುಣಗಳೋಂದಿರುವ ನಿರ್ಧಿಷ್ಟ ತಳಿಗಳನ್ನು ತಳಿಯ ಸಂವರ್ಧನೆಗಾಗಿ ಆಯ್ಕೆಮಾಡಲು ಸಹಕಾರಿಯಾಗುತ್ತದೆ. ಉತ್ತಮ ಶಾರೀರಿಕ ಫಲಿತಾಂಶ ಗುಣಗಳಾಂದತಹ ಎಲೆಯ ಮೇಣಾದಂಶ, ರಂಧ್ರಗಳ ಸಾಂದ್ರತೆ ಮತ್ತು ಬಾಷ್ಪೀಕರಣ ದರವು ಬರಸಹಿಷ್ಣುತೆಯ ಆಯ್ಕೆಯಲ್ಲಿ ಸಹಕಾರಿಯಗುತ್ತದೆ.

ಶಿಲ್ಪಾ, ಕೆ.ಎನ್.
ವಿದ್ಯಾರ್ಥಿ

ಅನುರಾಧ ಸಾನೆ
ಮುಖ್ಯಸಲಹೆಗಾರರು

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I INTRODUCTION

Bird of Paradise (*Strelitzia reginae* L.) commonly known as crane flower belongs to the family *Strelitziaceae* with a diploid chromosome number of 2n=22 and is indigenous to South Africa but naturalized in Mexico, Belize, Bangladesh and Madeira Islands. It was first introduced to Europe in 1773 at the Royal Botanical Gardens, Kew. Its scientific name commemorates the British queen Charlotte of Mecklenburg-Strelitz.

The genus *Strelitzia* comprises of five species *viz., S. reginae, S. augusta, S. kewensis, S. alba* and *S. nicholai.* Among these, *S. reginae* is very popular flowering species growing up to a height of more than one meter and bears very brilliant orange, purple flowers emerging from purplish spathe on a stem. *Strelitzia reginae* plant in full bloom looks as if there are several birds hidden in the foliage craning their necks just above the leaves and looking above in all directions. These are truly marvelous and extremely ornamental landscape plants. Without the flowering spikes also, these plants still have a striking appearance due to the large glaucous paddle shaped leaves which resemble those of *Heliconia* plants. It is the national flower of Madeira, Portugal since 2005 and has been chosen as the official flower of the City of Los Angeles.

In recent years some unexploited cut flower crops are gaining popularity because of their attractive size, form, color and keeping quality. Among them, Bird of Paradise (BOP) has got its own importance both in domestic and international market due to its attractive, remarkably shaped crested head of bird and combination of orange and purple color flower cluster. Bird of Paradise is used for flower arrangement. It occupies a place of pride in gardens and is an important choice for landscaping. It is grown in backyard and also for mass effect. The leaves of BOP are also used as filler material in flower arrangement.

Bird of Paradise is an evergreen perennial herbaceous plant, grown in regions having moderate subtropical climate and is cultivated in many parts of the world. The major growing countries on commercial scale are USA, Israel and South Africa. In India, flowers are grown in the places having tropical climate *viz.,* Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra and Kerala.

Strelitzia enjoys good popularity as a cut flower in many countries especially in temperate countries. Costa Rica is an increasingly important supplier to the United States and Europe; exports of this flower from Costa Rica amounted to $450,000 in 2002 (Anon., 2003). Mexico has entered the market supplying very good quality flowers mainly to the US (Laws, 1998). The Canary Islands are an important supplier for Europe (Anon., 2003). In the US, California is now the largest producer, followed by Hawaii (Anon., 2003 and Laws, 1998). Jamaica, Guatemala and other Caribbean countries export small quantities.

Assessment of morphological and physiological traits is considered easiest way to differentiate genotypes. To identify the desired genotype, various morphological traits (number of fans, leaf length and breadth, number of leaves, spike head diameter, spike head length, flower stalk length, *etc*.) and physiological traits (wax content, transpiration rate, relative water content, stomatal conductance, stomatal density, chlorophyll, anthocyanin, carotenoid content, *etc*.) are employed. To harness and utilize useful traits in BOP, it is essential to assemble, characterize and evaluate genotypes in order to maximize their utilization in crop improvement programme which is highly dependent on the amount of genetic variability that is available in the gene pool.

Postharvest longevity starts with the supply of the best possible growing conditions and harvesting at a proper stage. Plants grown in unsuitable environments are not as good as those grown in favorable environments. After harvest, flower quality cannot be improved but can be maintained and the vase life can be extended by supply of organic substrates, water and low temperatures (Bachmann, 2006). Unsuitable growing conditions result in stunted plants with fewer flowers, and consequently, lower vase life (Armitage and Laushman, 2003). The longevity of cut flowers is highly associated with physiological factors related to the species and environmental factors such as temperature and humidity, ethylene action and water quality (Dias-Tagliacozzo *et al*., 2005). The postharvest life of this species varies between 6 to 16 days. This difference are due to growing conditions, maturity at harvest, conditions of storage, transportation and the criteria used to evaluate the postharvest life (Jaroenkit and Paul, 2003).

Bird of Paradise has more demand in the international flower market due to its vibrant flower color and long lasting flower quality. The quality of the flower depends up on wide range of factors that include environment and genetics factors which predominantly affect the physiological and morphological characters of plant. Expectedly, any successful breeding programme can only be achieved when there is valid information about the genetic variability of the traits of interest in the crop population. In other words, the availability of genetically based variations for morphological traits and physiological characters is a prerequisite for screening the genotypes.

So, it is necessary to harness and utilize useful physiological and morphological traits in BOP to maximize their utilization in any crop improvement programme. Hence, the study is undertaken to screen the genotypes for their morphological, physiological and post-harvest traits.

OBJECTIVES

1. To study the morphological and physiological traits in different genotypes of Bird of Paradise.
2. To study the spike yield, quality and post harvest life of Bird of Paradise.

II REVIEW OF LITERATURE

In this chapter, a review of the existing literature on BOP and related crops with respect to morphological, physiological and vase life studies in identification of genotypes based on available genetic diversity of cultivars has been done.

2.1 Morphological evaluation studies

Correlation analysis among forty progenies of Bird of paradise showed significant variations in vegetative, flowering and yield parameters indicating wide variability among the progenies that can be utilized in crop improvement work (Angadi and Archana, 2014).

The study on genetic variability in vegetative parameters among hundred genotypes of Bird of Paradise resulted in higher phenotypic coefficient of variation (PCV) than genotypic coefficient of variation (GCV) for all of the characters studied. Further it was observed that high heritability with high genetic advance as per cent of mean for plant height, stem girth, leaf length, leaf width and number of leaves per plant (Angadi and Archana, 2014).

Heliconia accessions collected from different sources were evaluated for biometric and flowering characters by Shankari *et al.* (2017). The study revealed that out of 38 types Lady Di, Strawberry Cream, Diroj, Lathyspathy and Fire Flash performed well under Yercaud and year round blooming was found to be the best criteria for floral quality and yield and recommended for cut flower production under Yercaud.

Morphological characterization of wild species of the genus Heliconias for qualitative and quantitative morphological characters was studied in 25 accessions. The result is significant for leaf length, limb width, limb's petiole length, pseudostem thickness, rachis width / thickness, second bract width, growth and type of inflorescence, petiole and peduncle length, rachis color, and wax in limb and in pseudostem (Avendano-arrazate *et al*., 2017).

Genetic variability, the heritability and the correlations for floral stem characters in seven *Heliconia psittacorum* genotypes and hybrids was studied. The result indicated positive genetic correlation for number of days for the inflorescence emergence, after shoot formation with number of leaves in the stem at the moment of inflorescence emergence and negative genetic correlation for stem length, number of days for the inflorescence emergence, after shoot formation (Costa *et al*., 2007).

Simao *et al.* (2003) studied morphology of seed and vegetative propagation in *Heliconia vellozian* L. Emygd and vegetative propagation by rhizomes is found faster than the sexual one.

The experiment on 26 *Heliconia spp*. genotypes resulted in varied number of shoots per clump and area per clump due to the inappropriate single plant spacing for different heliconia genotypes in cultivated in full sun and partial shade (Costa *et al*., 2006).

The study on genetic variability in 18 *Heliconia* cultivars by Kumar *et al.* (2011) resulted in higher phenotypic coefficients of variation than genotypic coefficient of variation with high heritability and genetic advance for spike length and number of bracts.

The survival and performance of Bird of Paradise was evaluated using different mutagens with different concentration. Accordingly, the study resulted in better seed germination (72%) and seedling survival (52.38%) when treated with methyl ethane sulphonate demonstrating that lower doses of various mutagens results in good germination and survival than higher doses. (Sane *et al*., 2010).

The study on evaluation of Zinnia cultivars for morphological and yield traits was found to be significant for each cultivar. Cultivar Zinnia double supper yoga 3F1 Mixed was found good regarding plant height and number of flowers per plant, while number of branches and number of leaves per plant in Zinnia F1 swizzle bicolor was at top position (Pasha *et al*., 2015)

The study on genetic variability among different growth characteristics in thirteen cultivars of *Zinnia elegans* showed significant differences among population densities, varieties and their interaction with high genetic variability for plant height, length of lateral shoots, growth rate per week and period of blooming (Saleem *et al.*, 2003).

The study on high level of genetic diversity and morphological variations among and within different *Rosa* species was studied by Singh *et al.* (2017). Desirable variations were observed for flower colour, petal number, lack of prickles, perpetual flowering, large flower diameter and large fruit size which contribute significantly to diversity of the roses and for potential use in breeding.

A study was carried out to evaluate and identify superior and most promising commercial variety in respect of important morphological and economic trait among 18 exotic cultivars of gerbera under naturally ventilated Polyhouse. Prominent variations in different growth parameters were observed. 'Diablo' found superior with respect to plant height (47.9 cm), disc diameter (22.8 mm), neck thickness (5.6 mm) and fresh weight (40.3 g). 'Primerose' had maximum lower diameter with minimum disc diameter and maximum length of ray floret. 'Universal' recorded longer stalk length (67 cm). 'Amulet' had maximum stalk diameter (6.7 mm). The cultivar 'Jaffer' recorded highest number of flowers (372) per m^2. 'Dreamer' was completely rejected due to low yield (143) and quality point of view (Biswal *et al.*, 2017)

Forty cultivars of chrysanthemum (*Dendranthema grandiflora* [*D. morifolium*]) were evaluated for yield and related traits by Isac and Chezhiyan, (2002). Acc 68, Acc 4 and Acc 1 recorded highest plant height, profuse branching and early bud initiation respectively. Acc 4 and Acc 32 recorded highest flower yield. Among all the accessions, Acc 4 was identified as a hardy genotype with highest total phenol content.

Small flowered varieties of chrysanthemum were evaluated for morphological characters such as plant height, plant spread, number of flowers, flower weight, etc. The results showed significant differences among the varieties for various characters (Mishra, 1999).

Morphological evaluation of twenty-eight genotypes of gladiolus found highly significant for all the parameters. The cluster analysis of genotypes indicated that 'Anjali' from cluster I, 'Dhanvantari' and 'Her Majesty' from cluster VIII, 'American Beauty' from cluster III and 'Sylvia' from cluster VI are potent parents (Swaroop, 2010).

Study on morphological variations and relationship with flower yield and yield components in *Rosa damascena* genotypes found significantly varied for all the traits. phenotypic and genotypic coefficients of variation for flower yield per plant (48.03%, 36.49%), number of flowers per plant (40.65%, 26.99%), number of petals per flower (37.56%, 32.31%) were found higher with 90 percent of total variation of flower yield per plant suggesting number of flowers per plant as the most important component determining flower yield per plant (Zeinali *et al*., 2009).

Study on vegetative, flowering and flower characters of twelve cultivars of gerbera revealed that cv. Pride of Sikkim was the tallest (61.80 cm) with longest stalk length (49.51 cm). Cultivar Red Gem produced maximum number of leaves per plant (46.55), plant spread (54.10 cm) and number of suckers per plant (24.04). Cultivar Pink Melody took least number of days, 63.78 and 76.00 for bud visibility and full bloom respectively. With respect to flower characters, cv. Red Gem recorded the maximum number of flowers per plant (53.17) and possessed longest shelf life (19.96 days) and vase life (9.81 days). Largest flower diameter was found in cv. Orange Gleam (11.20 cm) which was followed by cv. Classic Beauty (10.95 cm). Heaviest flowers were produced by the cv. Classic Beauty (16.71 g). Duration of flowering was longest in cv. Red Gem (130 days). Wide variation in flower colour was also observed among the cultivars. Cultivar Red Gem expressed best performance on various growth and flower characters followed by other cultivars viz. Orange Gleam, Classic Beauty and Pink Melody (Deka and Talukdar, 2015).

Deka and Paswan, (2001) studied the performance of ten chrysanthemum cultivars to assess their suitability as pot plants using various morphological traits. The results indicated significant differences among the cultivars for all the traits.

Eighteen chrysanthemum (*Chrysanthemum morifolium* Ramat.) genotypes were evaluated for their perforrmance under net house. The result found significant for quantitative and qualitative attributes studied. Genotypes like Snowball Yellow, Snowball White, Sunil, Andaman Star Red, Pusa Anmol, H-3 and Miller White were found to be promising for commercial cultivation as cut flower as well as loose flower under shade net (Singh *et al*., 2017).

Nine varieties of *Dendrobium* orchids were evaluated for growth and yield traits. The study revealed that among the different varieties evaluated, Sonia-17 recorded maximum plant height (54.57 cm), length of internode (5.00 cm) and number of pseudobulbs per plant (9.73), whereas Medame uraiwan registered more number of leaves (18.33) and maximum pseudo bulb girth (6.23 cm). Maximum leaf length (16.5 cm) was recorded in Burana fancy whereas leaf breadth was maximum (4.9 cm) in the varieties Sonia-17 and Medame uraiwan (Sugapriya *et al*., 2012).

2.2 Physiological evaluation studies

Ray *et al*. (2013) characterized the n-alkane profile of the epicuticular waxes in cultivars of *Psophocarpus tetragonolobus* (Stickm.) DC using Thin Layer Chromatography, Infrared region and Scanning Electron Microscopy techniques. Accordingly, twenty-four n-alkanes from n-C14 to n-C38 (except n-C19) were found varying in composition in the leaves of seven cultivars and nonacosane (n-C29) and hentriacontane (n-C31) were the predominant alkane in all the seven cultivars.

The role of epicuticular wax on the rate of water loss of sorghum plants was studied in relation with relative water content, transpiration rate, stomatal conductance and stomatal density. Data indicated positive relationship between wax content and internal water content. Bloomless sorghum variety showing less wax content was found to have higher stomatal conductance and transpiration rate indicating rapid decrease in plant water potential (Hamissou and Weibel, 2004).

Mohammadian *et al*. (2007) investigated the seasonal modification of wax deposition and its impact on gas exchange in *Leucadendron lanigerum*. The results demonstrated that the deposition of epicuticular wax in *L. lanigerum* is dependent on the age of the leaf as well as the season and wax regeneration occurred in spring than in winter. Epicuticular waxes found to decrease cuticular water loss and consequent decrease in stomatal conductance, transpiration and photosynthesis.

Thirteen banana genotypes belonging to different genomic groups were examined for total leaf cuticular wax and their relationship with leaf water retention capacity (LWRC). The genotypes were found to be positively correlated for epicuticular wax content and LWRC. The identification and classification of the cuticular wax components revealed that compounds with >C28 carbon chain length had a positive correlation with LWRC, indicating the role of longer carbon chain length in maintaining the water status of banana leaves (Ramaiah *et al*., 2016).

The effect of cuticular waxes on diffusion of water before and after extraction was determined in *Citrus aurantium* L. leaves, pear *(Pyrus communis* L.) leaves and onion *(Allium cepa* L.) bulb scales. Water permeability increased by a factor of 300 to 500 after cuticular wax extraction from membranes, there by showing the positive relationship between wax and water permiabilty (Schonherr, 1976).

The effect of light, temperature and leaf position, during imbibition, on measurements of relative water content in hydrated and water stressed leaves of *Araucaria angustifolia* (Bert.) O. Ktze was tested. The compared patterns of water absorption indicated longer periods of imbibitions for *Araucaria angustifolia* leaves than broad leaf species. Also, leaves that developed under drought conditions showed longer periods of imbibition than those that developed under conditions of high water availability (Yamaksaki and Dillenburg *et al*., 1999).

Cicevan *et al.* (2016) evaluated three ornamental *Tagetes* species for drought tolerance by inducing stress. The study resulted in identification of *Tagetes erecta* as drought tolerant compared to *T. patula* and *T. tenuifolia* with the retention of higher water content, chlorophyll and carotenoid content.

Screening of banana cultivars and hybrids for water stress showed significant positive influence of relative water content on yield, number of leaves and chlorophyll content in control plants compared to water stressed plants. Karpuravalli, Karpuravalli x Pisang Jajee, Saba, and Sannachenkathali were identified as tolerant to water stress and showed less reduction in morphological characters (3-14%) and physiological character (8-10%) over control. Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee were identified as sensitive cultivars due to reduction to the extent of 22 percent in morphological and physiological characters over control with water stress (Surendar *et al*., 2013).

The study of leaf anatomy of the *Heliconia latispatha* under different day length treatments showed significant differences for leaf blade width and mesophyll layers. The stomatal density and index, thickness of the blade increased with day length with the reduced stomatal size (Ch *et al*., 2005).

Response of plant leaf stomatal conductance and photosynthesis to water deficit was studied by Xu and Zhou (2007). Stomatal size was found to decrease with water deficit, and stomatal density showed positive correlation with stomatal conductance, net CO_2 assimilation rate, and water use efficiency. A significantly negative correlation of specific leaf area with stomatal density was observed, suggesting that the balance between leaf area and its matter may be associated with the guard cell number.

Physiological studies in four pomegranate accessions by Drogoudi *et al*. (2012) revealed highest photosynthetic rate and leaf area with lowest leaf mass area for accession 11005. Intrinsic water use efficiency was highest, and stomatal conductance and transpiration were found lowest in 11005 and Kallisti, a characteristic that may enable water conservation. Significantly higher stomatal density was found in Kallisti, which may suggest for a flexible stomata regulation to water deficit conditions.

The effect of irrigation intervals (10, 20, 30 days) on the growth, flowering and chemical constituent of *Strelitzia reginae* plant indicated enhanced vegetative growth as well as inflorescence yield with short irrigation interval compared to longer intervals. The chlorophyll content in both leaves and inflorescences gradually decreased with increasing irrigation intervals. The most significant irrigation interval was 10 days followed by 20 days interval treatment (Fetouh and Hassan, 2014).

The evaluation of physiological traits in nine cultivars of dendrobium recorded maximum leaf area (61.06 cm), leaf area index (7.3) and leaf chlorophyll content (80.53 spad units) in Sonia-17 (Sugapriya *et al*., 2012).

The study on leaf characteristics of *Heliconia stricta*, including area, leaf area index, specific leaf area, leaf area duration, chlorophyll content and wax content to determine the light use efficiency of the plants showed positive influence of these characteristics on plant growth and flower quality of *Heliconia stricta* when grown as intercrop with coconut than in open condition (Nihad and Krishnakumar, 2013).

Physiological and morphological characterization of American oil palms and their hybrids showed higher positive correlation of photosynthetic rate with chlorophyll content and a negative correlation with the specific leaf area. The ‘Peru’ American oil palm and‘hybrid 2’ (Sinu-Coari × La Me) showed higher CO_2

internal concentrations, total chlorophyll contents, light saturation points and photosynthetic rates (Rivera *et al*., 2013).

Jazayeri *et al*. (2015) evaluated gas exchange and photosynthetic capacity to determine physiological effects on the tolerance potential of two oil palm genotypes under water-deficit conditions. The data suggested higher photosynthetic capacity during the drought stress for genotype IRHO7010 than IRHO1001.

Investigation on carotenoid content and profile using HPLC in four varieties of Calendula (Double Esterel Orange, Radio Extra Selected, Bonbon Abricot and Double Esterel Jaune) was carried out. The higher carotenoid content of 276 mg/100 g fresh flower in Double Esterel Orange and 111 mg/100 g fresh flower in Radio variety and significant differences for the ratio between individual pigments was identified (Pintea *et al*., 2003).

Fifteen spray chrysanthemum cultivars were grown under polyhouse and open field condition for estimation of anthocyanins content in flower tepals. The anthocyanin content was significantly higher in cv. Tata red (19.95 and 19.24 mg in polyhouse and open field, respectively) and significantly lowest in cv. Kelvin Brisk (0.50 and 0.56 mg in poly house and open field, respectively). The cultivars like Tata red, Red gold, Arati, Apsara violet and Jaya were identified as cultivars with high anthocyanin content (Gantait and Pal, 2010).

2.3 Vase life studies

Kartsen *et al*. (2012) characterized Bird of Paradise (BOP) stems and florets harvested with different diameters: thin (less than 10 mm), medium (between 10 and 12 mm) and thick (bigger than 12 mm of diameter) based on number of open florets, longevity, length of the sepals and bracts, fresh mass, and absorption area at the base. Thicker stems kept in vase containing distilled water and recut every 48 hr showed a higher number of florets opened (2.3 florets) and longevity (8 days) than thinner stems.

Experiment was conducted by treating BOP flower with ethephon, silver thiosulphate and sucrose (Finger *et al*., 1999). Ethephon had little influence on flower longevity whereas 1MM silver thiosulphate reduced flower longevity, increased flower vase life and number of opened florets were noticed with 40 per cent sucrose for 24 hours.

The effect of pulsing treatment on postharvest quality of *Heliconia wagneriana* L. using sucrose at 10, 30 and 50 per cent for 30 min, 60 min, 12 h and 24 h was evaluated by Costa *et al.* (2015). The result showed that the stems subjected to pulsing with 10 per cent sucrose for 60 min maintained the quality of inflorescence with longevity of 20 days.

Banuelos-Hernandez *et al.* (2016) evaluated the effect of different range of storage conditions on *Heliconia psittacorum* L. f. cv. Tropica. at temperature of 12-26 °C, RH of 37-90 per cent and light between 0-150 $molm^2s^{-1}$ on fresh weight, colour, peroxidase activity, respiratory intensity and ethylene. The temperature, RH and light of 15 °C, RH of 63 per cent and light 0 $\mu mol\ m^{-2}\ s^{-1}$, 16 °C, 60 per cent and 150 $\mu mol\ m^{-2}s^{-1}$ and 12 °C, 90 per cent and 26 $\mu mol\ m^{-2}s^{-1}$ were better for stem storage. The average vase life of 6.6 days with and total postharvest longevity of 16.6 days was observed with storage at 15 °C, 63 per cent RH and 0 $\mu mol\ m^{-2}s^{-1}$.

Among different preservative solutions, higher postharvest quality and longest vase life (30.5 and 31.62 days) of *Strelitzia* cut flowers were observed when pulsed with silver thiosulphate (STS) (0.463 mM) for 30 minutes + 10 per cent sucrose + 200 ppm 8-Hydroxy Quinoline Sulphate (8-HQS) for 12 hours and holding in solution containing sucrose 5 per cent + 8-HQS 200 ppm + citric acid 150 ppm in both season (Gendy and Mahmoud, 2012).

Finger *et al.*, (2003) studied the effect of pulsing time and cold storage treatment on cut flowers of Bird of Paradise, which involved 40 per cent sucrose pulsing before or after storing flowers at 10 °C for 7, 14, 21 and 28 days. Among them storing the flowers initially at 10 °C for seven days followed by pulsing with 40 per cent sucrose for 24 hours found effective in improving flower longevity and number of open florets than control and pulsed before storage.

Koley *et al*., (2016) studied the effect of pulsing on vase life, postharvest quality and biochemical aspects of cut stems in Bird of Paradise. Results indicated that pulsing for 48 hours with 20 per cent sucrose + 250 µM Thidiazuron + 150 ppm citric acid was effective in increasing the postharvest longevity as well as VL (13.73 days).

Hernandeza *et al.,* (2015) studied the effect of combination of different storage conditions on postharvest quality and vase life (VL) of *Heliconia psittacorum* L. f. cv. Tropica. Storage condition at 15 °C, 63 per cent relative humidity, photo flux density of 0 µmol $m^{-2}s^{-1}$ resulted in higher VL of 6.6 days than control (CT) (24$\pm$2 °C, 60$\pm$5 per cent RH, photo flux density 10 µmol $m^{-2}s^{-1}$) that had VL of 2.5 days.

Effect of different plant growth regulators and chemicals on postharvest physiology and vase life of *Heliconia* inflorescence cv. Golden torch were studied. Postharvest spray of Gibberlic Acid (GA_3) 100 mg l^{-1} or Bovine Serum Albumin (BSA) 50 mg l^{-1} showed significant increase in the VL with 15.44 and 14.13 days respectively (Mangave *et al.*, 2013).

Bayogan *et al*. (2007) reported that the postharvest life of Bird-of Paradise inflorescence ranges from 6 to 16 days. Overnight treatment of Bird-of Paradise inflorescence prior to packing with 20 or 40 per cent sucrose, 250 or 500 mg L^{-1} 8-hydroxyquinoline citrate (8-HQC) plus 150 or 300 mg L^{-1} citric acid or silver thiosulphate for 10 min and gibberellic acid overnight increased postharvest life from 10 to 13 days. Inflorescences held in 10 per cent sucrose and 200 mg L^{-1} 8-HQC with 10 mg L^{-1} silver nitrate after unpacking had 1.2 times longer postharvest life than the de-ionized water. The author suggested that Bird of Paradise inflorescence should be harvested when the first floret was just about to emerge from the boat, pulsed with 5% sucrose overnight then shipped and upon unpacking held in 10 per cent sucrose, 200 mg L^{-1} 8-HQC and 10 mg L^{-1} silver nitrate.

Several post-harvest treatments were evaluated for their potential to improve the postharvest performance of Bird of Paradise inflorescence. It was reported that extended floret longevity (2.3-3.2 days) with 500 µM thidiazuron (TDZ) for 24 hours, increased number of floret opening (1 in control to 2.0 per inflorescence) with TDZ + 20 per cent sucrose and less reduction in vase life with storage for 7 days at 0 °C (Macnish *et al*., 2010).

The effect of different harvesting stages and pulsing treatments for better water relation and enhanced vase life of Bird of Paradise cut flower showed highest cumulative uptake of water, less cumulative physiological loss in weight (2.67%) and highest vase life (16.00 days) with 10 per cent sucrose + 200 ppm 8HQS + 150ppm citric acid for 48 hours for the flowers harvested at commercial stage. Maximum cumulative physiological loss in weight was recorded in the flowers harvested at two days prior to commercial stage of harvest and held in distilled water (8.37%) due to the un opening of remaining florets and wilting of the flower (Jeevitha *et al*., 2013).

The post-harvest study on *Strelitzia* with respect to its floret longevity and opening of florets revealed longer lifespan of 14.2 days for the Button stage and 12.5 days for the stems harvested with the first open button (FRO). However, the flower stalks harvested and transported with closed buds had lower flower opening percentage (94.2%) than those that were harvested with the first rapier already open (99.3%) (Dias *et al*., 2013).

Physiological responses were evaluated in cut inflorescence of *Heliconia bihai* cv*.* Lobster Claw and cv. Halloween flowers based on symptoms of senescence and chilling injury with respect to fresh weight, bract color, percentage of absolute integrity of cell membranes and leakage of potassium ions at five different intervals after harvest with different storage temperature (6.5 °C and 24 °C) and RH (%). Both cultivars showed symptoms of senescence and chilling injury at 6.5 °C. The severity of chilling injury increased with the length of storage time in both cultivars (Costa *et al.,* 2011).

III MATERIAL AND METHODS

The present investigation entitled "Characterization of Bird of Paradise (*Strelitzia reginae* L.) for morphological and physiological traits" was carried out at ICAR - Indian Institute of Horticultural Research, Hessaraghatta (ICAR-IIHR), Bengaluru, Karnataka during 2016-2017. In this experiment, morphological and physiological characterization and post-harvest studies of twenty-one genotypes were done. The details of materials used, techniques and observations recorded during the course of the investigations are presented in this chapter.

3.1 Geographical location of the experimental site

ICAR – IIHR, Bengaluru is situated in South-East tract of Karnataka state at 12°58′ North latitude and 77°34′ East longitude and at an altitude of 900 m above the mean sea level.

3.2 Materials

3.2.1 Bird of Paradise (*Strelitzia reginae* L.)

Twenty-one genotypes of 6-year-old (Plate1, Plate 2a & 2b, Plate 3a & 3b) plants maintained in the farm of Indian Institute of Horticultural Research, Bengaluru were used in the experiment.

3.2.2 The experimental details are as follows

1.	Location	ICAR-IIHR, Hessaraghatta.
2.	Genotype(Treatments)	21
3.	Replication	3
4.	Spacing	2 m × 2 m
5.	Design	Randomized Complete Block Design (RCBD)

The details of the twenty-one genotypes with their accession numbers are presented in the Table 1.

Plate 1: Field view of Bird of Paradise at ICAR-IIHR, Bengaluru

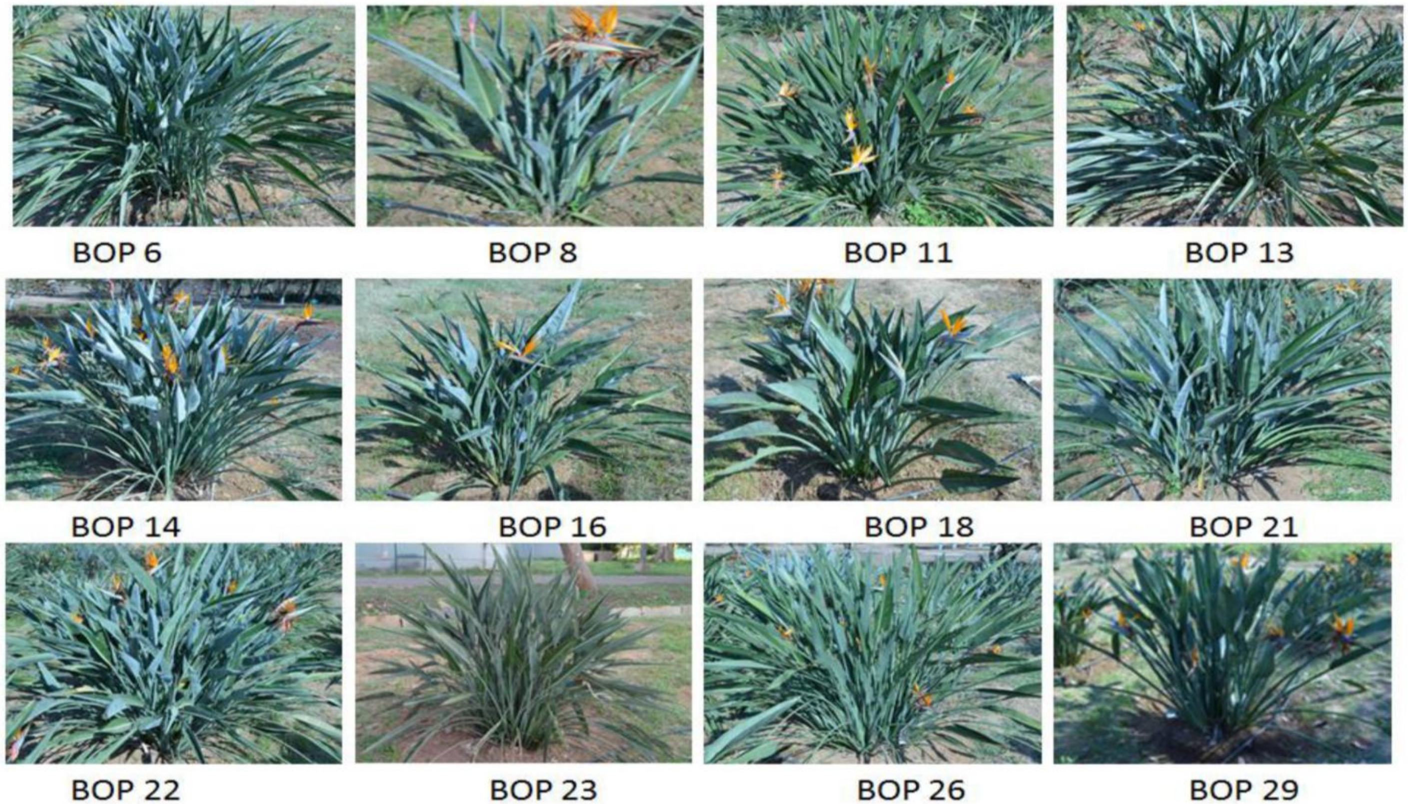


Plate 2a: Plants of 21 Bird of Paradise genotypes used in the study

BOP 31

BOP 33

BOP 35

BOP 38

BOP 40

BOP 41

BOP 45

BOP 47

BOP 51

Plate 2b: Plants of 21 Bird of Paradise genotypes used in the study

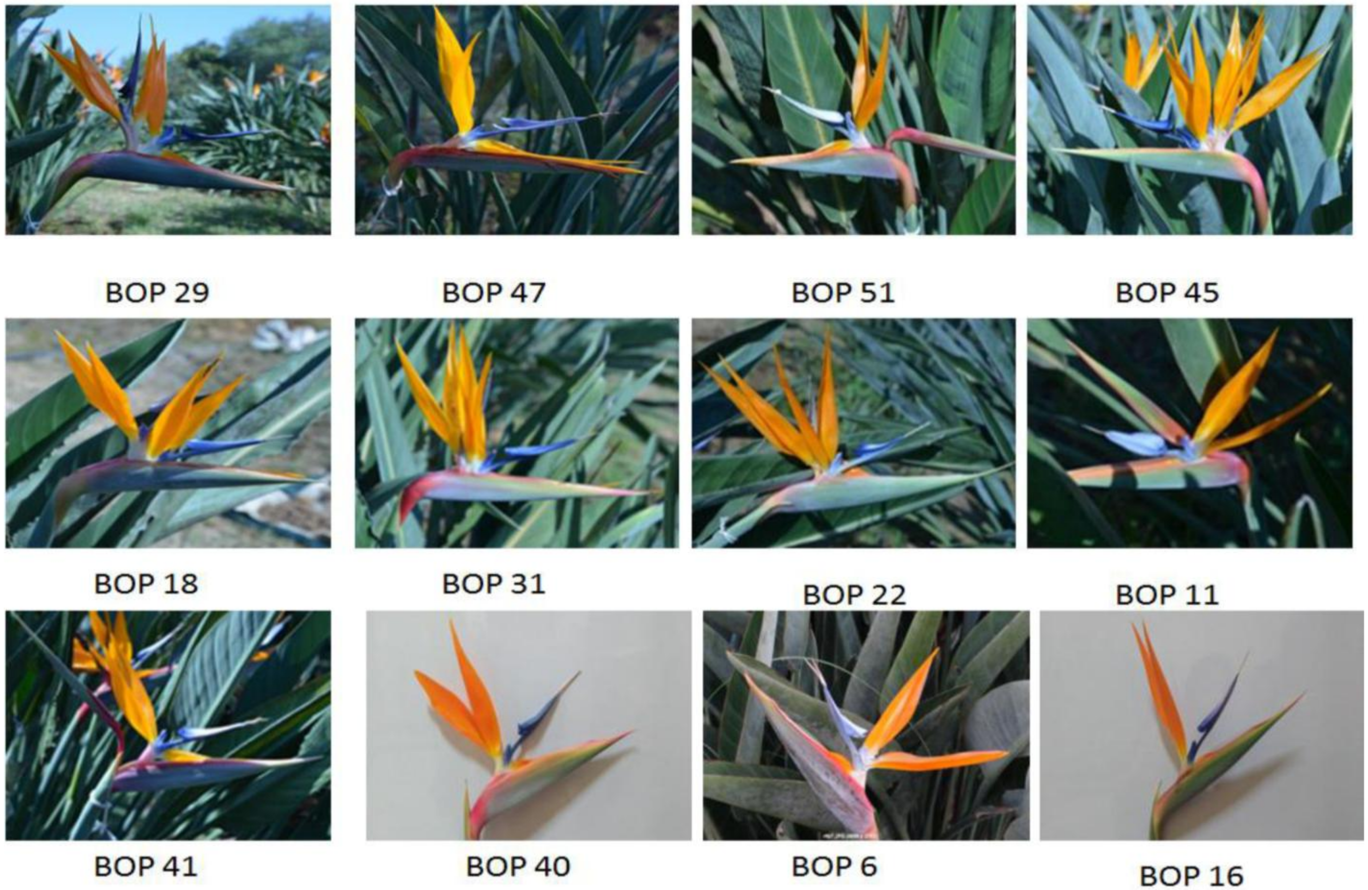


Plate 3a: Inflorescence spikes of 21 Bird of Paradise genotypes used in the study

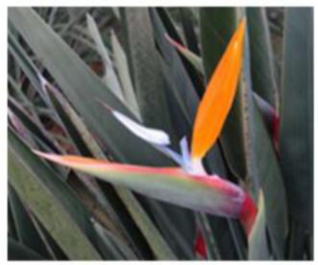
BOP 35

BOP 23

BOP 6

BOP 21

BOP 33



BOP 11

BOP 13

BOP 14

BOP 26

Plate 3b: Inflorescence spikes of 21 Bird of Paradise genotypes used in the study

Table 1: List of Bird of Paradise genotypes used in the experiment.

Sl. No.	Accession No.	Sl. No.	Accession No.
1.	BOP 6	12.	BOP 29
2.	BOP 8	13.	BOP 31
3.	BOP 11	14.	BOP 33
4.	BOP 13	15.	BOP 35
5.	BOP 14	16.	BOP 38
6.	BOP 16	17.	BOP 40
7.	BOP 18	18.	BOP 41
8.	BOP 21	19.	BOP 45
9.	BOP 22	20.	BOP 47
10.	BOP 23	21.	BOP 51
11.	BOP 26		

3.2.3 Chemicals

All the chemicals used in this investigation were of analytical grade from Hi-Media Laboratories chemical supplier.

3.3 Study of morphological characters

Morphological observations were recorded during December, 2016. The parameters are as follows.

3.3.1 Plant growth parameters

3.3.1.1 Plant height (cm)

The plant height was measured from the ground level to the tip of longest leaf using measuring scale.

3.3.1.2 Number of fans per plant

The Bird of Paradise plants produces natural suckers (that arise from clump) referred as fans. The fans were counted and recorded.

3.3.2 Leaf characters

In each plant third leaf from growing point was taken for recording leaf characters. In each plant total 5 leaves from different clumps with in a plant were taken for observation. The leaf characters taken are as follows.

3.3.2.1 Number of leaves per plant

Total number of leaves in each plant was counted and recorded.

3.3.2.2 Leaf length (cm)

Leaf length was measured from the base of the petiole to the tip of the leaf.

3.3.2.3 Leaf lamina breadth (cm)

Leaf breadth was measured at the broader part of leaf where breadth was found maximum using measuring scale.

3.3.2.4 Specific leaf area (cm^2 g^{-1})

Specific leaf area (SLA) is defined as the ratio of leaf area to dry mass. Specific leaf area was measured using digital leaf area meter

3.3.2.5 Petiole length (cm)

The length of plant from the ground level to distal end of leaf was taken as petiole length.

3.3.2.6 Plant spread (cm)

Plant spread in both North-South and West-East directions was measured using measuring tape and expressed in cm.

3.3.2 Yield and quality parameters

In each plant five inflorescence were selected and following observations were taken.

3.3.2.1 Number of inflorescence (spike) per plant

Total number of inflorescence in each genotype was counted and recorded in the month of November-January and February – April.

3.3.2.2 Number of florets per spike

Each flower will have six to eight florets. The number of florets in each inflorescence was counted at the end of the full opening.

3.3.2.3 Spike length (cm)

The length of the spike from the ground level to the tip of the spathe was taken as spike length. Spike length was measured using measuring scale.

3.3.2.4 Spike diameter (mm)

The diameter of the spike was taken at the middle of the spathe using Vernier calipers at a height of 45 cm above ground level.

3.3.2.5 Spathe length (cm)

The length of inflorescence from the neck portion of the spathe up to the beak was taken as spathe length using measuring scale.

3.3.2.6 Spathe diameter (mm)

The spathe diameter was measured using Vernier caliper at the middle portion where diameter was found maximum.

3.3.2.7 Spathe color

Spathe color was recorded as per the color code of RHS Color chart.

3.3.2.8 Floret length (cm)

Total length of the first opened floret was measured using scale.

3.3.2.9 Flower stalk length (cm)

Length of spike from the ground level to the distal end of the spathe was taken using measuring scale, as flower stalk length.

3.4 Physiological parameters

3.4.1 Wax content (mg cm^{-2})

Procedure (Ebecorn *et al*., 1977)

i. Leaf sample with dimension 2×2 cm was taken from the middle portion of third fully opened mature leaf from the top.

ii. Sample was immersed in test tube containing 15 ml of Chloroform and shaken well for 15 seconds at room temperature.

iii. Extract was sieved immediately into another test tube using funnel and extract was evaporated to dryness in a water bath maintained at 70 °C.

iv. Later 5 ml of Acidic potassium dichromate solution was added and heated in a boiling water bath for 30 minutes.

v. After cooling 5 ml of distilled water was added and absorbance was read at 590 nm using spectrophotometer (T80+UV/VIS, PG Instruments Ltd, Lutterworth, UK).

vi. A standard graph for wax content was developed using carnauba wax (Sigma-Aldrich, St Lois, MO, USA; CAS No: 8015–86–9).

vii. Wax content was calculated using the formula

$$\text{Wax (mg cm}^{-2}\text{)} = \frac{\text{OD of sample at 590 nm} \times \text{Standard value of sample}}{\text{Area of sample used}}$$

3.4.2 Relative water content (%)

Procedure

i. Fresh weight of ten discs each from middle portion of third fully opened mature leaf from top was recorded and incubated overnight in 20 ml of distilled water.
ii. Next day turgid weight was recorded.

Discs were kept in oven for complete drying at 60 °C and dry weight was recorded (Barrs and Weatherley, 1962).

Calculation:

$$\text{RWC (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight – Dry weight}} \times 100$$

3.4.3 Photosynthesis rate (μmol CO_2 $m^{-2}s^{-1}$)

It was measured using portable photosynthesis system (LC pro+, ADC Bio Scientific limited, UK) in third fully opened mature leaf from the top on a sunny day between 9 am and 12 noon.

3.4.4 Stomatal conductance (mmol $m^{-2}s^{-1}$)

It was measured using portable photosynthesis system (LC pro+, ADC Bio Scientific limited, UK) in third fully opened mature leaf from the top on a sunny day between 9 am and 12 noon.

3.4.5 Transpiration rate (m mol m^{-2} s^{-1})

It was measured using portable photosynthesis system (LC pro+, ADC Bio Scientific limited, UK) in third fully opened mature leaf from top on a sunny day between 9 am and 12 noon.

3.4.6 Leaf chlorophyll content (mg g^{-1} fresh weight)

Procedure

i. Leaf sample of 0.1 g was taken from the middle portion of the top third fully opened mature leaf.
ii. Leaf was incubated in test tubes containing 10 ml solution of Dimethyl sulfoxide (DMSO) and Acetone in 1:1 ratio till the leaf sample turn colourless due to bleaching of chlorophyll.
iii. The final volume was made to 10 ml and absorbance were recorded using spectrophotometer at 663, 647 and 470 nm.

Calculation:

$$\text{Chlorophyll a} = (12.25 \times \text{OD at 663 nm} - 2.79 \times \text{OD at 647 nm}) \times \frac{\text{Volume made}}{1000 \times \text{Fresh weight}}$$

$$\text{Chlorophyll b} = (21.5 \times \text{OD at 647 nm} - 5.10 \times \text{OD at 663 nm}) \times \frac{\text{Volume made}}{1000 \times \text{Fresh weight}}$$

3.4.7 Anthocyanin content in florets (mg 100 g^{-1})

Procedure:

i. Freshly opened blue petal of 2g weight was homogenized with acidified methanol (Hydrochloric acid and Methanol in the ratio 1:99) and incubated for 72 h.
ii. Mixture was squeezed and residue was re-extracted 2 to 3 times till the sample turns colourless.
iii. Extracts were pooled and volume was made to 50 ml.
iv. Intensity of color was read at 540 nm in spectrophotometer by adjusting 100% transmission against Acidic methanol (Fuleki, 1969).

Calculation:

$$\text{Anthocyanin (mg per 100g)} = \frac{\text{OD at 540 nm} \times \text{Standard value (µg)} \times \text{Total Vol. of Extract} \times 100}{\text{Weight of the sample (g)} \times 1000}$$

3.4.8 Total Carotenoids (mg 100 g^{-1})

Procedure:

i. Total carotenoids content was analyzed by spectrophotometric method suggested by Lichtenthaler (1987).
ii. Freshly opened 2 g of orange petal was taken in to a mortar and ground with acetone and one spatula of $CaCO_3$.
iii. Residue was extracted with more solvent until the supernatant became colourless.
iv. Extract was taken in separating funnel and added 15 ml of Hexane, 100 ml of water and 2 spatula of NaCl and was shaken well and allowed to stand for few minutes.
v. The two phases formed were separated and the lower aqueous phase was re-extracted with additional hexane, until the aqueous phase was colourless.
vi. Upper layer was collected and repeated the procedure by adding 5 ml of hexane
vii. Extract was taken in test tube and added a spatula of anhydrous Na_2SO_4 and volume was made to 25 ml with Hexane.
viii. Absorbance was read at 470 nm

Calculation:

$$\text{Carotenoid (mg per 100 g)} = \frac{\text{OD at 470 nm} \times \text{Standard value (µg)} \times \text{Total Vol. of Extract} \times 100}{\text{Weight of the sample (g)} \times 1000}$$

3.4.9 Stomatal number per mm^2

An impression of epidermal surface of the leaf was taken using clear nail polish and observed under light microscope with 40X magnification. The average number of stomata per mm^2 area was worked out.

3.5 Vase life studies

The Bird of Paradise inflorescence of 50 cm long stalk was harvested at the bud burst stage *i.e*., when orange petals of the first floret were exposed but not extended (Plate 4). Immediately after harvest stalks were kept in bucket containing tap water and brought to laboratory. Stalks were recut to 5 cm inside the water and individual flower stalks were labeled and kept in 250 ml conical flask containing 150 ml of tap water after talking fresh weight using digital balance. These conical flasks were kept undisturbed till the completion of vase life studies (Plate 5a & 5b). The parameters recorded for postharvest study is as follows.

3.5.1 Fresh weight (g)

Inflorescence fresh weight was taken at the beginning of the experiment before placing it in a conical flask containing water.

3.5.2 Dry weight (g)

Weight of the inflorescence at the end of the vase life study was taken as dry weight of the flower.

3.5.3 Water uptake (ml)

Difference between the initial volume and final volume of the water in the conical flask at the end of the vase life was taken as water uptake.

3.5.4 Physiological loss of weight (PLW)

PLW was taken using the formula,

$$\text{PLW (g)} = \frac{\text{Initial fresh weight (g)} \times \text{Final weight (g)}}{\text{Initial fresh weight (g)}}$$

3.5.5 Number of florets opened

Total number of florets opened were counted at the end of the experiment and recorded.

Plate 4: Harvesting stage

Plate 5a: Spikes of 21 Bird of Paradise genotypes used in the vase life study

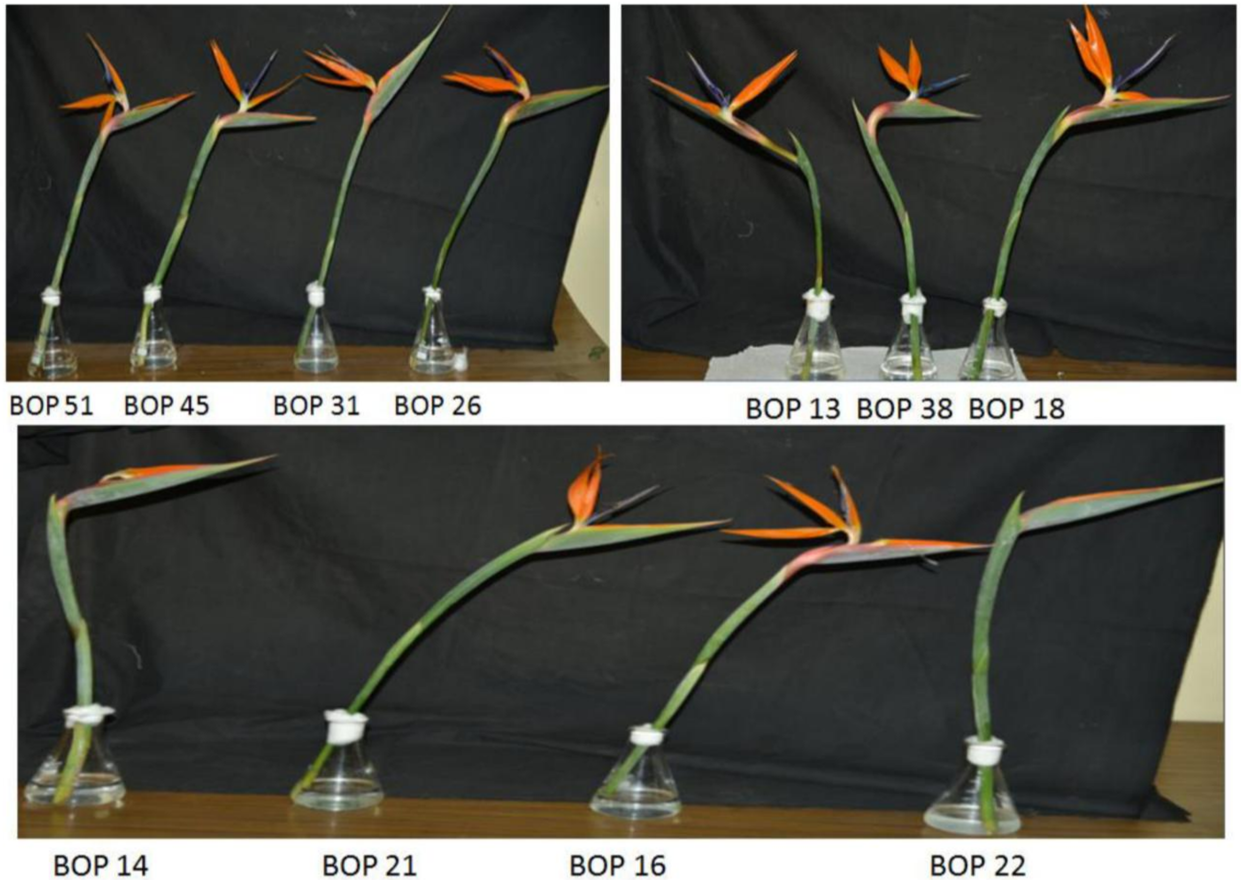


Plate 5b: Spikes of 21 Bird of Paradise genotypes used in the vase life study

3.5.6 Vase life

Vase life was recorded from the time of opening of first floret of inflorescence to its senescence *i.e.*, when 75 per cent of the total opened florets in an individual inflorescence shows the symptoms of wilting or browning of petals and bracts.

3.6 Statistical analysis

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data collected and recorded from the selected genotypes in accordance with different parameters. The recorded data on the selected parameters were subjected to analysis of variance using "Web Agri Stat Package 2" of ICAR Research Complex, Goa. 'F' test at $p = 0.05$ was performed to assess the level of significance. The relation between important physiological traits is explained with scatter diagram.

IV EXPERIMENTAL RESULTS

The major emphasis of the study on “Characterization of Bird of Paradise (*Strelitzia reginae* L.) for morphological and physiological traits” is to classify and identify the best genotypes based on available variations among twenty-one genotypes maintained at the field gene bank of Indian Institute of Horticultural Research, Hessaraghatta (ICAR-IIHR) Bengaluru, Karnataka for further use in breeding programme.

The morphological and physiological characterization includes identification of variability among BOP genotypes using several important morphological and physiological characters of both quantitative and qualitative nature. Twenty-one genotypes were evaluated to study their morphological and physiological diversity and vase life. Observations were recorded regularly and the results of the investigation are presented in this chapter.

4.1 Morphological studies

4.1.1 Plant growth parameters

4.1.1.1 Plant height (cm)

The plant height varied among genotypes (Table 2). The genotype BOP 41 recorded the highest plant height (166.33 cm) and BOP 47 was the shortest (91.00 cm).

4.1.1.2 Number of fans per plant

Number of fans per plant varied among the genotypes from 5.33 to 29.67. The maximum number of fans was recorded in BOP 41 and minimum in BOP 33 (Table 2).

4.1.1.3 Number of leaves per plant

The genotypes showed wide and significant variation in number of leaves. The number of leaves was higher in BOP 41 (389) and lower (16.33) in BOP 8 (Table 2).

4.1.1.4 Specific leaf area (cm^2 g^{-1})

Specific leaf area varied from 87.07 to 311.92 cm^2 g^{-1} in different genotypes (Table 2). The genotype BOP 33 recorded the maximum specific leaf area (311.92 cm^2 g^{-1}) and was on par with BOP 29 (306.15 cm^2 g^{-1}) whereas minimum recorded for BOP 47 (87.07 cm^2 g^{-1}).

4.1.1.5 Plant spread North- South and East – West (cm)

Plant spread varied significantly among the genotypes (Table 2). Plant spread for North-South (279.67 cm) and East-West (275.33 cm) was maximum for BOP 41 whereas minimum was recorded for BOP 47 in both North- South (130 cm) and East- West (129.67 cm) directions.

4.1.1.6 Leaf petiole length (cm)

The length of the leaf petiole ranged from 40.55 cm to 84.09 cm (Table 3). BOP 26 recorded maximum (84.09 cm) value for leaf petiole length while minimum in BOP 35 (40.55 cm).

4.1.1.7 Leaf lamina length (cm)

Leaf lamina length ranged from 27.83 cm to 40.51 cm. Higher leaf lamina length was recorded in BOP 33 and lowest in BOP 47 (Table 3).

4.1.1.8 Leaf length (cm)

There was variation (73.50 cm to 124.18 cm) in leaf breadth amongst the genotypes (Table 3). The genotype BOP 33 attained maximum leaf length (124.18 cm), followed by BOP 26 (119.52 cm). Length of leaf was found to be minimum in BOP 35 (73.50 cm).

4.1.1.9 Leaf lamina breadth (cm)

Leaf lamina breadth found to vary among the genotypes (Table 3). BOP 33 recorded higher leaf lamina breadth (13.67 cm) followed by BOP 18 (11.29 cm). It was the lowest in BOP 8 (5.94 cm).

Table 2: Plant growth parameters in various BOP genotypes.

Accession No.	Plant height (cm)	No. of fans/ plant	No. of leaves/ plant	Specific leaf area ($cm^2 g^{-1}$)	Plant spread (cm)	
					North -South	East - West
BOP 23	126.13	16.67	164.33	158.61	180.00	187.33
BOP 29	141.53	7.33	47.67	306.15	192.00	191.33
BOP 51	125.40	9.67	79.67	230.98	189.67	211.67
BOP 45	138.17	21.00	234.33	265.18	213.67	219.33
BOP 31	130.23	22.00	210.00	135.39	199.00	196.67
BOP 22	125.60	18.00	212.00	211.04	180.33	174.33
BOP 6	128.00	25.67	272.67	159.14	213.33	205.00
BOP 11	114.87	16.00	234.00	129.33	198.67	196.00
BOP 33	163.80	5.33	45.67	311.92	234.33	241.00
BOP 26	159.33	18.33	194.33	154.70	262.67	263.00
BOP 14	153.10	13.33	158.67	204.19	248.67	258.67
BOP 13	137.30	18.00	263.33	192.34	250.33	233.00
BOP 38	113.77	15.67	65.00	139.51	178.33	185.00
BOP 47	91.00	20.67	95.00	87.07	130.00	129.67
BOP 8	94.67	11.67	16.33	135.50	138.00	131.33
BOP 18	98.53	18.67	25.00	241.50	147.67	151.43
BOP 40	122.73	28.33	60.00	117.57	173.87	176.77
BOP 16	109.93	27.33	78.33	198.43	182.67	234.67
BOP 35	104.80	8.33	65.67	91.08	146.23	154.00
BOP 41	166.33	29.67	389.00	203.43	279.67	275.33
BOP 21	150.00	9.33	95.67	136.10	160.00	165.33
Mean	**128.34**	**13.71**	**143.17**	**181.39**	**195.20**	**199.09**
S. Em±	**7.63**	**1.10**	**7.01**	**23.95**	**18.85**	**15.98**
C.V.	**10.29**	**13.95**	**8.48**	**22.87**	**16.73**	**13.91**
C.D. (5%)	**21.80**	**3.16**	**20.03**	**68.44**	**53.89**	**45.69**

Table 3: Leaf characteristics in various BOP genotypes

Accession No.	Leaf characteristics			
	Petiole length (cm)	Leaf lamina length (cm)	Leaf length (cm)	Leaf lamina breadth (cm)
BOP 23	62.20	37.70	99.90	7.64
BOP 29	72.54	34.20	106.74	9.98
BOP 51	60.12	33.55	93.67	9.53
BOP 45	80.11	36.48	116.59	9.67
BOP 31	60.72	34.15	94.87	6.93
BOP 22	67.99	29.72	97.71	10.55
BOP 6	64.47	36.11	100.58	8.22
BOP 11	66.58	30.78	97.36	7.56
BOP 33	83.67	40.51	124.18	13.67
BOP 26	84.09	35.43	119.52	6.63
BOP 14	78.69	34.22	112.91	9.32
BOP 13	64.13	33.19	97.32	7.48
BOP 38	62.77	31.57	94.35	6.77
BOP 47	50.60	27.83	78.43	7.15
BOP 8	50.19	32.51	82.71	5.94
BOP 18	49.97	31.50	81.46	11.29
BOP 40	61.91	33.71	95.62	6.85
BOP 16	65.04	35.91	100.95	9.23
BOP 35	40.55	32.94	73.50	6.76
BOP 41	74.53	37.43	111.96	6.80
BOP 21	76.13	35.63	111.76	8.28
Mean	**65.57**	**34.05**	**99.62**	**8.39**
S. Em±	**4.09**	**1.33**	**4.68**	**0.41**
C.V	**10.81**	**6.78**	**8.13**	**8.53**
C.D. (5%)	**11.70**	**3.81**	**13.37**	**1.18**

4.1.2 Yield parameters

4.1.2.1 Spathe length (cm)

Spathe length in different genotypes ranged from 16.03 to 22.77 cm (Table 4). The longest spathe was noticed in BOP 16 (22.77 cm) which was on par with BOP 21 (22.21 cm), while the shortest one was observed in BOP 11 (16.03 cm).

4.1.2.2 Spathe diameter (mm)

Maximum spathe diameter was recorded in BOP 33(23.09 cm) which was followed by BOP 45 (21.04 cm) and minimum (14.55 cm) for BOP 16 (Table 4).

4.1.2.3 Spike length (cm)

The length of the spike varied among the genotypes (Table 4). Spike length was maximum in BOP 45 (149.43 cm) followed by BOP 22 (130.12 cm) and minimum in BOP 23 (74.09 cm).

4.1.2.4 Inflorescence stalk length (cm)

The genotype BOP 45 recorded highest stalk length (128.66 cm) followed by BOP 22 (108.44 cm) with lowest stalk length (56.32 cm) for BOP 23 (Table 4).

4.1.2.5 Spike diameter (mm)

Variation with respect to spike diameter among the BOP genotypes ranged from 9.6 mm to 16.33 mm (Table 4). Spike diameter was significantly high for BOP 33(16.33 mm) and found on par with BOP 29 (15.75 mm) where as it was lowest for BOP 11 (9.60 mm).

4.1.2.6 Floret length (cm)

The floret length was significantly higher for BOP 16 (16.23 cm) which was on par with BOP 47 (15.68 cm) and minimum of 10.53 cm was noticed in BOP 11 (Table 4).

4.1.2.7 Spathe colour

As per the observations taken, the RHS colour chart reference number was indicated for spathe of each genotype which is as follows; 147 A (BOP 51, BOP 29); N 137 A (BOP 6, BOP 32); N 137 B (BOP 18, BOP 16); 137 A (BOP 22, BOP 11, BOP 26, BOP 40, BOP 8, BOP 23, BOP47); 137 B (BOP 45, BOP 31, BOP 14, BOP 13, BOP 21, BOP 35, BOP 33, BOP 38).

4.1.2.8 Number of florets per spike

The data pertaining to number of florets per spike showed significantly higher value for BOP 13 (8.48) which was on par with the BOP 40 (8.42), whereas lowest (4.89) was in BOP 23 (Table 4).

4.1.2.9 Number of spikes per plant

The number of spike production varied among genotypes ranging from 4.33 to 41.33 (Table 4). It was highest in BOP 41 (41.33) and lowest in BOP 35 (4.33) and BOP 21 (4.33).

4.2 Physiological parameters

The variability in BOP genotypes for physiological traits like wax content, relative water content, total chlorophyll, photosynthetic rate, stomatal conductance, transpiration rate, stomatal number, anthocyanin and carotenoids was recorded. The observations on these parameters were recorded in leaves and flowers.

4.2.1 Wax content (mg cm^{-2})

The variation among genotypes for wax content found ranging from 0.20 to 0.62 mg cm^{-2} (Table 5 and Fig. 1). Wax content was significantly higher in BOP 45 (0.62 mg cm^{-2}) followed by BOP 13 (0.49 mg cm^{-2}) whereas lowest wax content was recorded for BOP 11 and BOP 31 (0.20 mg cm^{-2} each).

Table 4: Yield parameters in various BOP genotypes.

Accession No.	Spathe length (cm)	Spathe diameter (mm)	Spike length (cm)	Inflorescence stalk Length (cm)	Spike diameter (mm)	No. of florets/ spike	Floret length (cm)	No. of spikes/ plant
BOP 23	17.77	15.10	74.09	56.32	13.68	4.89	12.30	18.67
BOP 29	21.54	18.38	102.45	80.91	15.75	8.00	15.47	12.67
BOP 51	16.33	15.63	92.89	76.56	12.34	5.87	13.13	11.00
BOP 45	20.77	21.04	149.43	128.66	13.52	7.63	14.65	23.00
BOP 31	18.04	18.43	97.54	79.50	12.20	5.93	12.97	16.67
BOP 22	21.68	17.97	130.12	108.44	10.91	7.77	13.96	22.67
BOP 6	20.93	17.25	84.57	63.63	11.42	6.40	14.64	30.00
BOP 11	16.03	17.86	87.84	71.81	9.60	8.24	10.53	23.00
BOP 33	21.46	23.09	125.55	104.09	16.33	6.93	14.35	7.33
BOP 26	20.48	15.00	110.99	90.51	12.45	7.68	12.53	20.67
BOP 14	20.84	20.85	125.79	104.95	15.03	5.47	14.05	28.67
BOP 13	19.83	18.81	79.98	60.15	10.86	8.48	13.12	8.00
BOP 38	19.51	16.15	109.17	89.66	11.78	6.20	12.47	24.33
BOP 47	19.27	15.67	76.08	56.81	11.47	6.53	15.68	35.67
BOP 8	17.05	15.96	85.47	68.42	10.65	6.36	12.66	6.33
BOP 18	16.09	19.69	90.80	74.71	13.39	7.18	11.61	9.33
BOP 40	18.41	16.76	82.38	63.97	11.25	8.42	12.57	22.67
BOP 16	22.77	14.55	104.35	81.58	11.69	6.34	16.23	29.33
BOP 35	18.61	16.41	91.95	73.34	13.33	5.72	13.46	4.33
BOP 41	19.47	16.16	95.92	76.45	12.81	8.07	14.00	41.33
BOP 21	22.21	15.49	79.10	56.88	12.04	7.30	14.37	4.33
Mean	**19.48**	**17.44**	**98.88**	**79.40**	**12.50**	**6.92**	**13.56**	**19.05**
S. Em±	**0.52**	**0.65**	**5.50**	**5.22**	**0.41**	**7.44**	**0.22**	**1.17**
C.V	**4.59**	**6.48**	**9.64**	**11.38**	**5.66**	**7.44**	**2.80**	**10.60**
C.D. (5%)	**1.47**	**1.87**	**15.73**	**14.91**	**1.17**	**0.85**	**0.63**	**3.33**

4.2.2 Relative water content (%)

Data pertaining to RWC showed high significance among the genotypes. It was maximum for BOP 45 (94.91%) which was on par with BOP 47 (94.49%). BOP 22 was found to have low (89.24%) RWC compared to all the genotypes studied (Table 5 and Fig. 2).

4.2.3 Stomata density (mm^{-2})

Stomata number (Table 5 and Fig. 3) was found significantly higher in BOP 31 (40.8 per mm^2) which was on par with BOP 41 (40.13 per mm^2), whereas lowest stomata number was recorded for BOP 51 (22.4 per mm^2).

4.2.4 Stomatal conductance (gs; mol m^{-2} s^{-1})

The stomatal conductance differed among genotypes and ranged from 0.03 to 0.11 mol m^{-2} s^{-1} (Table 5 and Fig. 4). Genotype BOP 16 recorded significant value (0.11 mol m^{-2} s^{-1}) and was on par with BOP 40 and BOP 14 which had stomatal conductance of 0.09 mol m^{-2} s^{-1}. The lowest (0.03 mol m^{-2} s^{-1}) stomatal conductance was recorded in genotypes BOP 38 and BOP 23.

4.2.5 Transpiration rate (m mol m^{-2} s^{-1})

Significantly higher transpiration rate was recorded in BOP 16 (5.61 m mol m^{-2} s^{-1}) which was on par with BOP 11 (4.37 m mol m^{-2} s^{-1}) (Table 5 and Fig. 5). The lowest transpiration rate was recorded in BOP 23 (1.24 m mol m^{-2} s^{-1}).

4.2.6 Photosynthesis rate (µmol CO_2 m^{-2} s^{-1})

Among all genotypes, photosynthesis rate was found significantly higher in BOP 16 (7.33 µmol Co_2 m^{-2} s^{-1}) and minimum in BOP 47 (3 µmol CO_2 m^{-2} s^{-1}) (Table 5 and Fig. 6).

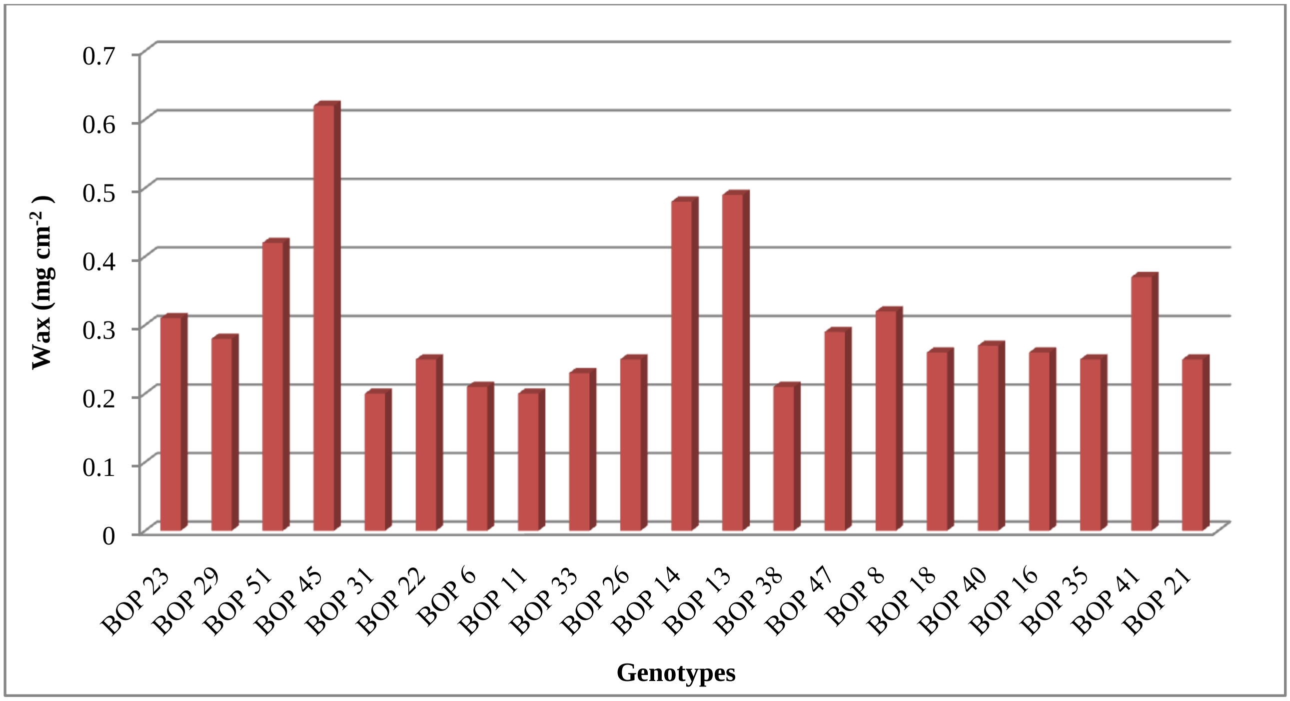


Fig. 1. Wax content in 21 genotypes of BOP evaluated under field conditions

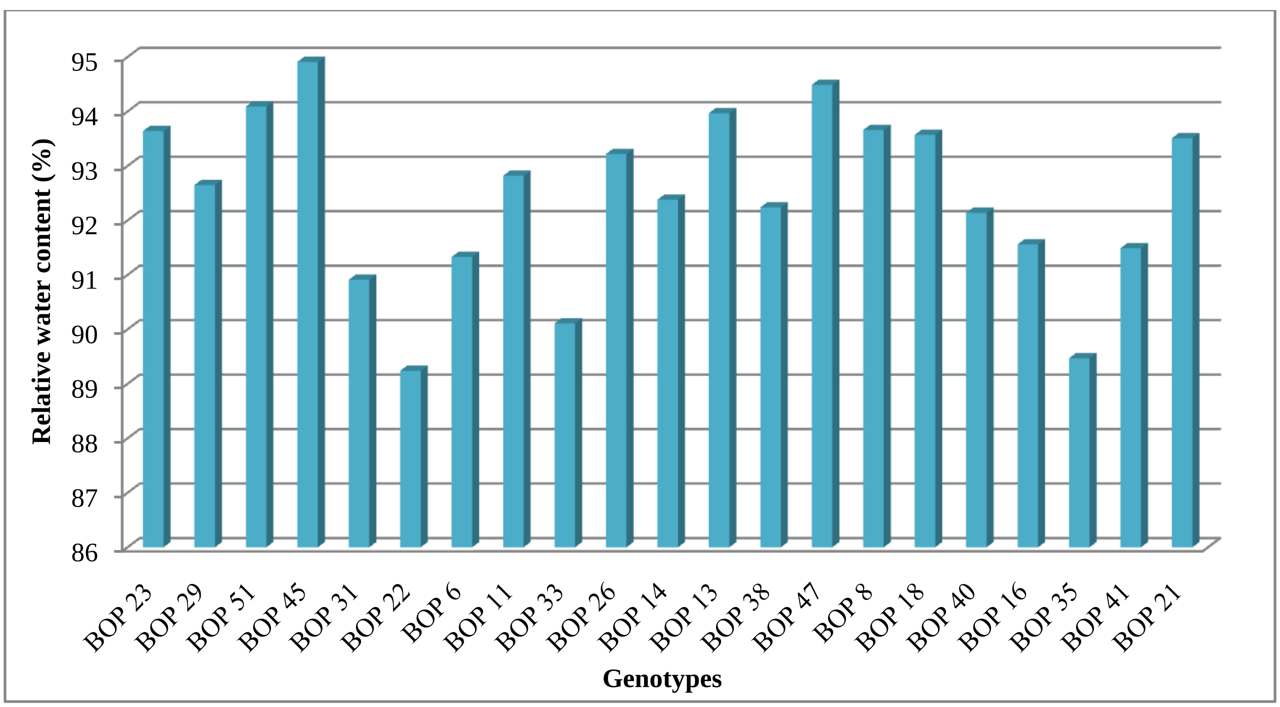


Fig. 2. Relative water content in 21 genotypes of BOP evaluated under field conditions

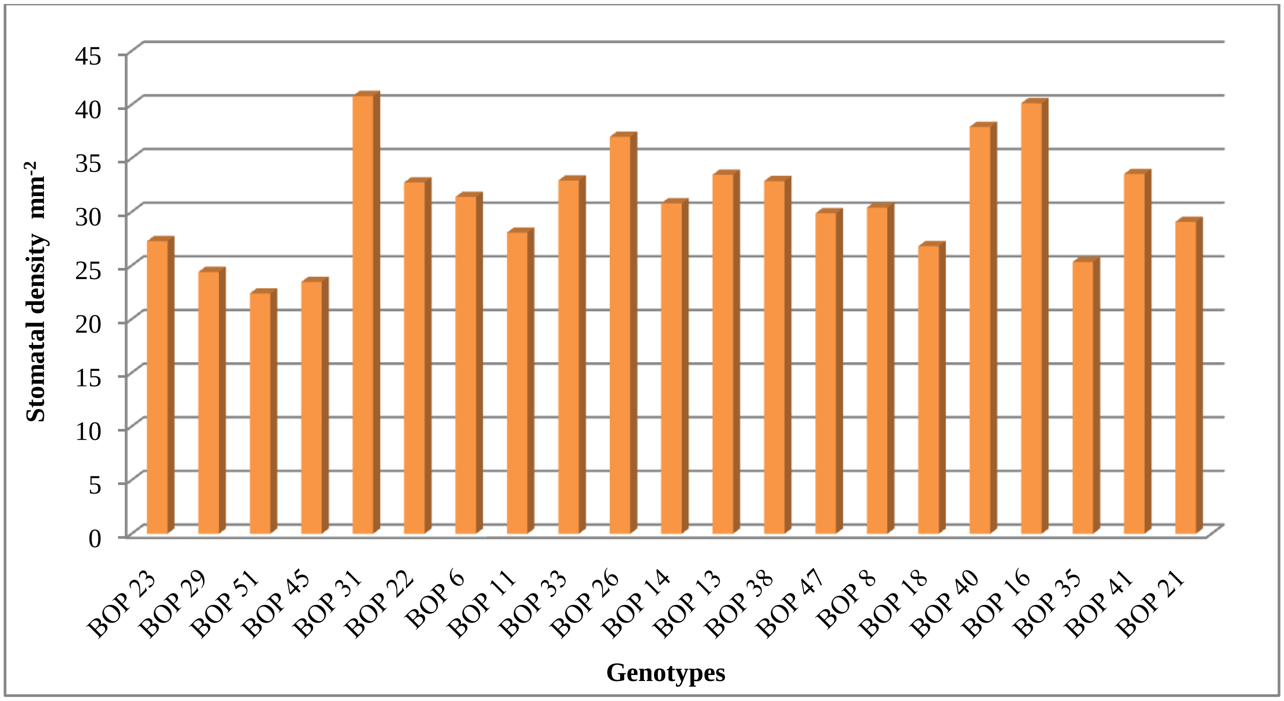


Fig. 3. Stomatal density in 21 genotypes of BOP evaluated under field conditions

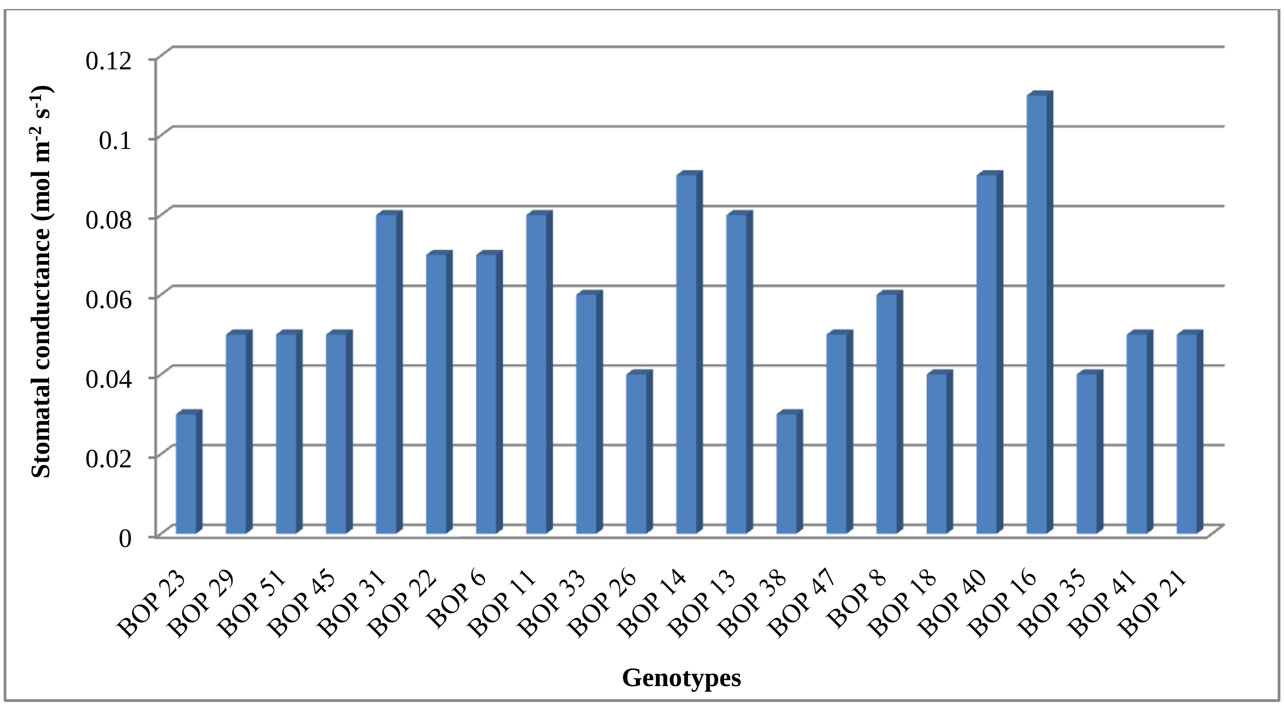


Fig. 4. Stomatal conductance in 21 genotypes of BOP evaluated under field conditions

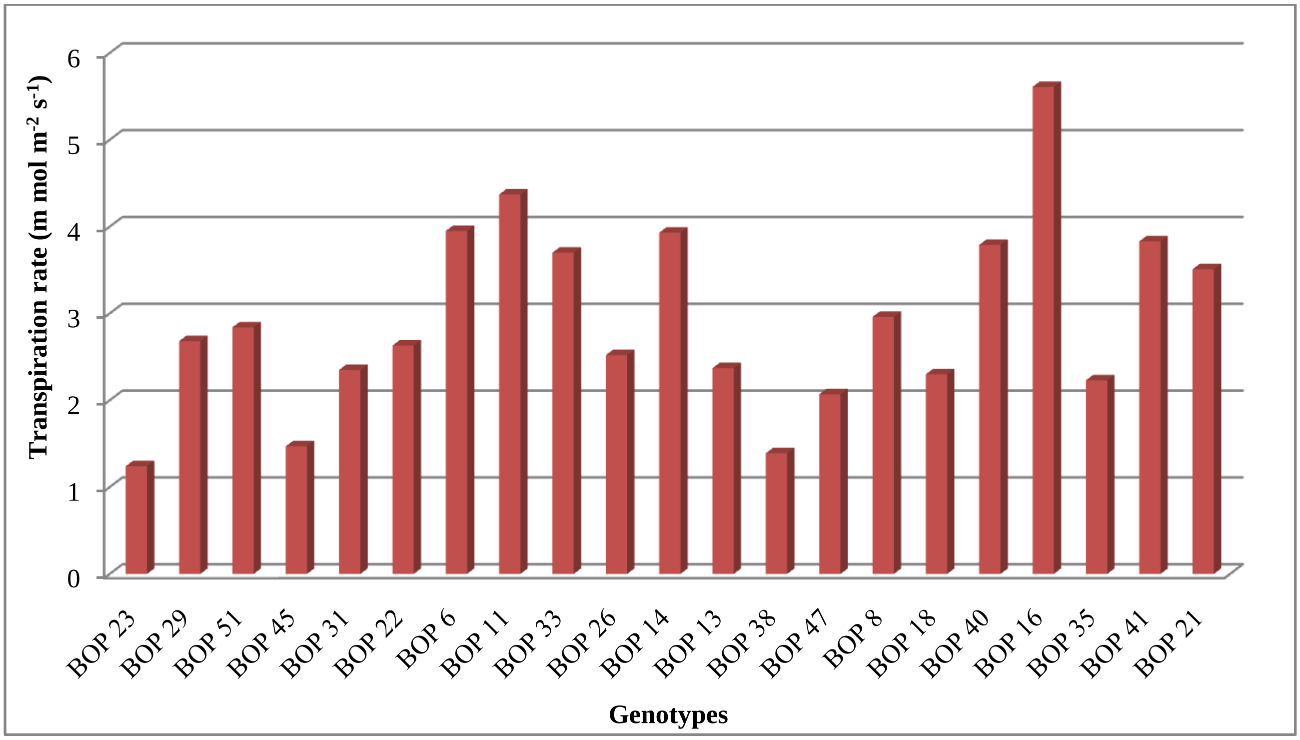


Fig. 5. Transpiration rate in 21 genotypes of BOP evaluated under field conditions

4.2.7 Total leaf chlorophyll content (mg g^{-1} fresh weight)

Significant variation was found among the genotypes for total chlorophyll content (Table 5 and Fig. 7). Genotype BOP 16 recorded maximum (2.63 mg g^{-1} fresh weight) and was on par with BOP 33 (2.61 mg g^{-1} fresh weight t) and minimum was recorded in BOP 47 (1.49 mg g^{-1} fresh weight).

4.2.8 Carotenoid contents in florets (mg 100 g^{-1} fresh weight)

The quantity of carotenoid significantly varied between the genotypes (Table 5 and Fig. 8). The maximum content was recorded in genotype BOP 6 (22.31 mg 100 g $^{-1}$ fresh weight) followed by BOP 40 (19.06 mg 100 g^{-1} fresh weight) whereas minimum was in BOP 14 (8.77 mg 100g $^{-1}$ fresh weight).

4.2.9 Anthocyanin content in florets (mg 100 g^{-1} fresh weight)

Anthocyanin content among the genotypes varied from 40.89 mg 100 g^{-1} fresh weight to 124 mg 100 g^{-1} fresh weight (Table 5 and Fig. 9). Genotype BOP 22 recorded highest which was on par with BOP 45 (122.25 mg 100 g^{-1} fresh weight). The lowest anthocyanin content was recorded in the florets of BOP 13 (40.89 mg 100 g^{-1} fresh weight).

The genotypes have been divided in to four classes based on the quantity of anthocyanin produced (Table 6). Accordingly, nine genotypes BOP 29 (100.28 mg), BOP 38 (100.93 mg), BOP 26 (102.12 mg), BOP 33 (103.62 mg), BOP 8 (105.91 mg), BOP 40 (116. 52 mg), BOP 41 (121.15 mg), BOP 45 (122.25 mg), BOP 22 (124.65 mg) were found to have high anthocyanin content of more than 100 mg per 100 g fresh weight.

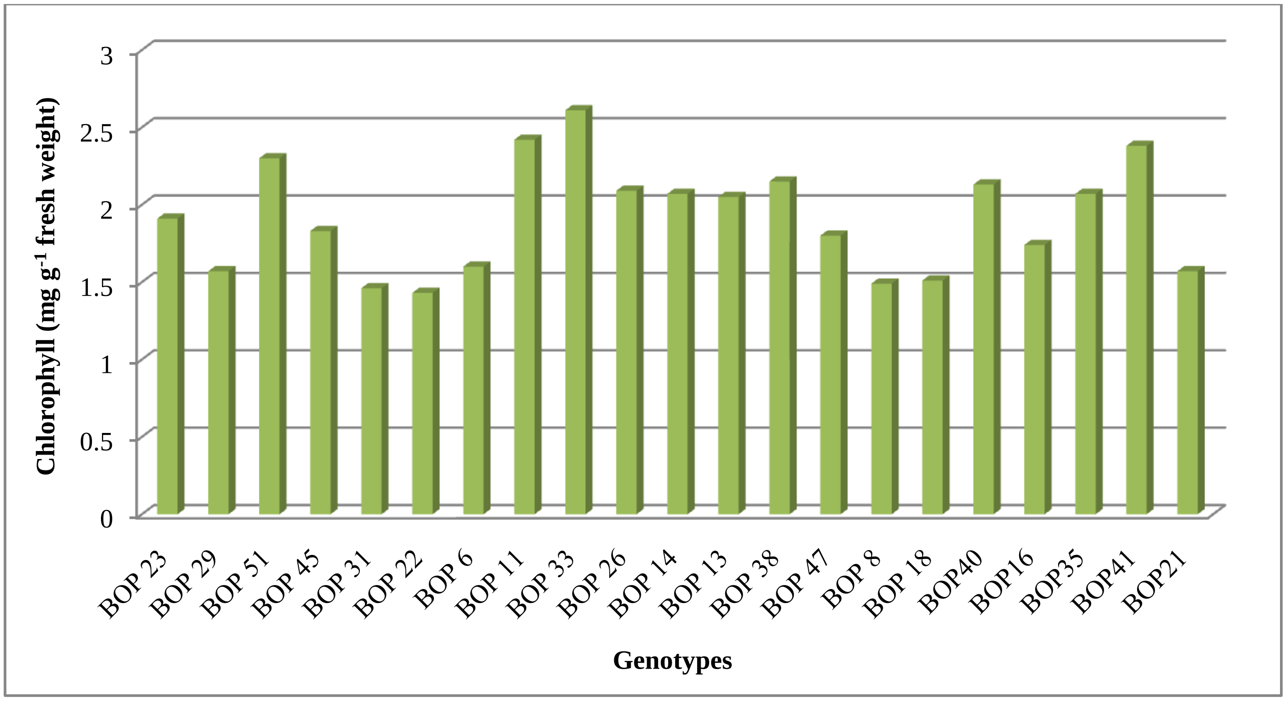


Fig. 6. Total chlorophyll in 21 genotypes of BOP evaluated under field conditions

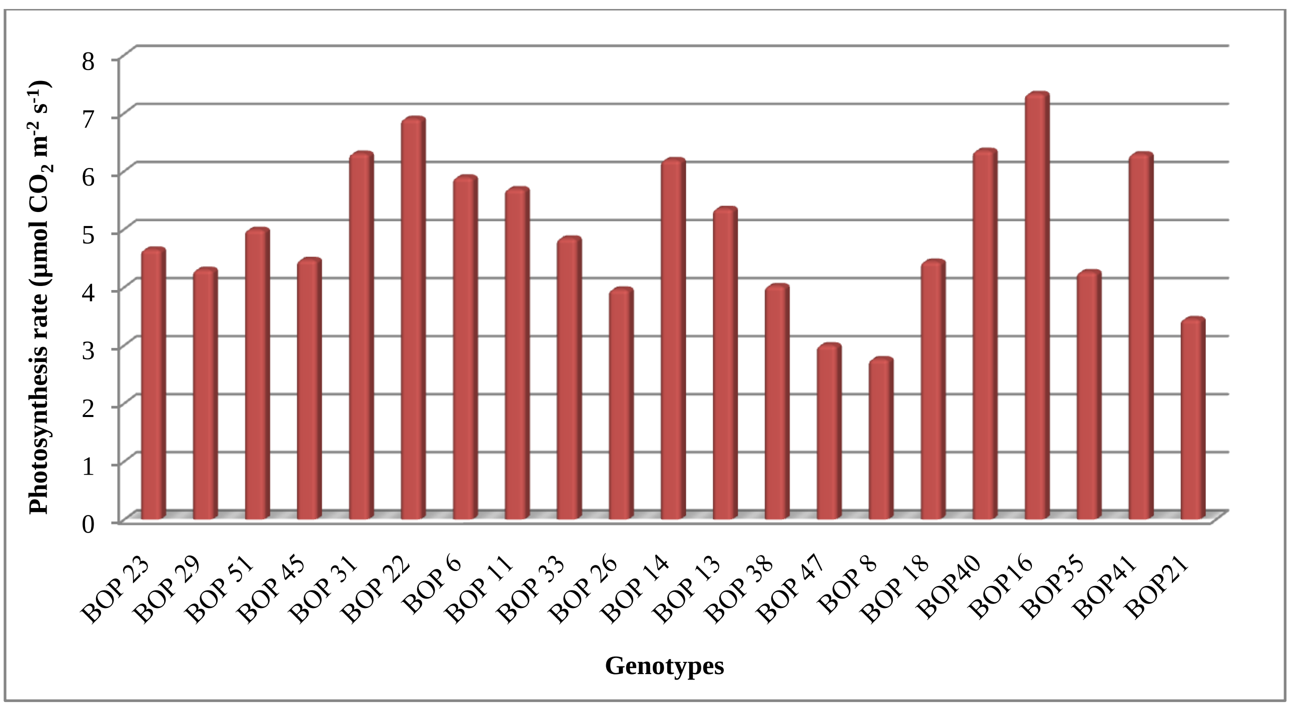


Fig. 7. Photosynthesis rate in 21 genotypes of BOP evaluated under field conditions

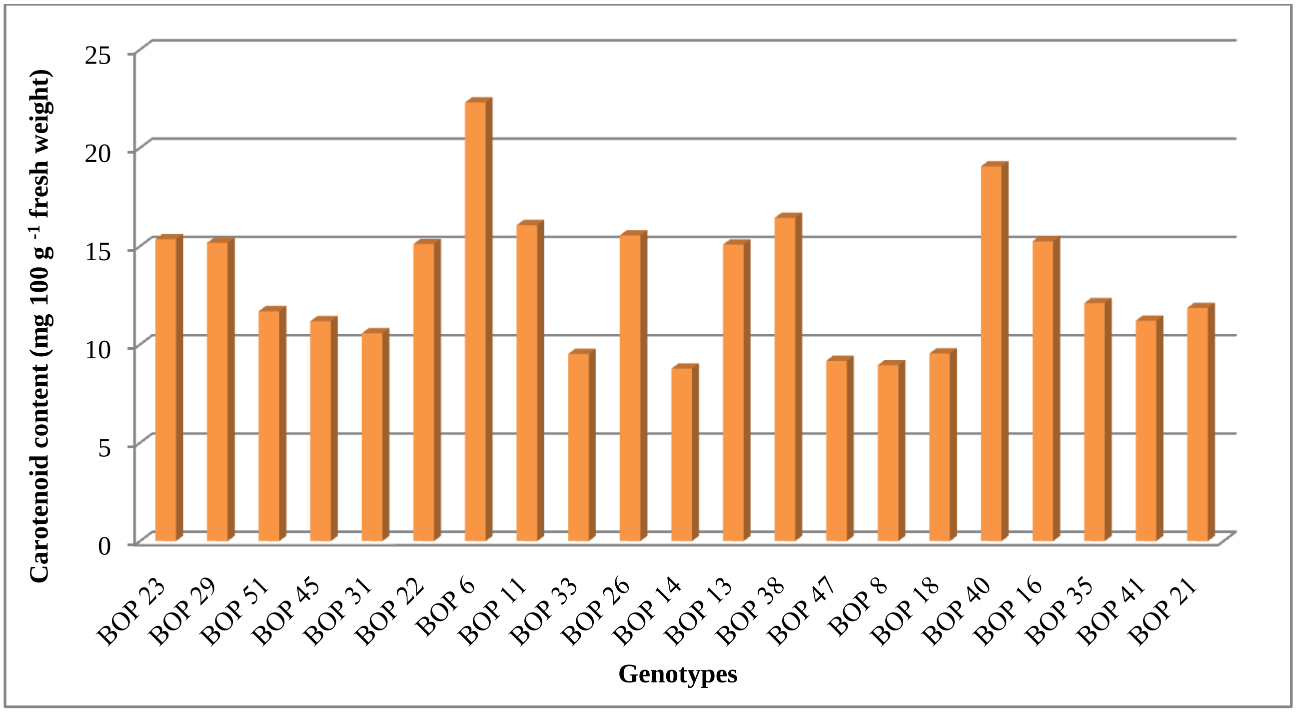


Fig. 8. Carotenoid content in 21 genotypes of BOP evaluated under field conditions

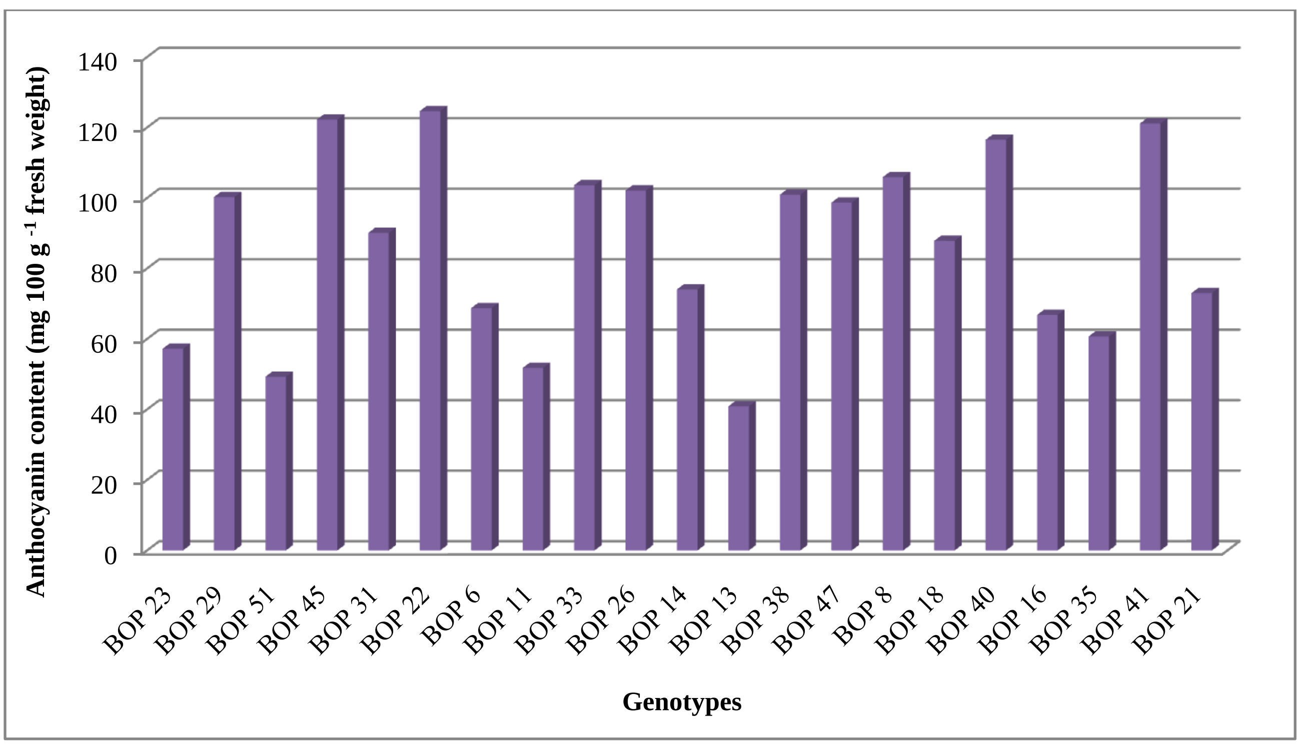


Fig. 9. Anthocyanin content in 21 genotypes of BOP evaluated under field conditions

Table 5: Performance of 21 genotypes for physiological traits

Accession No.	Wax (mg cm^{-2})	Relative water content (%)	Stomatal density (mm^{-2})	Stomatal conductance (mol m^{-2} s^{-1})	Transpiration rate (m mol m^{-2} s^{-1})	Total chlorophyll (mg g^{-1})	Photosynthesis rate (μ mol CO_2 m^{-2} s^{-1})	Anthocyanin (mg 100 g^{-1})	Carotenoids (mg 100 g^{-1})
BOP 23	0.31	93.64	27.27	0.03	1.24	1.91	4.65	57.21	15.35
BOP 29	0.28	92.65	24.40	0.05	2.68	1.97	4.30	100.28	15.17
BOP 51	0.42	94.09	22.40	0.05	2.84	2.31	4.99	49.27	11.69
BOP 45	0.62	94.91	23.47	0.05	1.47	1.83	4.47	122.25	11.18
BOP 31	0.20	90.91	40.80	0.08	2.35	1.86	6.30	90.10	10.57
BOP 22	0.25	89.24	32.74	0.07	2.63	1.82	5.90	124.65	15.11
BOP 6	0.21	91.33	31.40	0.07	3.95	1.91	5.89	68.75	22.31
BOP 11	0.20	92.82	28.07	0.08	4.37	2.42	5.69	51.77	16.07
BOP 33	0.23	90.11	32.93	0.06	3.70	2.61	6.84	103.62	9.52
BOP 26	0.25	93.22	37.00	0.04	2.52	2.09	3.96	102.12	15.55
BOP 14	0.48	92.38	30.80	0.09	3.93	2.07	6.19	74.06	8.77
BOP 13	0.49	93.97	33.47	0.08	2.37	2.05	5.35	40.89	15.08
BOP 38	0.21	92.24	32.87	0.03	1.39	2.15	4.02	100.93	16.44
BOP 47	0.29	94.49	29.87	0.05	2.07	1.49	3.00	98.66	9.17
BOP 8	0.32	93.66	30.40	0.06	2.96	1.80	4.73	105.91	8.95
BOP 18	0.26	93.57	26.8	0.04	2.30	1.91	4.44	87.83	9.54
BOP 40	0.27	92.14	37.93	0.09	3.79	2.13	6.35	116.52	19.06
BOP 16	0.26	91.56	40.13	0.11	5.61	2.63	7.33	66.81	15.25
BOP 35	0.25	89.47	25.33	0.04	2.23	2.08	4.26	60.69	12.10
BOP 41	0.37	91.49	33.53	0.05	3.83	2.38	6.29	121.15	11.21
BOP 21	0.25	93.51	29.07	0.05	3.51	1.56	3.45	73.01	11.86
Mean	**0.31**	**92.45**	**30.51**	**0.06**	**2.94**	**2.05**	**5.16**	**86.50**	**13.33**
S. Em±	**0.02**	**1.01**	**1.81**	**0.02**	**0.50**	**0.15**	**0.60**	**3.55**	**0.81**
C.V.	**8.72**	**1.89**	**10.29**	**43.26**	**29.34**	**12.91**	**19.99**	**7.10**	**10.49**
C.D. (5%)	**0.04**	**2.89**	**5.18**	**0.04**	**1.42**	**0.44**	**1.70**	**10.13**	**2.31**

Table 6: Classification of the genotypes based on the anthocyanin content in the florets

Less than 60 mg $100g^{-1}$ fresh weight	BOP 13 (40.89 mg), BOP 51 (49.27 mg), BOP 11 (51.77 mg), BOP 23 (57.21 mg)
60 to 80 mg $100g^{-1}$ fresh weight	BOP 35 (60.69 mg), BOP 16 (66.81 mg), BOP 6 (68.75 mg), BOP 21 (73.01 mg), BOP 14 (74.06 mg)
80 to 100 mg $100g^{-1}$ fresh weight	BOP 18 (87.83 mg), BOP 31 (90.10 mg), BOP 47 (98.66 mg)
More than 100 mg $100g^{-1}$ fresh weight	BOP 29 (100.28 mg), BOP 38 (100.93 mg), BOP 26 (102.12 mg), BOP 33 (103.62 mg), BOP 8 (105.91 mg), BOP 40 (116. 52 mg), BOP 41 (121.15 mg), BOP 45 (122.25 mg), BOP 22 (124.65 mg)

4.2.10 Correlation study

The study was carried out to find out the relationship between the important physiological parameters recorded in different genotypes of BOP. The wax content showed significant positive relation with the relative water content (R^2 = 0.26) (Fig. 10). It was also observed that stomatal density had highly positive and significant relation with stomatal conductance (R^2 = 0.30) (Fig. 11) and photosynthesis rate (R^2 = 0.28, p = 0.05) (Fig. 12). Further, it was also observed that the gas exchange characteristic, stomatal conductance had highly significant positive relationship with transpiration rate (R^2 = 0.54) (Fig. 13) and photosynthesis rate (R^2 = 0.56) (Fig. 14). The analysis of the relationship between total chlorophyll content and photosynthesis rate (R^2 = 0.45) was also observed to be highly significant (Fig. 15)

4.3 Vase life studies

Data with respect to initial fresh weight, dry/ final weight of spike at the end of the vase life, physiological loss in weight, water uptake, water content, number of florets opened and vase life (in days) were recorded for the 21 BOP genotypes.

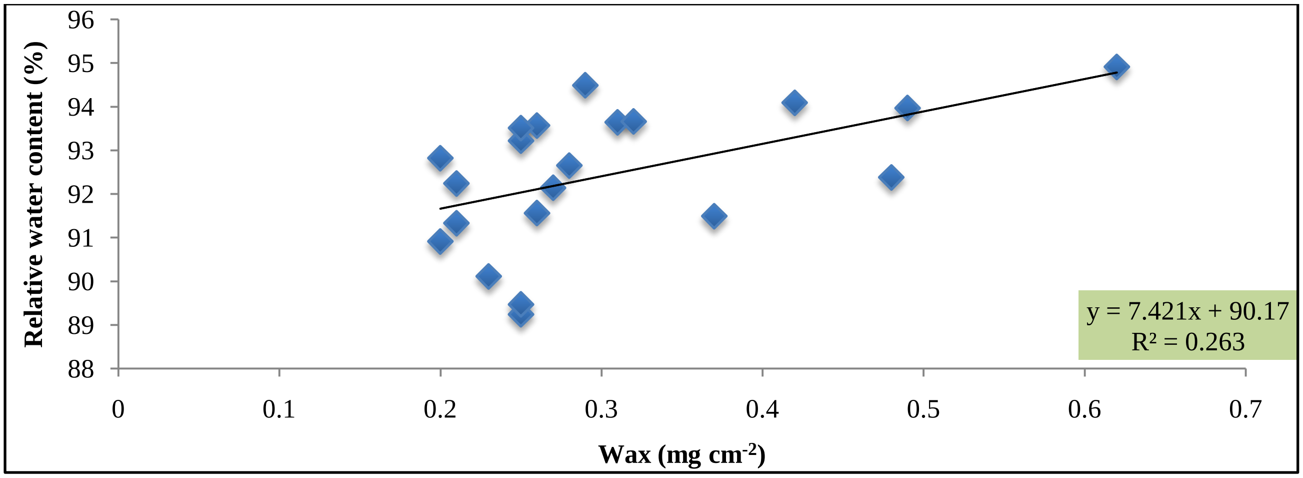


Fig. 10. The scatter diagram of relative water content and wax in 21 BOP genotypes

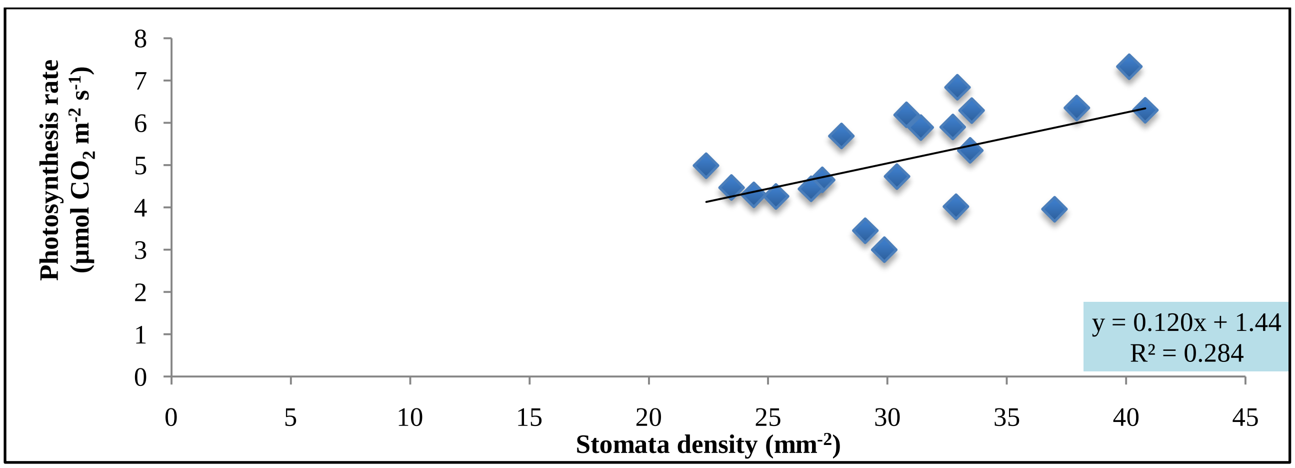


Fig. 11. The scatter diagram of stomatal conductance and stomatal density in 21 BOP genotypes

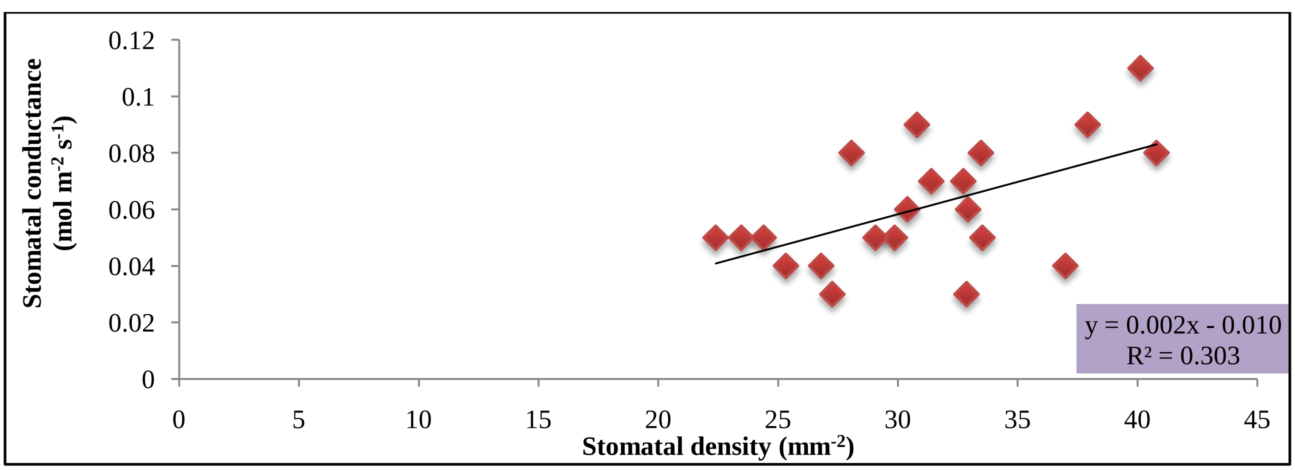


Fig. 12. The scatter diagram of photosynthesis rate and stomatal density in 21 BOP genotypes

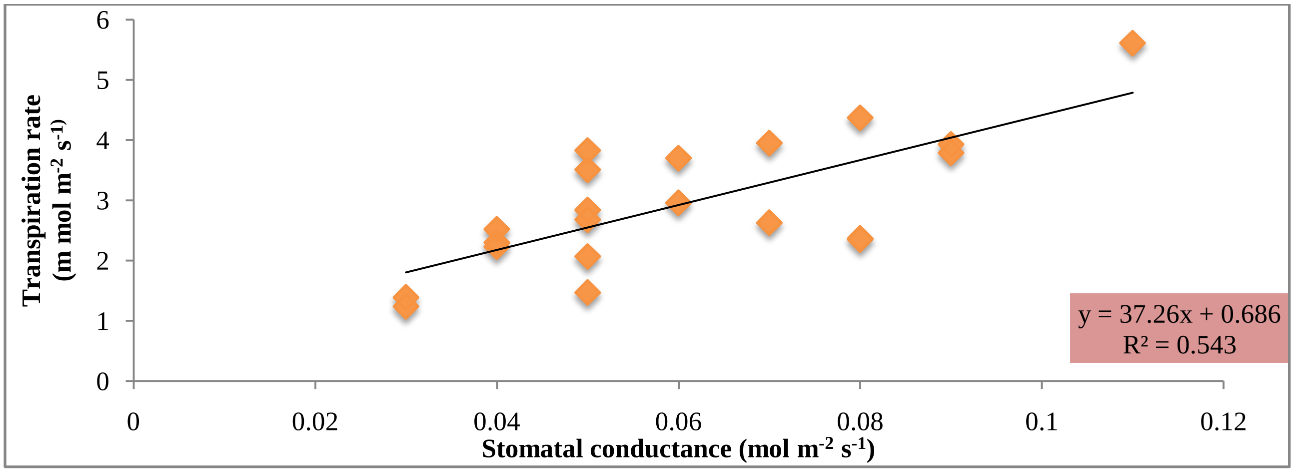


Fig. 13. **The scatter diagram of transpiration rate and stomatal conductance in 21 BOP genotypes**

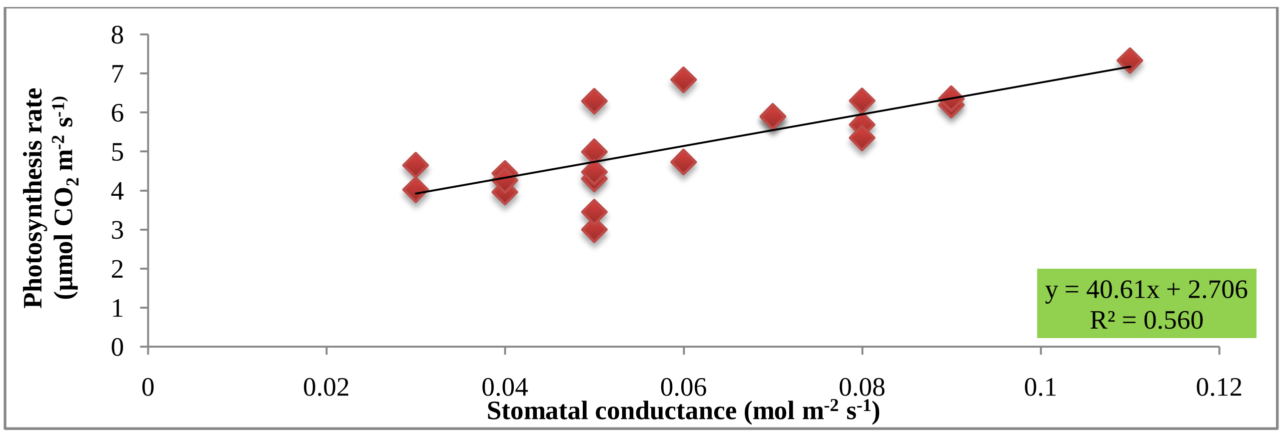


Fig. 14. **The scatter diagram of photosynthesis rate and stomatal conductance in 21 BOP genotypes**

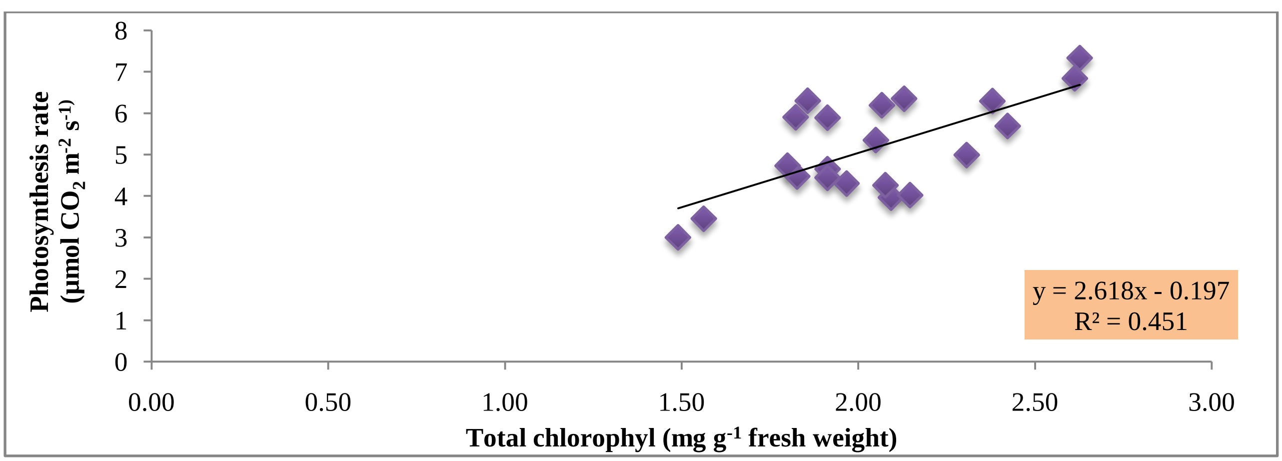


Fig. 15. **The scatter diagram of photosynthesis rate and total chlorophyll content in 21 BOP genotypes**

4.3.1 Initial fresh weight (g)

Initial fresh weight of the spikes varied among the genotypes ranging from 140.09 to 68.99 g (Table 7). Genotype BOP 33 (140.09 g) recorded maximum fresh weight whereas minimum fresh weight was recorded in BOP 11 (68.99 g).

4.3.2 Dry weight/ final weight of the spike at the end of vase life study

Spike dry weight varied significantly among the genotypes (Table 7). BOP 33 (118.830 g) recorded highest dry weight while lowest was found in BOP 11 (51.760 g).

4.3.3 Physiological loss in weight (g)

The data with respect to physiological loss in weight varied significantly among the genotypes (Table 7), recording highest for the genotype BOP 23 (0.29 g) and lowest was recorded in BOP 6 (0.04g).

4.3.4 Water uptake (ml)

The variation among the genotypes with respect to water uptake is presented in table 7. Water uptake was varied among genotypes and ranged from 18.80 to 43.25 ml. Genotype BOP 33 recorded highest water uptake (43.25 ml) whereas lowest was in 22 BOP (18.80 ml).

4.3.5 Water content (%)

The water content in the spikes found significantly high in BOP 23 (28.89 %) and minimum (3.62%) in BOP 6 (Table 7).

4.3.6 Number of floret opened

Data with respect to number of florets opened are presented in table 7. The maximum number of florets opening was observed in genotype BOP 47 (mean value of opened florets 1.5) while none of the florets opened in BOP 13, BOP 38, BOP14, BOP 45, BOP 8 and BOP 22.

4.3.7 Vase life

The variation among the genotypes for vase life is presented in table 7 with maximum vase life of 10 days for BOP 33 and with minimum (4.5 days) for BOP 8 and BOP 14.

Table 7: Vase life studies in BOP genotypes.

Accession No.	Initial fresh weight (g)	Spike final weight (g)	Physiological loss in weight (g)	Water uptake (ml)	Water content (%)	Number of florets opened	Vase life (days)
BOP 23	88.76	63.080	0.29	24.70	28.89	1 (1.23)	8.50
BOP 29	86.78	81.520	0.06	21.00	6.05	1 (1.23)	7.50
BOP 51	84.46	69.715	0.18	25.10	17.41	1(1.23)	5.00
BOP 45	102.73	92.050	0.10	32.50	10.27	0.5 (0.97)	6.50
BOP 31	84.20	71.200	0.16	30.50	15.44	1 (1.23)	6.50
BOP 22	83.89	74.115	0.12	18.80	11.64	0 (0.71)	6.50
BOP 6	82.64	79.650	0.04	22.60	3.62	1 (1.23)	5.00
BOP 11	68.99	51.760	0.25	34.25	24.96	1 (1.23)	8.50
BOP 33	140.09	118.830	0.15	43.25	15.25	1 (1.23)	10.00
BOP 26	82.60	67.830	0.18	25.30	17.95	1 (1.23)	6.50
BOP 14	99.58	88.060	0.12	22.80	11.70	0.5 (0.97)	4.50
BOP 13	81.42	67.155	0.18	23.00	17.47	0 (0.71)	5.00
BOP 38	88.81	80.205	0.10	25.85	10.01	0 (0.71)	6.00
BOP 47	82.70	64.105	0.23	20.70	22.48	1.5 (1.40)	5.50
BOP 8	87.61	64.895	0.26	25.30	25.91	0.5 (0.97)	4.50
BOP 18	116.39	110.095	0.06	21.64	5.42	1 (1.23)	5.00
BOP 40	80.77	65.155	0.20	29.40	19.59	1 (1.23)	7.50
BOP 16	86.58	80.610	0.07	36.70	6.83	1 (1.23)	6.00
BOP 35	119.05	112.665	0.06	23.83	5.40	1 (1.23)	6.00
BOP 41	97.06	78.085	0.20	29.85	19.56	1 (1.23)	5.50
BOP 21	77.43	73.435	0.05	32.10	5.23	1 (1.23)	5.50
Mean	**91.55**	**78.77**	**0.14**	**14.33**	**14.33**	**1.12**	**6.26**
S. Em±	**4.49**	**4.99**	**0.02**	**2.48**	**2.48**	**0.20**	**0.72**
C.V.	**6.93**	**8.97**	**24.24**	**16.50**	**24.46**	**12.26**	**16.2**
C.D. (5%)	**13.24**	**14.73**	**0.07**	**9.33**	**7.31**	**0.29**	**2.11**

V DISCUSSION

Characterization of genetic diversity among the genotypes is an easy and cheapest way in any crop improvement programme to identify the superior quality. As there are only few varieties available in *Strelitzia*, the present study might help the breeders in identifying the genotypes with desirable characters and their utilization in the breeding programme to develop new varieties. *Strelitzia* being an important high value commercial cut flower crop due to good demand for floral arrangement, identification of genotypes having longer vase life is very important.

Keeping this in view, the present investigation was conducted mainly to characterize the twenty-one BOP genotypes based on their morphological and physiological traits. The results obtained are discussed in this chapter under the following headings.

5.1 Morphological studies

5.1.1 Plant growth parameters

5.1.1.1 Plant height

Plant growth is usually a good index of plant vigor which may contribute towards greater productivity. It also serves as guide to determine the suitable varieties for obtaining maximum yield. The maximum plant height was recorded for genotype BOP 41 followed by BOP 33. The variation in plant height can be attributed to genetic constitution which controls the expression of genotypes in terms of variation of the characters. The role of additive gene action in Bird of Paradise was observed for plant height by Angadi and Archana (2014). Similar results were obtained by Kumari and Misra (2009) and Kumar *et al.* (2011) in snapdragon; Hossain *et al.* (2011), Sindhu *et al.* (2016), Horo *et al*. (2009) in gladiolus.

5.1.1.2 Number of fans per plant

Number of fans per plant varied among the genotypes from 5.33 to 29.67. The highest number of fans was recorded in BOP 41. Fans or suckers are the prime material for propagation in BOP. Production of more high quality shoot/suckers is reported as one of the important objectives in Heliconia breeding programmes (Costa *et al*., 2011). Production of suckers is highly cultivar dependent. Being genetically controlled factor, the sucker production varied among the cultivars. These results are in line with that of Nirmala (1996) and Smitha (1999), Jawaharlal *et al.* (2001) in Anthurium; Bhaskaran (2001), Jayanthi and Vasanthachari (2003) in chrysanthemum; Islam *et al*. (2013) in *Heliconia*.

5.1.1.3 Number of leaves per plant

The development of foliage determines the canopy architecture as well as photosynthetic activity of plant. With increasing number of leaves, photosynthesis generally increases, and plant can produce more food that influences the growth and development of the plant. In Bird of Paradise each leaf will produce a flower. So, genotypes that can produce more leaves have more plant growth leading to higher yield.

The data on number of leaves per plant recorded during investigation period indicated highest number of leaves in BOP 41. This variation might be due to genotype as well as some known and/or unknown environmental factors. Positive genetic correlation was obtained for number of leaves in Heliconia by Costa *et al*. (2007).

Variations in production of number of leaves were reported by Hossain *et al*. (2011) in gladiolus and Malakar *et al*. (2015) in heliconia.

5.1.1.4 Specific leaf area ($cm^2\ g^{-1}$)

Specific leaf area (SLA) is one of the most widely accepted leaf characteristics. Among different genotypes, specific leaf area varied from 311.92 to 87.07 $cm^2\ g^{-1}$. Among the different genotypes, the genotype BOP 33 recorded the maximum specific leaf area.

SLA found inversely proportional to leaf thickness, which plays an important role in light and nutrient use efficiency of plants (Vile *et al.,* 2005). SLA may depend up on the thickness of the leaf. This is in line with the findings of Middleton, (2001) where he reported higher SLA in thinner leaves in the intercropped plants. Leaf thickness has often been used as a tool to screen species or cultivars for productivity (White and Montes, 2005).

5.1.1.5 Plant spread in the North -South and East -West directions (cm)

Significant results were obtained for plant spread among the genotypes. Among the genotypes plant spread for North-South and East-West direction was maximum for BOP 41.

Increase in plant spread might be due to production of increased number of branches and leaves with more petiole length. The increasing plant spread due to increased number of branches was reported by Mishra (1999) and Kulkarni and Reddy, 2004 in chrysanthemum. This is in accordance with the findings of Bantu (2013) in chrysanthemum; Biswal *et al.* (2017) in gerbera.

5.1.1.6 Leaf petiole length (cm)

The length of the leaf petiole ranged from 40.55 cm to 84.09 cm. The longest petiole was recorded in genotype BOP 26. The leaf petiole length decides the form of plant. The plant with shorter leaf length will usually have erect plant form whereas plant with higher petiole length will have more plant spread. Similarly, variation in leaf petiole length was recorded in gerbera variety Power Play by Bisawal *et al*. (2017).

5.1.1.7 Leaf lamina length (cm)

Leaf lamina length significantly varied and ranged from 27.83 to 40.51 cm. The longest leaf lamina length was recorded in genotype BOP 33. Maximum leaf lamina length of 79.2 cm and 80 cm were recorded in *Heliconia caribaea* by Gilman and Meerow (1999).

5.1.1.8 Leaf lamina breadth (cm)

Leaf lamina breadth found to vary among the genotypes. BOP 33 recorded maximum leaf lamina breadth compared to all other genotypes. Variation in leaf lamina breadth was reported by Bhagur (1989) and Hossain *et al*. (2011) in gladiolus; Krishnamoorthy (2014) in tuberose; Malakar *et al*. (2015) in Heliconia. This variation in leaf breadth could be due to genetic character of the genotypes (Shankari *et al*., 2016).

5.1.1.9 Leaf length (cm)

There was variation (124.18cm to 73.50 cm) in leaf length amongst the genotypes. The genotype BOP 33 attained the maximum leaf length followed by BOP 26.

Similarly, wide variation in leaf length among some genotypes of gladiolus was observed by Singh and Dadlani (1990); Krishnamoorthy (2014) in Tuberose. Similar studies by Shankari *et al*. (2016) reported maximum leaf length for genotype Marginata Luta and minimum for Shee in heliconia. The differences among the varieties for leaf characters were attributed to the variation in their genetic makeup (Vijayalakshmi *et al.*, 2010).

5.1.2 Yield parameters

5.1.2.1 Spathe length (cm)

Spathe length varied among genotypes (16.03 to 22.77cm). The longest spathe was recorded in BOP 16. This is in accordance with the findings of Islam *et al.* (2013) in anthurium where spathe length was significantly varied among varieties with maximum spathe length for Triticaca (15.3 cm) and minimum (6.3 cm) for Ivory.

5.1.2.2 Spathe diameter (mm)

The diameter of spathe recorded highest for BOP 33 followed by BOP 45. The variations may be due to the difference in the genetic makeup of the genotypes.

5.1.2.3 Spike length (cm)

Significant differences were observed among the BOP genotypes with respect to spike length. The values for different genotypes ranged from 74.09 cm to 149.43 cm. Genotype BOP 45 recorded maximum spike length. The length of spike is very important parameter in cut flower export. The variation in spike length in different genotypes might be due to the genetic differences of the cultivars and superiority of some of the genotypes of BOP over the others in respect of spike length. These findings are in conformity with those of Arora and Khanna (1986), Lal *et al.* (1985), Arora *et al.* (2002), Patil (2003) and Rani *et al.* (2007) in gladiolus; Malakar *et al*. (2015) in *Heliconia*.

5.1.2.4 Inflorescence stalk length (cm)

Stalk length is another important character as the genotype having more stalk length is generally preferred for preparation of bouquets. The stalk length varied significantly among the genotypes. The genotype BOP 45 recorded highest stalk length. Two heliconia grouping has been done based on the inflorescence stalk length (Malakar, 2015).

5.1.2.5 Spike diameter (mm)

Spike with more thickness can bear the weight of inflorescence during full bloom. The spike diameter was found maximum for BOP 33 followed by BOP 29. Variation in spike diameter was reported by Kumari *et al*. (2010) in gerbera. Confirms the results of the present investigation.

5.1.2.6 Number of florets per spike

Number of florets per spike is an important consideration when it is to be used as cut flower and also it determines the floriferousness. The genotype BOP 13 had more number of florets followed by BOP 40.

Maximum number of florets per spike was recorded in gladiolous cultivar Swarnima (Priya, 2014). Maximum number of floret per spike was reported in genotype Prajwal in tuberose (Dimri *et al*., 2017)

The number of florets per spike indicates the quality of spike. The differences in number of florets per spike might be due to the variation in genetic makeup of different cultivars and efficient utilization of natural resources and inputs besides the size of planting material (Shaukat *et al.,* 2013).

5.1.2.7 Floret length (cm)

The floret length was recorded maximum for BOP 16. The increased floret length may be due to the higher photosynthesis activity of the plant. The increased floret length might also be attributed to the greater leaf area as well as maximum photosynthetic activity which ultimately results in production of bigger sized flowers. Similarly, variation in floret length was observed by Soocheon *et al*. (1998) in Dendrobium; Barman *et al.* (2007) in cymbidium orchids.

5.1.2.8 Number of spikes per plant

Number of spikes produced per plant ultimately determines the vigor of the genotype or variety for the flower production. The number of spikes varied among genotypes from 4.33 to 41.33. Genotype BOP 41 produced highest number of spikes.

Similar work was conducted in gladiolus (Hossain *et al*., 2011). Maximum number of spike per plant was obtained in tuberose variety Prajwal (Dimri *et al*., 2017). This variation in the production of number of spikes per plant might be due to the genetically controlled factor and also due to the hereditary traits of different cultivars under prevailing environment.

5.1.2.9 Spathe colour

Colour evaluation using RHS colour chart is a common procedure for colour description worldwide which is a qualitative analysis. In the present study the spathe colour was assessed by referring RHS colour chart and the reference number was indicated for each genotype. Spathe colour is used as one of the descriptor in characterization of *Anthurium andraeanum* Hort. by Elibox and Umaharan (2012).

5.2 Physiological studies

5.2.1 Wax and relative water content

Moisture conservation is possible if the plants synthesize and accumulate epicuticular waxes which act as barrier for water loss from the leaf surface.

The data pertaining to wax and relative water content (RWC) in different genotypes maintained in the open field condition with regular drip irrigation shows the variation among the genotypes with maximum wax and relative water content observed in genotype BOP 45.

According to Zang *et al*. (2005) the variation in epicuticular wax content among the rice germplasm lines could be due to differential expression of few relevant genes involved in epicuticular wax biosynthesis. Similarly studies on relative gene expression for wax production in contrasting rice cultivars found higher gene expression levels (ACC, CER 6, MAH 1) in low wax cultivars than high wax cultivars (Prathiba, 2012). The variation in the genotypes for relative water content may be due to the variation in the thickness of the leaf (Burques, 1987). Hence, quantity and quality of wax in the plants can be due to the genetic makeup as well as the thickness of the leaves.

In the present study, the wax content showed significant positive correlation with the relative water content. Significant positive relation between wax and relative water content was observed by Hamissou and Weibel (2004) in Sorghum and Schonherr (1976) in citrus and pear leaves.

5.2.2 Stomatal density (mm^{-2})

Stomatal function is important on the physiology, adaptation and productivity of plants. Adaptation ability of the plants is closely associated with transpiration and photosynthesis process occurring in the leaves. The number and distribution of the stomata in unit leaf area have an important role in these processes by adjusting CO_2, O_2 and moisture exchange between the leaves and the atmosphere (Brownlee, 2001).

In the present investigation stomatal density varied among the genotypes ranging from 22.4 to 40.8 mm^{-2}. Maximum stomatal density was recorded in BOP 31. The number of stomata per unit area varied among plant species, cultivars and clones as reported by Abak and Yanmaz (1985). The number of stomata per unit leaf area is special to cultivars (Marasali and Aktekin, 2003). Thus, the variation in the stomata number might be due the leaf size and genetic makeup of the genotypes.

5.2.3 Stomatal conductance (mol $m^{-2}s^{-1}$)

Stomatal conductance (gs) is an important trait responsible for the genotypic difference in gas diffusion for photosynthesis and transpiration. Present investigation revealed significantly higher stomatal conductance for BOP 16. It is observed that the stomatal density had positive and significant correlation with stomatal conductance. These findings are in conformity with the results of Xu and Zhou (2008) where positive correlation was found between stomatal density and stomatal conductance.

5.2.4 Transpiration rate (m mol $m^{-2}s^{-1}$)

Transpiration rate varied among the genotypes and is found to be affected by stomatal number, stomatal conductance, wax and relative water content. Maximum transpiration rate was found in genotype BOP 16. This may be due to the low wax accumulation and higher stomatal density which accounted for higher stomatal conductance for the genotype. This is in agreement with the findings of Xu and Zhou (2008) where positive correlation between stomatal density and stomatal conductance was observed. It was also observed that the stomatal conductance had highly positive significant correlation with transpiration rate and photosynthesis rate. These results are in accordance with Ancu *et al.* (2014) in walnut where transpiration rate and photosynthesis rate was significantly positively correlated with stomatal conductance.

5.2.5 Total chlorophyll content (mg/ fresh weight)

Chlorophyll is said to play a vital role in photosynthesis of the plants. The present investigation showed significant variation among the genotypes in total chlorophyll content. The maximum amount of total chlorophyll content was recorded in genotype BOP 16.

Amount of chlorophyll shows variations depending on many edaphic and climatic factors, such as salt stress (Yildirim *et al*., 2008) and light (Johnston and Onwueme, 1998; Dai *et al*., 2009; Khan *et al*., 2000). Thus, the variation in the amount of chlorophyll content may be due to the environmental factors.

5.2.6 Photosynthesis rate (μ mol CO_2 m^{-2} s^{-1})

Photosynthesis process is quite important as it contributes to growth and development of the plants. The variation in photosynthesis rate among the genotypes ranged from 3 to 7.33 μ mol CO_2 m^{-2} s^{-1}. The highest photosynthesis rate was observed in genotype BOP 16 which may be due to the high chlorophyll content. The relationship between total chlorophyll content and photosynthesis rate was highly significant among the genotypes tested. Similar results were obtained by Buttery and Buzzell (1977) in Soyabean where photosynthesis rate was positively correlated with total chlorophyll content.

These findings are in relation with the findings of Buttery and Buzzell (1977) where higher photosynthesis rate was observed at high chlorophyll content.

5.2.7 Carotenoids content in flowers (mg 100 g^{-1} fresh weight)

The genotypes varied for carotenoids content in flowers. The genotype BOP 6 recorded maximum carotenoids content. The variation among the genotypes for carotenoids content might be due to the genetic makeup. Pahalvani *et al*. (2004) in safflower reported duplicate dominance and duplicate recessive types of epistasis for flower color.

5.2.8 Anthocyanin content in florets (mg 100 g^{-1} fresh weight)

The statistical analysis revealed that there were highly significant differences among different genotypes for the anthocyanin content in florets. The anthocyanin content in flowers was observed to be significantly maximum in genotype BOP 22. Further nine genotypes were identified having high anthocyanin content and could be used to exploit for extraction of anthocyanin as organic color.

Similar findings are obtained by Gantait and Pal (2009) in chrysanthemum cultivars. The variation in the anthocyanin content might be due to the genetic makeup of the plant.

5.3 Vase life studies

In Bird of Paradise, senescence symptoms include floret desiccation and bract darkening and commercial flower preservatives have not been shown to consistently extend postharvest life. The cause for the loss of postharvest life is probably a rapid decline in water uptake after harvest, associated with a possible blockage of the stem vascular tissue and bract senescence (Jaroenkit and Paull, 2003).

In the present investigation, vase life of Bird of Paradise genotypes was studied keeping the flower spikes in tap water without adding floral preservatives to identify the best genotype exhibiting maximum vase life under natural condition.

The result showed maximum vase life in genotype BOP 33 which recorded highest initial fresh weight and maximum water uptake among the genotypes. This may be due to the thickness of the spike and more absorption area at the stem end. This is in conformity with the findings of Karsten *et al*. (2012) where thick stemmed spikes showed longevity of 8 days and maximum water uptake than the flower spikes of thin size due to more absorption area.

In contradictory to the above result vase life of 8.50 days was observed for the genotype BOP 11 which possessed lowest initial fresh weight among all the genotypes with comparatively good water uptake and numbers of opened florets. Since the light flower stem is a desirable characteristic for *Strelitzia* due to its transportation costs the genotype BOP 11 was found to be the most promising one due to its low weight and comparatively higher vase life.

This is in line with reports of Pizano (2005) where fresh weight of the flower stems affected the transportation costs thus acting as a limiting factor for the export of tropical flowers such as heliconia. However, although lighter stems reduce transport costs, Nowak and Rudnicki (1990) pointed out that flower stems with greater weight contain a higher amount of carbohydrates and are, consequently, more durable.

VI SUMMARY

A study was conducted to characterize the available twenty-one genotypes of Bird of Paradise maintained at Indian Institute of Horticultural Research, Hessaraghatta (ICAR-IIHR) Bengaluru, Karnataka during 2016-2017. The genotypes were characterized based on the physiological and morphological traits. The study also concentrated in identifying the genotypes with better post-harvest life. Data were subjected to standard statistical analysis and the results obtained are summarized in the present chapter.

6.1 To study the morphological and physiological traits among different genotypes of Bird of Paradise

The major objective of characterization is to establish the distinctiveness among the genotypes. Keeping this in view, twenty-one BOP genotypes were characterized based on physiological traits and morphological traits.

The characterization of BOP genotypes based on physiological traits like leaf wax content, relative water content, stomatal density or number, stomata conductance, transpiration rate, chlorophyll content, photosynthesis rate, flower anthocyanin and carotenoid content and morphological traits like plant height, number of fans per plant, number of leaves per plant, leaf length, leaf lamina width, specific leaf area, petiole length, number of spikes per plant, number of florets per spike, spike length, spike diameter, spathe length, spathe diameter, spathe color, floret length and flower stalk length showed significant variation among the genotypes for each parameter studied.

The study on plant growth parameters among the genotypes revealed maximum plant height (166.33 cm), maximum number of fans per plant (29.67) and number leaves per plant (389) in BOP 41 among all the genotypes. The genotype BOP 33 recorded significantly higher leaf lamina length (40.51 cm), leaf lamina width (13.67 cm), leaf length (124.18 cm) and specific leaf area (311.92 cm^2 g^{-1}). Genotype BOP 26 recorded maximum leaf petiole length (84.09 cm) whereas plant spread was maximum in BOP 41 for both N-S (279.67 cm) and E-W direction (275.33 cm).

Significant variations were observed in floral characters. Among the twenty-one genotypes, the BOP 16 recorded maximum spathe length (22.77 cm). Maximum spike length (149.43 cm) and flower stalk length (128.66 cm) were recorded in BOP 45. The highest spike diameter (16.33 mm) and spathe diameter (23.09 mm) was found in BOP 33. Maximum of 41.33 inflorescences were recorded in BOP 41 whereas, number of florets per spike was highest (8.48) in BOP 13. The floret length varied significantly among the genotypes and was maximum (16.23 cm) in BOP 16.

Similarly, all the genotypes varied significantly with respect to the physiological traits. The genotype BOP 45 recorded highest wax (0.62 mg cm^{-2}) and relative water content (94.92%) whereas, BOP 31 recorded higher stomatal number (40.8 mm^{-2}). The genotype BOP 16 recorded maximum transpiration rate (5.61 m mol m^{-2} s^{-1}), total chlorophyll content (2.63 mg g^{-1} fresh weight), stomatal conductance (0.11 mol m^{-2} s^{-1}) and photosynthesis rate (7.33 µ mol CO_2 m^{-2} s^{-1}). The maximum anthocyanin content was recorded in BOP 22 (124.65 mg 100 g^{-1}). Carotenoid content varied significantly among the genotypes studied with maximum carotenoid content in BOP 6 (22.31 mg 100 g^{-1}).

The correlation study between the important physiological traits showed significant positive correlation between leaf wax content and relative water content. Stomatal density had positive and significant correlation with stomatal conductance and photosynthesis rate. Stomatal conductance was highly positively significantly correlated with transpiration rate and photosynthesis rate. Total chlorophyll content had highly significant positive relationship with photosynthesis rate.

6.2 Vase life studies

The genotypes varied significantly for all the parameters studied. The genotype BOP 33 with maximum fresh weight (140.09 g) retained its freshness up to ten days accounting for maximum vase life among the genotypes with one opened florets and maximum water uptake of 43.25 ml, whereas, BOP 47 recorded maximum number of opened florets (1.50). None of the florets were opened in case of genotypes BOP 45, BOP 22, BOP 14, BOP 13, BOP 38 and BOP 8.

In the present study, 21 genotypes of Bird of Paradise have been characterized based on physiological and morphological traits. The results of morphological studies will be helpful in identifying the better genotypes in terms of economical value and physiological characterization will be useful for breeders/ researchers/ farmers to identify superior BOP genotypes with better abiotic and biotic stress tolerance.

6.3 Future line of work

- To develop new varieties using the genotypes expressing better morphology in terms of growth and number of inflorescence per plant as a better parent in future breeding work.
- To develop varieties having tolerance to limited water conditions by selecting the genotypes expressing better physiological traits.
- The genotypes with higher color pigment with respect to anthocyanins and carotenoid content can be used in breeding for bright colored varieties.
- Since the vase life is affected due to irregular floret opening and inability of the floret to come out of the hard spathe, more post-harvest studies have to be carried out since it is a specialty cut flower with more market demand and lesser supply.

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APPENDIX I

Meteorological data recorded during the experimental period

Month	Temperature max. (ºC)	Temperature min. (ºC)	RH (%)	Rainfall (mm)
Jul-16	29.2	20.6	79	174.2
Aug-16	27	20.6	80.6	16.5
Sep-16	25.2	21.7	80.5	58
Oct-16	26	19	58	15
Nov-16	27	18	64	9
Dec-16	28	17	73	62
Jan-17	28.6	16.3	72.6	0
Feb-17	28.7	15.1	54.62	0
Mar-17	31.7	17.53	53.1	1.76
Apr-17	30.9	19.2	50.183	1.125
May-17	27.61	20.52	62.13	9.492
June -17	26.8	20.6	70.75	1.967

APPENDIX - II

List of abbreviations used

BOP	-	Bird of Paradise
%	-	Per cent
TDZ	-	Thiadiazuron
RH	-	Relative humidity
VL	-	Vase life
Mm	-	Mili molar
CD	-	Critical difference
Cm	-	Centimetre
cm^2	-	Square centimeter
cv.	-	Cultivar
et al.	-	Et allii (and others)
etc.	-	And so forth
G	-	Gram
µ	-	Micro
GCV	-	Genotypic coefficient of variation
PCV	-	Phenotypic coefficient of variation
L.	-	Linnaeus
ACC.	-	Accession
RHS	-	Royal horticulture society
l	-	Litre
mm	-	Millimeter
m^2	-	Meter square
CO_2	-	Carbondi-oxide
mg	-	Milli Gram
ml	-	Milli Litre
HQC	-	Hydroxyquinoline citrate
RWC	-	Relative water content
ppm	-	parts per million
PLW	-	Physiological loss in weight
NaCl	-	Sodium chloride
S. Em±	-	Standard Error of Mean
sq. m	-	Square meter
^oC	-	Degree Celsius
gs	-	Stomatal conductance
DMSO	-	Dimethyl sulfoxide
$CaCO_3$	-	Calcium carbonate