Quick Method to Quantify the Potassium and Sodium Content Variation in Leaves of Banana Varieties

Vadivel ARUNACHALAM, Cristabel M FERNANDES, and Diksha C SALGAONKAR

Horticulture Section, ICAR-CCARI (Indian Council of Agricultural Research-Central Coastal Agricultural Research Institute) Ela, Old Goa, Goa 403402, India

The current study describes novel and quick methods for the quantification of K+ and Na+ in banana leaves using Horiba Laga twin ion meters. Foliar K+ and Na+ content measured by ion meter significantly correlated with standard test values by coefficients of 0.83 and 0.46, respectively. About 48 absorbance values associated with potassium concentrations at wave numbers (1581 to 1583 and 3194 to 3410 cm⁻¹) and 15 sodium associated wave numbers (3773 to 3996 cm⁻¹) predicted potassium and sodium content with regression coefficients of 0.999 and 0.588, respectively. K+ and Na+ cations of fresh leaves in seven banana varieties were quantified using ion meters and new information of differences in the foliar potassium and sodium contents was found between banana varieties within the AAB group. The Rasbali (Silk subgroup) variety possessed greater potassium (5413 mg/L) and sodium (188 mg/L) ions than Amti (Mysore subgroup).

Keywords Foliar, Fourier transformed infrared spectroscopy, ion meter, Musa, potassium, sodium, K+/Na+ ratio

(introduced March 19, 2020; Accepted May 22, 2020; Advance Publication Released Online by J-STAGE May 29, 2020)

Introduction

Banana is an important fruit crop cultivated in the tropics and subtropics and is consumed around the globe. Potassium (K+) and sodium (Na+) are two important monovalent cations in banana plant nutrition1 and salinity stress management.2 The leaf and fruit of the banana plant are rich in potassium, hence K+ is required in large quantities for optimal growth and yield of bananas.3,4 K+ forms 3–4% of the cations in the dry weight of a banana plant.1 Banana plants grown in salt affected soils or irrigated by saline water can accumulate excess Na+ ions in the roots and leaves, which are partially secluded from the marginal veins,5,11 to reduce toxic effects. The ionic ratio of K+/Na+ determines the salt tolerance in the wild tomato.12 Banana plants of salt-sensitive variety irrigated by saline water suffer from a reduction in leaf area and increase in foliar Na+ content and reduced K+/Na+ ratio.2,13 Leaf K+/Na+ ratio is also crucial in determining the performance of banana plants in saline-sodic soils.1 Ash constitutes one-fifth of the leaf blade of the banana plant and nearly 42% of it is water soluble extractive. Banana leaf ash is mostly made of potassium, calcium and silicium salts.14 Banana leaf ash is used in food as a substitute for table salt and for treating acidity related digestion problems.15 Cultivated banana varieties are domesticated forms resulting from selection or hybridization and/or a polyploidy of two ancestral species of Musa, viz., M acuminata Colla and M balbisiana Colla. Banana varieties occur as diploid/triploid/tetraploid and are represented by the starting letter of the ancestral species, viz., AA (diploid acuminata), BB (diploid balbisiana), AAA (triploid acuminata), AAB (triploid hybrid of acuminata and balbisiana), etc. Varietal differences are observed for leaf traits16 and nutrient uptake especially for potassium.1,17 Cultivars with a high proportion of balbisiana genomes, such as ABB or BB groups, are known to possess greater ability for potassium uptake1 and tolerance to salinity (sodium chloride) stress.18 Rapid estimation of tissue nutrients using ion specific electrodes (ion meters) allow for the handling of a large number of samples in a short time and hence are of great help in the decision making of nutrient management strategies, food product analyses and in phenomics investigations. Portable ion meters are revolutionising the quick estimation of tissue K+ ion levels in the leaf of several vegetables,19,20 the zombie pea plant,21 and cotton.22 An ion meter can be used to rapidly measure sodium content in food products, especially fermented food.23 Determination of the suitability of ion meters for measuring potassium or sodium content in banana leaf tissue has not been attempted so far, despite the importance of the crop and the role of the two cations in plant nutrition and salinity management. Fourier transform infrared spectroscopy (FTIR) is used to characterize the spectral properties of substances and to identify organic compound specific peak(s) at specific wave number(s). Spectra in the mid-infrared region were found to be correlated with the potassium and sodium content of nutrient solutions of vegetable crops grown in hydroponics.24 Although banana tissues are characterized using FTIR spectroscopy,14 the potassium or sodium ion associated wave number(s) in banana tissues has not been studied so far. Near infrared spectroscopy was unable to predict potassium content in fresh/wet leaf samples25 of grasses. However infrared spectra peaks specific to analytical grade inorganic substances were identified in dry chemicals.26 Hence the current study employed dry powdered

1 To whom correspondence should be addressed.
E-mail: arun.ceo.innovations@gmail.com; v.arunachalam@icar.gov.in
leaf samples for FTIR spectroscopy analysis.

Objectives of the study were to rapidly measure potassium and sodium ion content in dry banana plant leaves by ion meters and FTIR spectroscopy and to evaluate varietal differences for the two ions in fresh banana leaves by using ion meters.

Experimental

Field experiment details

The field experiment of banana varieties was conducted as intercrop in an areca garden during the years 2015 – 2018. Soil of the plot was laterite with slightly acidic pH. The experimental location received annual rainfall of 3000 to 3500 mm from June to September. Plants were grown at a spacing of 2 × 2 m. A total of seven banana varieties (Velchi (AB), Rupa (BB), Amti (AAB), Rasbali (AAB), Robusta (AAA), Red banana (AAA), Grand Nain (AAA)) were grown in the randomized block design (RBD) with four replications. Velchi, Rasbali, and Amti belong to Neypoovan, Rasbali, and Mysore subgroups, respectively. Robusta and Grand Nain belong to the Cavendish group. Rupa is a local germplasm of Musa balbisiana Colla and was grown from sexual seeds. All other varieties were grown from suckers.

Reagents and chemicals

For preparing standard solutions, potassium chloride was purchased from Himedia and sodium chloride from Molychem. The standard solution was prepared using deionized water with concentrations ranging from 15 to 5000 mg/L for potassium and 5 to 5000 mg/L for sodium.

Apparatus

The ion specific Laqua twin flat sensor portable ion meters (Horiba, Kyoto, Japan) were used to measure the two ions (K⁺ and Na⁺) at mg/L levels. The accuracy of the ion meters was determined by calculation of relative standard error (%) using a range of standard solutions from 15 to 5000 mg/L concentrations of potassium chloride (Table S1, Supporting Information) and at concentrations from 5 to 5000 mg/L of sodium chloride (Table S2) for potassium and sodium, respectively. The ion meters were calibrated at two points using two standard solutions of 150 and 2000 mg/L of each ion before performing the analysis of samples. An atomic absorption spectrophotometer (AAS) (Analytik Jena, Germany) was used to estimate potassium content and a flame photometer for sodium content. The absorption spectra for each of the 49 dry leaf samples in the wave number range (650 – 4000 cm⁻¹) were recorded by FTIR.

Data analysis

Pearson correlation coefficient was worked out between the standard test and ion meter values. The F test is used to compare the least significant difference among the ion content/ratio of leaves in banana varieties. Correlation between absorbance at each wave number and of potassium and sodium content was also worked out. The wave numbers with high correlation coefficients were further used in regression analysis. The statistical analysis was performed using SAS (Statistical Analysis Software Ver. 13.0) software.28 The linearity, precision, signal to noise ratio, relative error, relative standard deviation, sensitivity and limit of detection (LOD) [3.3 × standard deviation/slope of regression line] were calculated for both the ion meters.

Results and Discussion

Measuring of potassium ions by ion meter vis-à-vis AAS, infrared spectroscopy

Potassium content measured by AAS in the 45 dry banana leaf samples varied from 13260 to 30720 mg/L (Table S6, Supporting Information). Correlation of measurement of K⁺ cations carried out by ion meter with the standard tests showed significant correlations at 0.01% level of confidence. The potassium content of dry banana leaf measured by ion meter was highly correlated (0.829) with the value measured by AAS for 45 samples. The scatter diagram of the potassium values of ion meter and AAS for 45 dry banana leaf samples.
Potassium content (mg/L) measured by AAS and mean absorbance spectra at selected FTIR wave numbers for 49 dry banana leaf samples.

Fig. 2 Potassium content (mg/L) measured by AAS and mean absorbance spectra at selected FTIR wave numbers for 49 dry banana leaf samples.

Potassium content in petiole sap of cotton measured by ion meter was 1.592 mg/L; linearity, precision, signal to noise ratio, relative standard deviation and sensitivity data for the ion meter is shown in Supporting Information (Table S8).

Absorbance values of FTIR spectra at 48 wave numbers ranging from 1581 to 1583, 3194 to 3410 cm–1 recorded high correlation with potassium content for 49 samples. Of these, all the 48 potassium associated wave numbers predicted potassium content with regression coefficients of 1.00. The 48 wave numbers (cm–1) predicting potassium content are listed here with W prefix viz., W1581, W1583, W3194, W3196, W3207, W3209, W3211, W3213, W3215, W3236, W3238, W3240, W3242, W3244, W3246, W3248, W3250, W3252, W3258, W3262, W3264, W3265, W3267, W3269, W3277, W3281, W3283, W3285, W3287, W3289, W3291, W3292, W3294, W3296, W3298, W3300, W3306, W3308, W3337, W3346, W3348, W3352, W3377, W3379, W3381, W3383, W3385, and W3410. Potassium content values (mg/L) measured by AAS are plotted with mean absorbance at selected wave numbers (3207, 3209, 3211, 3240, 3291, 3292, 3294 cm–1) of FTIR spectra (Fig. 2).

Potassium content in petiole sap of cotton measured by ion meter was highly correlated (0.588) with the same measured by flame photometer. The scatter diagram of the sodium values of ion meter readings on the X axis and flame photometer readings on the Y axis is plotted as Fig. 3. The raw data of sodium measurements by both methods described above are available as Table S7 (SI). The relative error for sodium measured by ion meter ranged from ~35.00 to 0.00% for the standard solution given in Table S2 (SI). The LOD for the ion meter was 2.181 mg/L; linearity, precision, signal to noise ratio, relative standard deviation and sensitivity data for the ion meter is available in Table S9 (SI).

Absorbance values of FTIR spectra at 60 wave numbers ranging between 3773 and 3996 cm–1 recorded high correlation with sodium content. Of these, 15 sodium-associated wave numbers predicted sodium content with regression coefficients of 0.588. These wave numbers (cm–1) predicting sodium content are given with W prefix as W3398, W3881, W3910, W3773, W3811, W3979, W3946, W3956, W3985, W3971, W3950, W3981, W3966, and W3968. Sodium content values (mg/L) measured by flame photometer are plotted with mean absorbance for the selected wave numbers (Fig. 4).

An ion meter is used to rapidly measure sodium content in food products such as turnip leaf pickles and fermented dry algal products. Sodium salts displayed a trend of strong bands at wave numbers above 3200 cm–1. Spectra at 3470, 3280, 3330 cm–1 wave numbers display strong band for each of the sodium values measured by flame photometer are plotted with mean absorbance for the selected wave numbers (Fig. 4).

Measuring of sodium ions by ion meter vis-à-vis flame photometry, infrared spectroscopy

Sodium content in the 42 dry banana leaf samples varied from 500 to 1600 mg/L by flame photometry (Table S7, SI). Correlation of measurement of Na⁺ cations carried out by ion meter with the standard tests showed significant correlations at 0.01% level of confidence. The sodium content of dry banana leaf measured by ion meter was highly correlated (0.455) with the same measured by flame photometer. The scatter diagram of the sodium values of ion meter readings on the X axis and flame photometer readings on the Y axis is plotted as Fig. 3.
Variation in potassium content

The Rasbali (AAB, Rasthali group) variety recorded significantly greater potassium (5413 ± 969.08 mg/L) on fresh weight basis than the Amti (AAB, Silk group) (2948 ± 671.07 mg/L) variety by ion meter (Table 1).Potassium is important for banana crops as it is accumulated in large amounts in fruit and other parts of the plant.9 Potassium is a crucial element in banana for dry matter production.5,8 Hence, the banana plant requires high levels of potassium. Our study highlights the differences within the AAB group of banana varieties, with the Silk subgroup recording higher foliar potassium content than the Mysore subgroup. Among the triploids, uptake of potassium was high in Monthan with ABB genome than Robusta with AAA genome.1 Inter-specific diploid or triploid banana varieties do not possess 100 percent AAB genome.34 The Silk subgroup variety of banana possesses a segment of ABB genome at chromosome 9 and four segments of AAA genome on the distal side of 2, 3, 4, 9 chromosomes. The Mysore subgroup banana variety possesses five segments of ABB genome at 4, 7, 8, 11 chromosomes, and four segments of AAA genome at 2, 4, 8, 11 chromosomes.34 Potassium content of the leaf of the Rupa variety (4387 ± 748.45 mg/L) with BB genome was on par with the Velchi variety (4583 ± 1236.55 mg/L) with AB genome in the current study. Ploidy level within acuminate banana varieties also influences the potassium uptake. Total potassium content was only half in soils grown with Kadali variety with AA genome compared to the soils grown with triploid AAA varieties of Robusta, Dwarf Cavendish.37

Among the diploid banana varieties, potassium uptake was greater in Kunnan with AB genome than Anaikomban with AA genome.1 Safet Velchi variety under AB group is supposed to possess 50% each of acuminate and balbisiana genomes but actually possessed a large segment (7 Mb) of pure AA at distal region of chromosome 6.34 Recent studies on potassium stressed transcriptome sequences15 indicate the role of ion transporter genes in potassium uptake. Ion transporter genes identified by Xu et al.36 and their promoters can be explored for genomic locations and differences of sequences of genomic mosaic regions/genomes of Mysore and Silk group varieties generated by Baurens et al.34 Such in silico studies followed by functional genomics could throw light on potassium uptake differences among banana varieties.

Variation in sodium content

The Rasbali (AAB, Rasthali group) variety recorded significantly greater sodium ions (188 ± 38.57 mg/L) on fresh weight basis than the Amti (AAB, Silk group) (118 ± 30.48 mg/L) variety in measurements by ion meter (Table 1). The sodium content for Rupa variety with (BB) genome (163 ± 35.80 mg/L) was on par with Grand Nain (AAA) variety (163 ± 30.40 mg/L) in the current study. Our study highlights the differences within the AAB group of banana varieties where the Silk subgroup (Rasbali) recorded higher foliar sodium content than the Mysore subgroup (Amti). Inter-specific triploid hybrids of banana (AAB) do not possess exact one-third B genome from balbisiana and two-third A genome from acuminate. Silk and Mysore subgroups vary with segments of mosaics of AAA and ABB genomes in specific chromosomes.34 The genomic locations and differences of sequences of salt-responsive genes were identified by Willadino et al.2 Genomic mosaic regions/genomes of AB and Silk and Mysore subgroups of AAB banana varieties were made available by Baurens et al.34 Salt tolerance genes2 and their promoters can be explored in the future using the genomic resources of Baurens et al.34 to understand the mechanisms and differences in genes of sodium uptake and salt tolerance among banana varieties.

Size and area of the banana leaf also decreases in salt-sensitive cultivars due to higher accumulation of sodium and chloride ions in lamina.2,11 Banana plants grown in saline or sodic saline soils or irrigated by salt water are likely to accumulate excess sodium ions in roots or leaf.9,10 Sodium content of banana shoots in tissue culture gradually increases from 2520 to 6580 mg/L when the culture medium is supplemented with increasing levels (0 to 150 mM) of sodium chloride.26 Cultivars with higher proportion of balbisiana genome, such as Saba (ABB), are able to tolerate excess sodium ions due to their ability to seclude sodium ions through marginal veins.

Potassium sodium ratio by ion meter

The K+/Na+ ratios of actual ionic content of banana varieties differed significantly. Amti (AAB) and Velchi (AB) varieties showed significantly lower (25 to 26) K+/Na+ ratio than Robusta (33.73 ± 3.63) (Table 1) when measured by ion meters. In the present study, Amti and Velchi varieties possessing balbisiana genome of 33 and 50%, respectively, showed lower K+/Na+ ionic ratios than Robusta with 100% acuminate genome. The K+/Na+ ionic ratio is also influenced by the pH and electric conductivity (EC) of the soil and irrigation water and the cultivar influence on differential uptake and seclusion abilities of genotype for K+ and Na+ ions. The K+/Na+ ratio is found to be

---

**Table 1** Cationic (K+ and Na+) concentrations and their ratios in fresh leaves of banana varieties determined by ion meters (values determined as mean ± standard deviation)

| Variety     | K+ mg L⁻¹ | Na+ mg L⁻¹ | K+/Na+ Ionic ratio |
|-------------|-----------|------------|--------------------|
| Velchi      | 4583 ± 1236.55 | 178 ± 49.98 | 25.80 ± 6.96 |
| Amti        | 2948 ± 671.07 | 118 ± 30.48 | 25.03 ± 6.06 |
| Rasbali     | 5413 ± 969.08 | 188 ± 38.57 | 28.90 ± 5.88 |
| Robusta     | 4762 ± 814.87 | 141 ± 24.76 | 33.73 ± 3.63 |
| Grand Nain  | 4795 ± 859.02 | 163 ± 30.40 | 29.61 ± 6.68 |
| Red Banana  | 5021 ± 750.11 | 151 ± 19.07 | 33.32 ± 4.57 |
| Rupa        | 4387 ± 748.45 | 163 ± 35.80 | 27.77 ± 6.35 |
| CV, %       | 9.94       | 12.25      | 13.25 |
| LSD at 5%   | 673.14     | 28.661     | 5.74 |

The significant differences at p ≤ 0.05 level is represented by values with different letters within the column.

---

**Fig. 4** Sodium content (mg/L) measured by flame photometer and mean absorbance spectra at selected FTIR wave numbers for 42 dry banana leaf samples.
less than 1 in saline-sodic soils. Banana plants irrigated with increasing concentrations of seawater (5, 10 and 20%) showed significant reduction of ionic ratio of K+/Na+ affecting the transport of K+ from roots to leaves due to salt stress. The critical value for foliar K+/Na+ ionic ratio varied among the varieties and according to their level of sodium accumulation in wood and displayed changes in the transport of K+ from roots to leaves due to salt stress. The current study found Robusta of AAA group with values in banana leaves were found to be optimum (>15) in all samples. The current study found Robusta of AAA group with significantly high foliar K+/Na+ ionic ratio than Velchi (AB) and Amti (AAB). The percent decrease in foliar K+/Na+ ionic ratio is lower in salt-tolerant than salt-sensitive banana varieties.

In this study, the ion meters were more portable compared to standard tests and FTIR instruments and can be easily handled, and were also found to be suitable for leaf potassium and sodium content measurements. After further validation, the ion meters could be recommended for large-scale use.

Conclusions

The values of potassium and sodium content of banana leaves from ion meter and standard tests showed significant positive correlation. Absorbance at FTIR spectroscopy at the range of wave numbers 1581 - 1583, 3194 – 3410, and 3773 – 3996 cm–1 predicted potassium and sodium content of banana leaves, respectively. Hence, portable ion meters are useful as a quick, novel and portable method for rapid quantification of potassium and sodium ions in dry banana leaves. The study also found varietal differences in fresh banana leaves for the potassium and sodium contents and their ionic ratio. Varieties with higher proportion of balbisiana genome and their higher salt tolerance and lower potassium requirements are inferred from their foliar potassium and sodium contents. Varieties within AAB group showed vast differences in potassium and sodium contents. Silk subgroup bananas record higher potassium and sodium contents than the Mysore subgroup variety due to mosaic of varying A and B chromosome segments possibly with regions of K+ or Na+ transporter genes.

Conflict of Interest

Authors declare no conflict of interest

Acknowledgements

Authors are grateful to Indian Council of Agricultural Research (ICAR) for the support.

Supporting Information

The sample details used for estimation are given as Supporting Information. This material is available free of charge on the Web at http://www.jsac.or.jp/analsci/.

References

1. S. Sathiamoorthy and K. J. Jeyabaskaran, Proceedings of the Regional Workshop of the International Potash Institute ed. A. E. Johnston, 2001, Amman, Jordan, http://www. keyplex.com/researchtopics/Banana/Potassium-Management-of-Banana.pdf, 499.
2. L. Willadino, T. R. Camara, M. B. Ribeiro, D. O. J. Amaral, F. Suassuna, and M. V. D. Silva, Rev. Bras. Frutic., 2017, 39, 723.
3. R. M. Warner and R. L. Fox, J. Am. Soc. Hort. Sci., 1977, 102, 739.
4. D. W. Turner and B. Barkus, Sci. Hort., 1980, 12, 27.
5. D. W. Turner and B. Barkus, Fert. Res., 1983, 4, 89.
6. A. López and J. Espinosa, Better Crops International, 1998, 12, 1.
7. A. R. Kumar, N. Kumar, and M. Kavinov, Agric. Rev., 2006, 27, 284.
8. G. Tauluy, Field Crops Res., 2013, 151, 45.
9. Y. Israeli, E. Lahav, and N. Nameri, Fruits., 1986, 41, 297.
10. O. Shapira, S. Khandai, Y. Israeli, Y. Shani, and A. Schwartz, Plant Cell Environ., 2009, 32, 476.
11. S. Junior, M. B. D. Moraes, T. R. Camara, and L. Willadino, Rev. Bras. Eng. Agríc. Ambient, 2012, 16, 1145.
12. R. Tahal, D. Mills, Y. Heimer, and M. Tal, J. Plant Physiol., 2000, 157, 59.
13. E. W. F. Gomes, L. Willadino, L. S. S. Martins, and T. R. Camara, “Plant Nutrition”, ed. W. J. Horst et al., 2001, Springer, Dordrecht, 410.
14. L. Oliveira, N. Cordeiro, D. V. Evtuguin, I. C. Torres, and A. J. D. Silvestre, Ind. Crops Prod., 2007, 26, 163.
15. P. Pushpangadan, J. Kaur, and J. Sharma, Anc. Sci. Life, 1989, 9, 20.
16. S. Uma, R. Selvarajan, S. Sathiamoorthy, A. Ramesh Kumar, and P. Durai, Plant Genetic Resources Newsletter, 2003, 134, 26.
17. J. G. Ray and K. S. Nidheesh, Commun. Soil Sci. Plant Anal., 2018, 50, 275.
18. I. Ravi, M. MayilVaganan, and M. M. Mustaffa, Andhra Agric. J., 2014, 61, 638.
19. G. J. Hochmuth, HortTech., 1994, 4, 218.
20. G. Niu, Y. Sun, and J. G. Masabni, Horticulturae, 2018, 4, 6.
21. K. Iseki, R. Marubodee, H. Ehara, and N. A. Tomooka, Plant Prod. Sci., 2017, 20, 144.
22. G. Stevens, M. Rhine, Z. Straatmann, and D. Dunn, Commun. Soil Sci. Plant Anal., 2016, 47, 2148.
23. M. Takei, T. Kuda, M. Eda, A. Shikano, H. Takahashi, and B. Kimura, Food Biosci., 2017, 19, 85.
24. R. Fan, X. Yang, H. Xie, and M. A. Reeb, Sci. Hort., 2012, 144, 48.
25. G. L. Miller and A. Thomas, HortScience., 2003, 38, 1247.
26. F. A. Miller and C. H. Wilkins, Anal. Chem., 1952, 24, 1253.
27. S. Yoshida, D. A. Forno, J. H. Cock, and K. A. Gomez, “Laboratory Manual for Physiological Studies of Rice”, 1976, International Rice Research Institute (IRRI), Manila, Philippines.
28. SAS Institute, SAS 9.3 Ver., 2002 - 2010, 2010, SAS Institute Inc., Cary, NC, USA.
29. L. A. Zemnukhova, E. A. Skiba, V. V. Budaeva, A. E. Pashenko, and N. V. Polyakova, Russ. J. Appl. Chem., 2018, 91, 230.
30. Z. A. Ostatek-Boczenski, D. E. Purcell, E. C. Keeffe, W. N. Martens, and M. G. O’Shea, Commun. Soil Sci. Plant Anal.,...
31. Y. Lu, C. Du, C. Yu, and J. Zhou, *Anal. Methods*, **2014**, 6, 2586.
32. S. Tomita, T. Nakamura, and S. Okada, *Food Chem.*, **2018**, 258, 25.
33. S. Y. Venyaminov and F. G. Prendergast, *Anal. Biochem.*, **1997**, 248, 234.
34. F. C. Baurens, G. Martin, C. Hervouet, F. Salmon, D. Yohomé, S. Ricci, M. Rouard, R. Habas, A. Lemainque, N. Yahiaoui, and A. D’hont, *Mol. Biol. Evol.*, **2019**, 36, 97.
35. M. Xu, C. B. Zeng, R. He, Z. Yan, Z. Qi, R. Xiong, and H. Tang, *Agronomy*, **2019**, 9, 169.
36. I. U. Haq, F. A. H. E. D. A. Soomro, N. Parveen, M. U. Dahot, and A. A. Mirbahar, *Pak. J. Bot.*, **2011**, 43, 1655.
37. Y. Lei, L. P. Zeng, S. Y. Zhou, D. Zhang, W. C. Wang, and X. G. Li, *Chinese Horticulture Abstracts*, **2015**, 5, 003.
38. W. Chirachint and D. W. Turner, *Sci. Hort.*, **1988**, 36, 1.
39. K. J. Jeyabaskaran and P. Sundararaju, *Indian J. Plant Physiol.*, **2000**, 5, 290.