‘NDMutant1’: A Novel Determinate Interspecific Grapevine for Genetic and Physiological Study and Breeding Applications

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Additional index words. Vitis labrusca, and Vitis riparia) with ‘Madeleine Angevine’ (V. vinifera). The initial hybridization was conducted to create low acid, early maturing white wine parental types for future breeding efforts for North Dakota. Accession ND 733 was further investigated because of its unique low initial titratable acidity at veraison. With the intention of further improvement, ND 733 was self-pollinated to create an S1 population. Within, the resulting S1 population a single shrub-like genotype was discovered that displayed determinate growth. This vine’s form was thought to be the result of a natural mutation; thus it was given the designation NDMutant1 (Fig. 1).

Description

Growth form. The growth form of the discovered plant is denoted by determinant reproductive and vegetative growth not typical to hybrid grapevine (Fig. 2). The plant’s shoots initiate normal vine growth through juvenility with nodes containing phytotypically normal and true-to-type leaves, axillary buds, and dormant resting buds. After producing several (≈4) phytotypically normal nodes, the vine produces altered nodes containing only leaves, tendrils, and reproductive structures and having no resting or axillary buds (Fig. 3). When altered nodes are formed, their reproductive structures are atypical with individual or grouped singly borne flowers produced in place of lateral and resting buds. This is in contrast to the paniclotype altered tendrils typically seen in Vitis. Last, stem growth ceases through conversion of the shoot tip to a tendril, inflorescence-like structure, giving the vine its unique determinate growth and reproductive habit. The plant creates several resting buds at the base of each new stem. These buds break over time, allowing for continuous growth under adequate heat and photoperiod. In addition to the defined growth pattern, the vine’s leaves are thick in nature and triangular to ovate in shape, and the plant produces extensive aerial roots along its trunk and lower stems.

Stem measurement comparisons with an S1 sibling showed differences in plant growth characteristics (Table 1). Data were taken on five subsampled stems of three replicates, clonally propagated plants of each genotype. Data were subjected to analysis of variance using the mixed procedure of SAS statistical software (SAS Institute Inc., Cary, NC) as a completely random design with stems treated as random subsamples and genotypes treated as fixed effects. Covariance parameters were estimated using the restricted maximum likelihood method; where sample error did not differ from experimental error, errors were allowed to be pooled. After the confirmation of significant variance (α = 0.05), mean separation was conducted using pairwise t tests. Plants were measured for internode length (cm), number of nodes at which the meristem was lost (meaning its conversion to a tendril like structure with growth cessation), number of altered nodes (those having no buds with singly borne flowers), number of singly borne flowers per stem, and number of singly borne flowers per altered node. Through these observations, NDMutant1 consistently had shorter internodes before bud morphogenesis to singly borne flowers. Typically, the apical meristem of NDMutant1 vines was lost at around the seventh node, whereas its S1 sibling never lost its apical meristem and continued to grow. The NDMutant1 genotype also had ≈2.5 altered nodes per stem, giving rise to ≈4.4 singly borne flowers, whereas no such altered nodes occurred in the S1 sibling vines. Given growth favorable conditions (warm temperature and long-days), the plant grows as a small shrub with periodic dormant bud-break, new shoot growth, flowering and fruiting, and growth cessation. Under these conditions, the plant needs no vernalization to maintain growth. This unique growth pattern enables the plant to show all reproductive stages simultaneously from flowering to mature fruit, similar to the vine Vitis ‘Pixie’ derived from the L1 layer from the L1/L2 periclinal chimera Vitis ‘Pinot Meunier’ (Boss and Thomas, 2002; Cousins and

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Fig. 1. Pedigree of NDMutant1.
Tricoli, 2006). Although these vines both continuously flower, the mechanism for their respective habits is likely to differ as they have markedly different growth forms. It is speculated that the current genotype’s form is related to the FLOWERING LOCUS T gene or related genes as the phenotype is similar to that described in controlled transformations of *Malus, Prunus,* and *Populus* (Böhlenius et al., 2006; Hsu et al., 2011; Srinivasan et al., 2012; Wenzel et al., 2013; Zhang et al., 2010). Homologs of similar genes have been identified in *Vitis* and should be investigated (Carmona et al., 2007).

The original vine was vernalized to evaluate its resting buds’ ability to break dormancy and grow after a simulated winter. After placement in 3 °C refrigeration for 45 d, resting buds broke dormancy normally on return to greenhouse conditions. The shoots arising from overwintered buds appeared normal in their growth including the creation of typical wild-type grapevine inflorescences. The initial nodes along the stem developed as wild-type whereas later developing nodes along shoots again were altered to enact a determinate growth habit.

**Reproduction.** To determine the stability of the phenotype, the plant was asexually propagated using green shoot-tip cuttings. Cuttings rooted readily when treated with 0.01% IBA, mist, and bottom heat in 100% perlite media. Outgrowth was limited as many buds reverted to reproductive

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**Fig. 2.** Schematic outlining the growth pattern of NDMutant1.

**Fig. 3.** Determinate growth of grapevine NDMutant1 (A1) stem growth and (A2) apical termination in comparison with the wild-type parent ND 733 (B1) stem growth and (B2) apical morphology; (C) the shrub form of NDMutant1; (D) NDMutant1 showing continuous flowering capability from flower initiation through berry maturation; and (E) altered nodal buds converted to groups of singly borne flower structures.
Table 1. Growth and reproductive characteristics of NDMutant1 and an S1 sibling.

| Genotype    | Internode length (cm) | Meristem loss (node) | Altered buds (no.) | Singly borne flowers per stem (no.) | Singly borne flowers per altered node (no.) |
|-------------|-----------------------|----------------------|--------------------|-------------------------------------|---------------------------------------------|
| NDMutant1   | 1.53 b*               | 6.9 b                | 2.5 a              | 4.4 a                               | 1.3 a                                       |
| S1 sibling  | 2.33 a                | 11.0 a               | 0.0 b              | 0.0 b                               | 0.0 b                                       |
| P value*    | 0.0078                | 0.0029               | 0.0129             | 0.0348                              | 0.0140                                      |

*S is significantly different from S1 at α = 0.05.

*P value from analysis of variance.

structures; however, this was overcome by taking cuttings early in development to ensure the presence of vegetative buds that had not reached dormancy. Through visual inspection, all propagules (n = 14) maintained the same growth habit as the mother plant. In addition, wild-type basal buds of NDMutant1 were top budded to interspecific hybrid seedling rootstock. Budded plants did not revert to a wild-type Vitis vining habit and vegetative buds continued to be altered to reproductive structures, again confirming the phenotypic stability of the trait and dismissing a root related causation.

To test progeny viability, open-pollinated mature fruit was harvested. The resulting seeds were found to be underdeveloped and nonviable. Through several fruiting cycles, the mother plant and all propagules produced only seed remnants and no fully developed seed. Genetic seedlessness cannot be dismissed as the seedless characteristic is found within the background of one parental type ‘Valiant’. ‘Valiant’ was derived from Vitis ‘Fredonia’ pollinated with a V. riparia selection from Montana (Hemstad, 2015). ‘Fredonia’ has been shown to be a recessive seedless donor as it was the seed parent of the seedless grapes Vitis ‘Einset Seedless’ and Vitis ‘Suffolk Red’. Although fruit were characterized as seedless, pollen collected from NDMutant1 has been found to be viable through controlled crosses and has produced progeny when placed on pistillate and emasculated perfect flowered vines. Through the F1 generation of such crosses, no progeny has exhibited a similar growth pattern.

The genotype may be useful in reducing generation time in grapevine breeding as a result of its early, continuous flowering nature if its inheritance can be confirmed. However, the greatest utility may come from its importance as a model organism for investigations into the physiology of reproductive expression as a complement to the ongoing efforts in annual species. In addition, the genotype may have utility in defining the basis for vining habit in woody plant systems and complement ongoing woody plant research in flowering expression, juvenility, and dormancy.

**Availability**

A small number of cuttings may be obtained by interested research personnel through Harlene Hatterman-Valenti (E-mail: h.hatterman.valenti@ndsu.edu) of the Plant Science Department at North Dakota State University for research purposes. It is requested that recognition be made in the case NDMutant1 contributes to published research or in the development of new germplasm or cultivars.

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