UDC 575:634.1
DOI: 10.2298/GENSR1302427M
Original scientific paper

INHERITANCE OF WARTY FRUIT TEXTURE AND FRUIT COLOR IN BOTTLE GOURD [*LAGENARIA SICERARIA* (MOLINA) STANDL.]

Emina MLADENOVIĆ[1], Janoš BERENJI[2], Ksenija HIEL[1], Marija KRALJEVIĆ-BALALIĆ[1], Vladislav OGNJANOV[1], Mirjana LJUBOJEVIĆ[1] and Jelena ČUKANOVIĆ[1]

[1] Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia
[2] Institute for field and crops, Novi Sad, Serbia

Mladenović E., J. Berenji, K. Hiel, M.Kraljević Balalić, V.Ognjanov, M.Ljubojević and J. Čukanović (2013): *Inheritance of warty fruit texture and fruit color in bottle gourd [Lagenaria siceraria (molina) standl.]*. Genetika, Vol 45, No. 2, 427-432.

Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] is one of the most interesting species in the plant kingdom, due to the diversity of fruit shapes, sizes and ways of use. Warty genotypes are rare compared to non warty genotypes. Considering unusual external appearance of warty fruits, we focused our research on the investigation of its inheritance patterns. By crossing different bottle gourd phenotypes, we studied the mode of inheritance and identified and verified genes responsible for the fruit skin color and warty phenotype segregation. Two parental lines, LAG 70 (with warty fruit of light green color) and LAG 71 (smooth fruit, variegated), F_1, F_2 and backcrosses populations along with both parents were evaluated. Genetic analysis indicated that warty fruit type is a result of monogenic inheritance, whereby the warty fruit type is dominant (*Wt*) trait over to the non-warty fruit type (*wt*). The mode of inheritance of fruit color was controlled by recessive epistasis, with a ratio of 9 variegated (A-, B-), 3 dark green colored (aaB-) and 4 light green colored (aabb) fruits in the F_2 generation.

Key words: bottle gourd, fruit color, inheritance, warty fruits

INTRODUCTION

Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] is an edible, medicinal and decorative plant. It belongs to the Cucurbitaceae family from which many species can be used as alternative

Corresponding author: Emina Mladenović, University of Novi Sad, Faculty of Agriculture, Department of fruit science, viticulture, horticulture and landscape arhitecture, Dositeja Obradovića Square 30, 21000 Novi Sad, tel: +38121 485 3269, fax:+381 21 450 123, e-mail: eminam@polj.uns.ac.rs

vegetable crops (MLADENOVIĆ *et al*., 2011a). One of the most important unique bottle gourd external traits of decorative significance and high market value is the warty fruit texture. Inheritance of warty characteristics was investigated by many authors; however, very few focused on Cucurbitaceae species. In a recent study, ZHANG *et al*. (2010) concluded that in cucumber, warty phenotype is dominant compared to the smooth one. The authors reported that warty fruit type was controlled by a single dominant gene (*Tu*), whereas smooth fruits are recessive types under control of *tu* gene. In addition, PARIS *et al.* (2004) presented a list of genes of some Cucurbitaceae species, stating that *Wt* gene is dominant and responsible for warty fruits in *Cucurbita pepo* L., in contrast to *wt* gene, which is recessive and responsible for smooth fruit skin appearance.

According to biological terminology, these warts are, in fact, tumors. There are several types of tumors (warts) in plants that are similar to cucurbita tumors and are product of increasing number of cells. Previous studies have shown that tumors develop due to the presence of endogenous hormones, as well as concentration changes in cytokinins and auxins (LOHAR, *et al.* 2004; MATVEEVA *et al.,* 2004; IL'INA *et al.,* 2006).

Bottle gourd is generally considered to originate from Africa, and it is likely that an independent subsistence exists in American and Asian continents (DECKER-WALTERS *et al.,* 2001; DECKER-WALTERS *et al*., 2004; ERICKSON *et al.,* 2005). Bottle gourd has been exploited for various uses around the world, mostly in tropical and temperate climates. Warty phenotype of bottle gourd represents an important aesthetic characteristic that can be significant factor for decorative purposes. As there are no records of previous investigations of a gene responsible for warty phenotype, our study can be considered as the first to study this trait in bottle gourds. There is a luck of research on qualitative traits and they deserve more attention. MLADENOVIĆ *et al.* (2011b) studied a collection of 36 bottle gourd genotypes of which only three had warty texture. Fruit color is an important qualitative trait. The yellow fruit color trait (*Y*) was found to be dominant to green color (*y*) in ornamental gourd (PARIS *et al.,* 2004). However, PARIS (2003) found that fruit color of pumpkin is a multifaceted trait with a complex mode of inheritance. MLADENOVIĆ *et al*. (2012) studied genetic variability of 40 bottle gourd genotypes of which thirty six had light green color and four had variegated color. Given that research on inheritance of warty texture and color of fruits is important for breeding work on Cucurbitaceae family, the primary objective of this study was to determine the genetic inheritance pattern of these two traits.

MATERIALS AND METHODS

Two selections were chosen from a collection of 44 bottle gourd genotypes according to our selection aims. One warty bottle gourd genotype with light green skin color (LAG 70) and one smooth fruit genotype with variegated skin color (LAG 71) were used as parents. Two cross-breeds were conducted in order to determine the inheritance of fruit warty texture and color: between a warty fruit of light color and a smooth fruit of variegated color (70 x 71) and opposite (71 x 70). F_1 plants were self-pollinated with the aim to produce F_2 plants. For both crosses (70 x 71 and 71 x 70), the F_1 plants were backcrossed with parents to obtain a BC_1 and BC_2 population. Subsequently, F_1, F_2, BC_1 and BC_2 plants, as well as their parents, were used in the genetic analysis.

The seeds of parents F_1 (smooth x warty and warty x smooth), F_2 and BC_1 (F_1 x smooth and smooth x F_1), were sown in the field nursery of the Faculty of Agriculture, University of Novi Sad on April 15th, 2011. The prepared plants with minimum one developed leaf were planted at

the field of Department of Fruit Science, Viticulture, Horticulture and Landscape Architecture near Novi Sad in Rimski Šančevi (Serbia) (45°19'40"N, 19°49'41"E) on dark chernozem soil, on May 10 th, 2011. The plants were sown in rows, allowing 280 cm between adjacent plants, and 320 cm between rows. After the fruit ripening, in October-November of 2011, fruit texture and color were evaluated, resulting in 1419 that produces 7000 fruits. During the season, regular fertilization and cultural conditions were applied.

The significance of differences between experimental and theoretical data is defined by the χ^2 test. This test indicates the deviation of the experimental data from the theoretical values and its results are used to determine whether the deviation is statistically significant or not. The value of the χ^2 test is compared to the tabular values of χ^2 test for the appropriate level of distribution of probability *P* for k-1 degrees of freedom (DJURDJICA, 2000).

RESULTS

The warty fruits are much more decorative than are smooth fruits, as warts take different sizes and shapes. These warts are distributed all over the surface of the fruit. The distribution of the warts can be localized only to the part of the fruit around the handle, the middle of the fruit, the lower part of the fruit, or can appear across any combination of these parts of the fruit. In this study, warts were mostly present in the part of fruit around the handle. The selected warty genotype was characterized by light green color, while smooth genotype had dark green color with light green patterns.

All F_1 plants that were obtained by crossing a warty fruit with a smooth fruit parent had warty fruit. After analyzing the texture and fruit color, BC_1 generation was found to contain 195 warty fruits and 209 smooth fruits. Based on the χ^2 tests of the two crosses, the ratios were 3 warty fruits to 1 smooth fruit in each F_2 population and 1 warty fruit to 1 smooth fruit in BC_1 backcross population. Thus, we concluded that a single dominant gene controls the warty fruit trait. Moreover, warty fruits were more decorative than smooth fruits (Table 1).

Table 1. Segregation analysis of the warty fruit trait

	Number of plants					
Generation	Total	Warty fruit	Smooth fruit	Expected ratio	χ^2	$P_{(1)}$
P_1	70	0	70	-	-	-
P_2	70	70	0	-	-	-
F_1, P_1 x P_2	69	69	0	-	-	-
F_1, P_2 x P_1	68	68	0	-	-	-
F_2, (P_1x P_2)	174	131	43	3:1	0.0076	0.90
F_2, (P_2x P_1)	185	139	46	3:1	0.0018	0.90
F_2, Total	359	270		3:1	0.0084	0.90
BC_1, P_1 x F_1	404	195	209	1:1	0.484	0.50
BC_2, P_2 x F_1	379	379	0	-	-	-

In adition to the warty texture, the fruit color is another significant qualitative characteristic. The first parent had a variegated fruit (green base with bright patterns) while the second one was a light colored. In the F_1 generation (in direct and reciprocal crosses) all fruits were variegated,

while in the F_2 generation approximately nine fruits were variegated, three were dark and four were light, which fitted a 9:3:4 ratio (Table 2).

Table 2. Segregation analysis of the fruit color

	Number of plants						
Generation	Total	Variegated fruit	Dark green	Light green	Expected ratio	χ^2	$P_{(2)}$
P_1	70	70	0	-	-	-	-
P_2	70	0	0	70	-	-	-
F_1, P_1 x P_2	69	69	0	0	-	-	-
F_1, P_2 x P_1	68	68	0	0	-	-	-
F_2, (P_1x P_2)	174	98	28	48	9:3:4	1.121	0.50
F_2, (P_2x P_1)	185	105	4	46	9:3:4	0.023	0.90
F_2, Total	359	203	62	94	9:3:4	0.625	0.70
BC_1, P_1 x F_1	404	362	24	18	-	-	-
BC_2, P_2 x F_1	379	94	83	202	1:1:2	2.287	0.30

Fruit color of bottle gourd is determined by two dominant genes. Under the influence of both dominant genes, color of fruit is variegated (A-B-), whereas dark green color is a result of one recessive one gene (A-bb) and light color occurs when another recessive or both recessive genes are expressed (aaB- and aabb). This inheritance pattern is recessive epistasis, characterized by complete dominance at both gene pairs. When one gene is homozygous recessive, it masks the phenotype of the other gene.

DISCUSSION

The genetic analysis of warty plants in *Lagenaria siceraia* indicated that the mode of inheritance of plant texture could be considered monogenic, whereby warty (*Wt*) is dominant over the smooth type (*wt*). The warty texture gene symbol in *Cucurbita* is *Wt* (PARIS *et al.,* 2004). Previous studies on inheritance of warty fruits in cucumber confirmed the existence of one dominant gene responsible for the warty texture (WALTERS *et al.,* 2001). Recent investigations conducted by ZHANG *et al.* (2010) also focused on cucumber fruit. The authors found that all F_1 fruits had warty texture with a ratio of three warty fruits to one smooth fruit in F_2 generation. In the backcross population, the ratio was one warty fruit to one smooth fruit. Genetic studies of the warty fruit of *Cucurbita pepo* L. were conducted by PARIS *et al*. (2008/2009). Many studies confirm that dominant gene (**Wt**) is responsible for warty fruit, whereas recessive gene (*wt*) is responsible for smooth fruit skin (PARIS, 2002; ROBINSON and PARIS, 2000). In addition, ZHANG *et al.* (2010) explained that the cytological mechanism of fruit tumor formation on the cucumber fruit surface would involve a plant hormone cytokinin.

Fruit color is an important qualitative trait. Yellow fruit color in *Cucurbita pepo* L. was studied by PARIS *et al.* (2004). They concluded that yellow fruit color (*Y*) is dominant to green color (*y*) in ornamental gourd. Other numerous studies indicate that fruit color of pumpkin is a multifaceted trait with complex inheritance mode (PARIS, 2003). PARIS *et al. (*2003) concluded that, when parents are dark green and light green, fruit color in pumpkin follows the inheritance mode, resulting in F_2 generation with the ratio of 9 dark, 3 bright and 4 bright fruits with no pattern.

Warty plants in bottle gourd have many valuable characteristics, primarily decorative features and many uses in horticulture, landscape architecture and art. Previous studies mostly focused on inheritance of resistance to red pumpkin beetle, fruit and leaf shape and fruit and seed coat color (AKHILESH and RAM, 2006). Since in the bottle gourd genotypes demonstrate marked variability in fruit texture, gaining more extensive knowledge of the inheritance mode of this trait is important.

CONCLUSION

The main characteristics of warty and smooth plants in *Lagenaria siceraria* were compared. The genetic analysis of fruit warty texture shows that a monogenic inheritance is expressed whereby warty (*Wt*) texture is dominant over to smooth type (*wt*). On the other hand, our genetic analysis of fruit color indicates that this trait is under the influence of two dominant genes. Moreover, the inheritance of bottle gourd fruit color is recessive epistasis.

This work is the first report of inheritance of warty fruit texture in bottle gourd and thus expands current body of knowledge on fruit color inheritance in the same species.

. Received January 31st, 2013
Accepted Juny 06th, 2013

REFERENCES

AKHILESH, T. and H.H. RAM (2006): Qualitative inheritance of segmented leaf shape in bottle gourd (*Lagenaria siceraria* (Molina) Standl.). (abstract) Veg. Sci. *33*: 117-121.

DJURDJICA, V. (2000): Biometrics and experiments in agronomy. Croatian agronomy society, Croatia, pp. 50-102.

DECKER-WALTERS, D., J. STAUB, A. LOPEZ-SESE and E. NAKATA (2001): Diversity in landraces and cultivars of bottle gourd (*Lagenaria siceraria*; Cucurbitaceae) as assessed by Random Amplified Polymorphic DNA. Genet. Resour. Crop Evol *48*: 369-380.

DECKER-WALTERS, D., M. WILKINS-ELLERT, S.M. CHUNG and E.J. STAUB (2004): Discovery and genetic assessment of wild bottle gourd [*Lagenaria siceraria* (Mol.) Standley; Cucurbitaceae] from Zimbabwe. Econ. Bot. *58*: 501-508.

ERICKSON, L.D., D.B. SMITH, C.A. CLARKE, H.D. SANDWEISS and N. TUROSS (2005): An Asian origin for a 10, 000 year-old domesticated plant in the Americas. Proc. Natl. Acad. Sci. USA *102*: 183150-18320.

IL'INA, L.E., E.I. DODUEVA, M.N. IVANOVA and A.L. LUTOVA (2006): The effect of cytokinins on in vitro cultured inbred lines of *Raphanus sativus* var. radicula Pers. With genetically determined tumorigenesis. Russ. J. Plant Physiol. *53*: 514-522.

LOHAR, P.D., J.E. SCHAFF, G.J. LASKEY, J.J. KIEBER, D.K. BILYEU and M.D. BIRD (2004): Cytokinins play opposite roles in lateral root formation, and nematode and Rhizobial symbioses. Plan J. *38*: 203-214.

MATVEEVA, V.T., V.N. FROLOVA, R. SMETS, E.I. DODUEVA, S.I. BUZOVKINA, H. VAN ONCKELEN and A.L. LUTOVA (2004): Hormonal control of tumor formation in radish. J. Plant Growth Regul. *23*: 37-43.

MLADENOVIĆ, E., I. BLAGOJEVIĆ, J. ČUKANOVIĆ, V. OGNJANOV, M. LJUBOJEVIĆ, A. GAČIĆ, A. KURJAKOV and J. BERENJI (2011a): Application of alternative vegetable crops in rural development. 22 th International Symposium „Safe food production". Trebinje, Bosnia and Herzegovina, pp.213-215.

MLADENOVIĆ, E., J. BERENJI, V. OGNJANOV, M. KRALJEVIĆ-BALALIĆ, M. LJUBOJEVIĆ and J. ČUKANOVIĆ (2011b): Conservation and morphological characterization of bottle gourd for ornamental use. 46th Croatian and 6th International Symposium on Agriculture. Opatija, Croatia, pp.550-553.

MLADENOVIĆ, E., J. BERENJI, V. OGNJANOV, M. LJUBOJEVIĆ and J. ČUKANOVIĆ (2012): Genetic variability of bottle gourd [*Lagenaria siceraria* (Mol.) Standley] and its morphological characterization by multivariate analysis. Arch. Biol. Sci. *64*: 573-583 .

PARIS, H.S. (2002): No segregation distortion in intersubspecific crosses in **Cucurbita pepo**. Cucurbit Genet. Coop. Rep. *25*: 43-45.

PARIS, H.S., F. BAUMKOLER and A. HANAN (2003): Fruit Color inheritance in a cross of a dark-colored accession with a light-colored accession in *Cucurbita pepo*. Cucurbit Genet. Coop. Rep. *26* :44-45.

PARIS, H.S. and B.R. NELSON (2004): Gene List for Cucurbita species. Cucurbit Genet. Coop. Rep. *27*: 77-96.

PARIS, H.S. and E. KABELKA (2008/2009)*:* Gene List for Cucurbita species, 2009. Cucurbit Genet. Coop. Rep. *31/32*: 44-69.

ROBINSON, R.W. and H.S. PARIS (2000): Cucurbita gene list update – 2000. Cucurbit Genet. Coop. Rep. *23*: 137–138.

WALTERS, S.A., N.V. SHETTY and T.C. WEHNER (2001): Segregation and linkage of several genes in cucumber. J. Am. Soc. Hort. Sci. *126*:442–450.

ZHANG, W., H. HE, Y. GUAN, H. DU, L. YUAN, Z. LI, D. YAO, J. PAN, and R. CAI (2010): Identification and mapping of molecular markers lunked to the tuberculate fruit gene in the cucumber (*Cucumis sativus* L.). Theor. Appl. Genet. *120*: 645-654.

NASLEĐIVANJE NABORANOSTI I BOJE PLODA VRGA [*Lagenaria siceraria* (MOLINA) STANDL.]

Emina MLADENOVIĆ[1,*], Janoš BERENJI[2], Ksenija HIEL[1], Marija KRALJEVIĆ-BALALIĆ[1], Vladislav OGNJANOV[1], Mirjana LJUBOJEVIĆ[1] i Jelena ČUKANOVIĆ[1]

[1] Univerzitet u Novom Sadu, Poljoprivredni fakultet, Departman za voćarstvo, vinogradarstvo, hortikulturu i pejzažnu arhitekturu, Novi Sad
[2] Institut za ratarstvo i povrtarstvo, Novi Sad

Izvod

Vrg [*Lagenaria siceraria* (Molina) Standl.] je jedna od najinteresantnijih vrsta biljnog sveta, s obzirom na veliku raznolikost oblika, veličiine ploda i načina upotrebe. Genotipovi vrga sa naboranom površinom ploda su ređi u poređenju sa genotipovima sa glatkom površinom ploda. Imajući u vidu neobične izraštaje naboranih plodova, ovaj rad imao je za cilj da ispita način nasleđivanja naboranosti. Ukrštanjem genotipova vrga sa naboranom i sa glatkom površinom ispitan je način nasleđivanja naboranosti i boje ploda. U radu su prikazani rezultati merenja dve roditeljske linije, LAG 70 (sa naboranom površinom i svetlo zelenom bojom ploda) i LAG 71 (sa glatkom površinom i sa šarama) F_1, F_2 generacija i povratno ukrštanje sa oba roditelja. Genetička analiza pokazala je da se naboranost nasleđuje dominantnim putem, pri čemu je naborani tip dominantan (*Wt*) u odnosu na tip ploda sa glatkom površinom. (*wt*). Boja ploda vrga nasleđuje se recesivnom epistazom sa odnosom 9 šarenih (A-, B-), 3 tamno obojena ploda (aaB-) i 4 svetlo zelena ploda (aabb) u F_2 generaciji.

Primljeno 31. I. 2013.
Odobreno 06. VI. 2013.