reduce by 65% and 70% for rose and marigold flowers respectively, than those dried in open sun. The effect of dust and loss of silica gel due to wind is also reduced by using the solar dryer. The flowers are subjected to constant temperature and higher drying rate throughout the drying process in the dryer, which minimize the effect of size reduction. The unutilized fresh flowers from domestic trade can be converted into value-added products after drying in the solar dryer for better returns. Besides flowers, this hybrid dryer can also be successfully used for the drying of other high-value crops/vegetables/spices/herbs.

1. Sahay, J., *Elements of Agricultural Engineering*, Standard Publishers Distributors, Delhi, 2005, 4th edn.
2. Garba, B., Sambo, A. S. and Mosugu, M. M., *Renew. Energ.*, 1991, **1**(5–6), 661–665.
3. Singh, A. and Dhaduk, B. K., *J. Ornament. Hortic.*, 2005, **8**(2), 155–156.
4. Singh, J., Kumar, D., Ramakrishnan, N., Singhal, V., Jervis, J., Garst, J. F. and Helm, R. F., *Appl. Environ. Microbiol.*, 2005, **71**(12), 8752–8763.
5. Singh, H. P., *Indian Hortic.*, 2009, **54**(1), 3–8.
6. Bhutani, J. C., *Adv. Hortic. Ornament. Plants*, 1995, **12**, 1053–1058.
7. Safeena, S. A. and Patil, V. S., *J. Agric. Sci.*, 2013, **5**(4), 179–189.
8. Rani, R. P. and Reddy, M. V., *Int. J. Appl. Res.*, 2015, **1**(10), 306–311.
9. Ugale, H., Alka, S., Timur, A. and Palagani, N., *J. Ornament. Hortic.*, 2016, **19**(1&2), 34–38.

Received 16 July 2018; revised accepted 13 March 2019

PADMAPANI PACHPINDE
P. K. SHARMA*
INDRA MANI

Division of Agricultural Engineering, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India
**For correspondence.*
e-mail: pks_ageg@iari.res.in

Occurrence of leaf tip mutation in black pepper (*Piper nigrum* L.)

Black pepper (*Piper nigrum* L., family: Piperaceae) is one of the oldest and most widely used culinary spices. Conventionally leaves of black pepper plant have a single acuminate or mucronate tip[1], but we found multiple tips in some black pepper plants. Panniyur-5 is a variety bred at the Pepper Research Station Panniyur by Kerala Agricultural University, Thrissur, India. It is a selection from open pollinated seedling progeny of Perumkodi with moderate susceptibility to foot rot disease at nursery[2]. Horticulture Section of ICAR-Central Coastal Agricultural Research Institute is engaged in research of black pepper as suitable inter/mixed crop in perennial crop-based cropping systems.

We observed some of the orthotropic stems of black pepper vine of one open pollinated seedling progeny of Panniyur-5 and their clonal progenies to display a rare leaf shape mutation with lobed leaf at tip. Mutations in leaf shape of 10 adult plants out of 330 plants were observed and studied in leaves of black pepper. Shape of the leaf varies among the pepper germplasm accessions and used as one of the descriptor traits to characterize the variation. Shape of the leaves of the pepper plants varies from ovate, ovate-lanceolate, ovate-elliptic, cordate, obovate, lanceolate, elliptic, ovate or broadly obovate[1,3].

All the mutant leaves studied possessed more than one tip and a broader leaf blade (Figure 1). Acuminate or drip tip is an adaptive feature in leaves of most tropical rain forest plants[4,5] to rapidly drip off water for natural drying of leaves. *Piper sagittifolium* is another species which has lobes at base[6] of the leaf. *Piper nigrum* L. does not possess any lobe at base or at tip as per the DUS descriptors[3].

About seventy mutant leaves were selected at random on the mutant plants. Another seventy leaves of similar age and position were selected on neighbouring plants of wild type. Inter nodal length, length and width of leaf, length and girth of petiole were measured. Pair of 10 wild type and mutant leaves were scanned on a flatbed scanner and the image was saved at 600 dpi as jpeg file. ImageJ software[7] with LeafJ plugin[8] was used to analyse the image files for measuring angle, circularity ($4 * \pi r^2$/(perimeter)^2), ferret diameter, ferret angle, roundedness and solidity (area/convex area)[7]. Paired *t*-test was performed using graphpad web service[9] to compare mean of the traits of mutant and wild-type plants for statistical significance.

Mean, range and variation values of leaf, petiole and internodal length of mutant and wild type are presented in Table 1. Leaf arrangement was opposite in some of the mutant leaves (Supplementary Figure 1). Leaves of the mutant plants possessed significantly larger leaf area than wild type (Table 1). Leaves of black pepper are simple and arranged alternate. Mutant leaves differed (Supplementary Table 1) based on number of tips, degree of fusion of leaves and changes in leaf arrangement (Supplementary Figure 1). Rooted cuttings with all mutant leaves having more than one acuminate tip (Figure 1) were selected and planted for further evaluation.

The long acuminate or the drip tip of the *Piper* leaves[5] was experimented to support leaf drainage in high rainfall regions. The water film due to excess rain fall held on the leaf surface if not drained can impact transpiration leading to decreased nutrient uptake[10]. The mutant leaf is able to drain water more effectively than wild type plants due to additional tips. Effective leaf size or leaf width of lobes/leaflets is known to increase due to increase in rainfall, but decrease with

Figure 1. Rooted cutting of mutant black pepper with modified leaf tip.

Table 1. Leaf, petiole traits and internodal length of mutant and wild-type black pepper

Trait	Wild-type		Mutant		
	Mean	Range (CV%)	Mean	Range (CV%)	*P* value
Leaf length (cm)	9.3 ± 0.2	4.8–14.2 (20.4)	8.5 ± 0.2	3.9–12.5 (21.0)	0.0005
Leaf width (cm)	6.5 ± 0.2	2.4–9.5 (22.9)	8.3 ± 0.3	2.4–15.5 (30.6)	<0.0001
Inter nodal length (cm)	7.0 ± 0.3	0–11.1 (35.1)	8.5 ± 0.3	0–12.1 (32.2)	<0.0001
Petiole length (cm)	4.9 ± 0.2	2.2–8.3 (25.6)	5.3 ± 0.2	1.9–10.0 (25.8)	0.0285
Petiole thickness (cm)	3.28 ± 0.1	1.19-4.96 (27.03)	4.50 ± 0.1	2.23–8.21 (27.35)	<0.0001
Leaf length × width (cm^2)	61.6 ± 2.5	11.5–118.8 (34.2)	72.6 ± 3.7	11.3–155.9 (43.2)	0.0018
Leaf Eccentricity	1.50 ± 0.1	0.8–3.2 (28.2)	0.91 ± 0.04	0.4–2.2 (34.3)	<0.0001

Values are means of 68–70 samples followed by standard error compared by paired *t*-test CV% are given in parenthesis.

increase in irradiance probably to adapt the leaves to the ecology[11].

Diverse forms of leaf shape evolve in plants due to thermoregulation, hydraulic and other biomechanical restrictions or biotic stress[12]. Among the image-based measures, only circularity and solidity were significantly lower in mutant leaves than those of wild type (Supplementary Table 2). Mutant leaves possessed larger surface area than wild type (Table 1) extending the photosynthetic area of plant. Leaf area in black pepper is an allometric function of leaf length with constants varying for each cultivar[13]. Leaf shape (*E*) eccentricity (ratio of leaf length to width) measures the degree of leaf elongation[14]. Wild-type leaves are elongated with high eccentricity and angle values (Table 1 and Supplementary Table 2).

Leaf shape mutations in chilli and cotton are known to be genetically controlled[15,16]. DNA-based marker (SSR[17] or RAPD[18]) systems are currently employed in black pepper improvement and variety identification. The current study identifies novel chimera with leaf tip shape. Pure clones of this mutant need to be first isolated by tissue culture or other tissue specific propagation tools. Later, it will be used in cultivar improvement programmes after further confirmatory studies.

1. Mathew, P. J., Mathew, P. M. and Kumar, V., *Euphytica*, 2001, **118**, 257–264.
2. Mammootty, K. P., Abraham, K. and Vijayaraghavan, R., *J. Trop. Agric*., 2008, **46**, 70–72.
3. PPV & FRA, Guidelines for the conduct of test for distinctiveness, uniformity and stability on black pepper (*Piper nigrum* L.) Protection of plant variety and farmers' rights authority (PPV & FRA), Government of India, 2009, pp. 1–32.
4. Malhado, A. C. M. *et al.*, *Biotropica*, 2012, **44**, 728–737.
5. Lightbody, J. P., *Biotropica*, 1985, **17**, 339–342.
6. Tebbs, M. C., In *Flowering Plants, Dicotyledons* (eds Kubitzki, K., Rohwer, J. G. and Bittrich, V.), Springer, Berlin, 1993, pp. 516–520.
7. Abràmoff, M. D., Magalhães, P. J. and Ram, S. J., *Biophoton. Int.*, 2004, **11**, 36–42; https://imagej.nih.gov/ij/docs/guide/146-30.html (last accessed on 23 February 2018).
8. Maloof, J. N., Nozue, K., Mumbach, M. R. and Palmer, C. M., *JoVE*, 2013, **71**, e50028.
9. http://www.graphpad.com/quickcalcs/ttest1/?Format=C (last accessed on 23 February 2018).
10. Leigh, E. G., *Annu. Rev. Ecol. Evol. Syst*., 1975, **6**, 67–86.
11. Gvinish, T. J., *New Phytol*., 1987, **106**, 131–160.
12. Nicotra, A. B., Leigh, A., Boyce, C. K., Jones, C. S., Niklas, K. J., Royer, D. L. and Tsukaya, H., *Funct. Plant Biol*., 2011, **38**, 535–552.
13. Kandiannan, K., Kaliasam, C., Chandaragiri, K. K. and Sankaran, N., *J. Agron. Crop Sci.*, 2002, **188**, 138–140.
14. Backhaus, A., Kuwabara, A., Bauch, M., Monk, N., Sanguinetti, G. and Fleming, A., *New Phytol*., 2010, **187**, 251–261.
15. Joshi, B. C., *Curr. Sci*., 1962, **10**, 425–426.
16. Ramiah, K. and Nath, B., *Curr. Sci*., 1941, **11**, 490–491.
17. Menezes, I. C., Cidade, F. W., Souza, A. P. and Sampaio, I. C., *Conserv. Genet. Resour*., 2009, **1**, 209–212.
18. George, K. J., Ganga, G., Varma, R. S., Sasikumar, B. and Saji, K. V., *Curr. Sci*., 2005, **88**, 216–218.

ACKNOWLEDGEMENTS. We are grateful to ICAR-AICRP (All India Coordinated research Project) on Palms, Kasaragod, Kerala, India and RKVY (Rashtriya Krishi Vikas Yojana) for the financial support.

Received 5 July 2016; revised accepted 5 March 2019

V. ARUNACHALAM[1,*]
DNYANDA C. PRABHU[2]

[1]*Section of Horticultural Science, ICAR-All India Coordinated Research Project on Palms, Goa Centre,*
[2]*ICAR-Central Coastal Agricultural Research Institute, Ela, Old Goa 403 402, India*
**For correspondence.*
e-mail: v.arunachalam@icar.gov.in