Inheritance and Morphological Traits of a Double Recessive Dwarf in Watermelon, *Citrullus lanatus* (Thunb.) Mansf.[1]

H. C. Mohr and M. S. Sandhu[2]
University of Kentucky, Lexington

Abstract. When 2 mutant dwarf watermelons were crossed, the F_1 was of normal vine type, indicating that these genes for dwarfness were non-allelic. The F_2 segregated 9:3:3:1, with the double recessive a plant form hitherto unreported. The designated genotype of this digenic recessive dwarf is $dw_1\, dw_1$, $dw_2\, dw_2$. It has much shorter internodes than either parent, the crown branching characteristic of 1 parent and the naked bud characteristic of the other, and it was later in maturity than either parent.

Breeding lines derived from double recessive plants show promise of horticultural value as cultivars for the home garden and intensive commercial culture with the possibility of a mechanized harvest.

Most cucurbit cultivars are characterized by an extensive procumbent vine type of growth which is a drawback to efficient land use. In recent years plant breeders have been developing dwarf (bush) forms which are better adapted to intensive cultural techniques (8), but no evidence of germplasm for dwarfness in watermelon existed prior to 1956 (4). In 1958 the short internode cv. *Bush Desert King* was released (5) as a source of germplasm for developing dwarf watermelon cultivars. Another short internode, monogenic recessive mutant was discovered in the Japanese cultivar *Asahi Yamato*[3] and was available in 1962.

In 1972, Liu and Loy (3) reported on 2 different dwarf mutants, one of which was 'Bush Desert King' (BDK) and the other, designated WB-2, was of uncertain origin. They designated the genotype of BDK as $dw_1\, dw_1$, and that of WB-2 as $dw_2\, dw_2$, since the cross of BDK × WB-2 produced an F_1 of normal vine type indicating that the genes for dwarfing were non-allelic. Their description of the morphological characteristics of WB-2 (as grown under an artificial environment, quite different from the "natural" environment) revealed several differences between it and the dwarf mutant of 'Asahi Yamato' (as evaluated under field conditions in Kentucky). The question of whether dwarfness in WB-2 was controlled by the same gene as in the 'Asahi Yamato' mutant was thus raised.

Liu and Loy (3) also verified the previously reported (4) mode of inheritance of dwarfness in 'Bush Desert King' and its gross morphological characteristics (6). Their analysis of the anatomical features associated with dwarfing (cell numbers and cell size) provides criteria for distinguishing between BDK and WB-2, and indicates that the genes dw_1 and dw_2 differ in biochemical actions that regulate plant growth.

Double recessive dwarfs have been investigated in barley (1) and rice (2). This report will describe the inheritance and some morphological characteristics of a digenic recessive watermelon dwarf and its parents.

Materials and Methods

A dwarf breeding line derived from BDK and designated as W-45 was one parent. This line has the typical features associated with the $dw_1\, dw_1$ genotype (3, 6), as shown in Fig. 1, but differs from BDK in fruit characteristics and in being resistant to *Fusarium* wilt.

The other parent was the dwarf mutant of 'Asahi Yamato,' hereafter referred to as AYB. In addition to short internodes, the Japanese parent possesses the hitherto unreported characteristic of multiple branching at the crown (Fig. 2), a morphologic feature of great potential value for concentrated fruit production.

The cross AYB × W-45 was made in 1962, and the F_1 was grown and self-pollinated in 1963. The F_2 generation was grown in 1964 and 1965.

The extremely late maturity of the double recessive F_2 segregants resulted in no seed being obtained from self-pollinations in 1965. In 1966 an outcross to 'New Hampshire Midget' was made to introduce genes for earlier maturity into the double recessive dwarf types.

The F_1 of the outcross was selfed in 1967 and early maturing double dwarf segregants were selected in 1968. Continued selection for desirable horticultural characteristics, followed by selfing, and sibbing in 1969, 1970, 1971 (2 generations), 1972 (2 generations) and 1973 have culminated in lines of sufficient homozygosity for cultivar status. To determine whether a new dwarfing gene was involved, the cross of WB-2 and AYB was made and the F_1 grown. Seed of WB-2 was obtained from Denna (origin of Liu and Loy's inbred line) and from Loy (3).

Results and Discussion

The F_1 plants of W-45 × AYB were all normal vine type, indicating that the genes for the 2 dwarf mutants are non-allelic. The dwarf genotype of BDK has already been designated as $dw_1\, dw_1$ by Liu and Loy (3), but that of the dwarf mutant in 'Asahi Yamato' was not given a designation. When the 2 WB-2 lines were grown under field conditions, both appeared to be nearly identical to AYB. The F_1 of the cross AYB × WB-2 was also of the same type, hence it is evident that dwarfness in AYB is controlled by $dw_2\, dw_2$. The differences observed between AYB and the description of the morphology of WB-2 as given by Liu and Loy (3) must be attributed to environmental influences on phenotypic expression.

The F_2 generation of W-45 produced normal vines, dw_1 type dwarfs, dw_2 type dwarfs, and a plant type hitherto undescribed. This plant type was not immediately identified as the double recessive because its growth was so restricted that at first it appeared to be severely stunted, as if by disease. Its general morphological characteristics, particularly multiple branching at the crown, caused it to be classed as a much retarded AYB type when first evaluations were made.

A second field planting of the F_2 was made the following year and data on segregation included the correct identification of the double recessive dwarfs. Table 1 shows that the conformance to the expected 9:3:3:1 dihybrid ratio was good, with a Chi square value of 2.092 and probability of .70-.50. The designated genotype of the double recessive dwarf is $dw_1\, dw_1$, $dw_2\, dw_2$.

No seed was obtained from self-pollinations of the double recessive segregants because of late maturity. Most segregants of vine type and of the 2 parental dwarf types, however, did mature fruit under these conditions. The following year the double dwarf segregants were outcrossed with 'New Hampshire Midget' to incorporate genes for

[1] Received for publication February 28, 1974. Published with approval of the Director of the Kentucky Agricultural Experiment Station as Scientific Contribution No. 74-10-39.

[2] Professor and Post Doctoral Research Assistant, respectively, Horticulture Department, University of Kentucky, Lexington.

[3] Seed obtained from Dr. M. Shimotsuma, Kihara Institute for Biological Research, Yokohama, Japan. Mutant discovered by Mr. K. Ara, Toyama Agricultural Experiment Station, Tonami, Toyama.

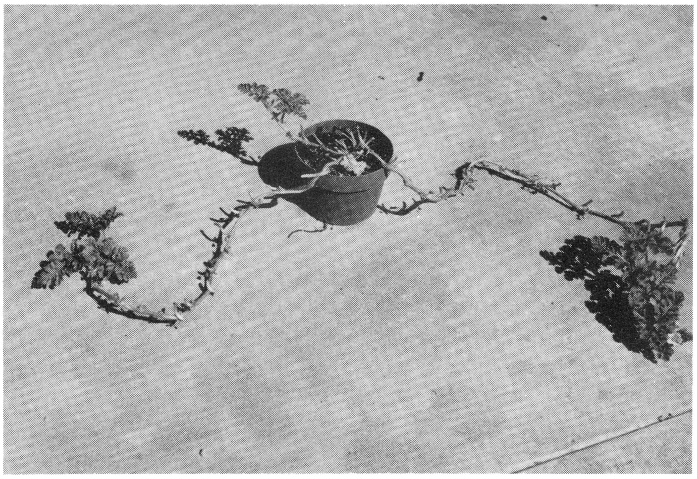

Fig. 1. Plant of BDK type (leaves removed). Note limited branching. Internodes are shortened compared to vines, but not as much as in the double recessive dwarf (see Fig. 3).

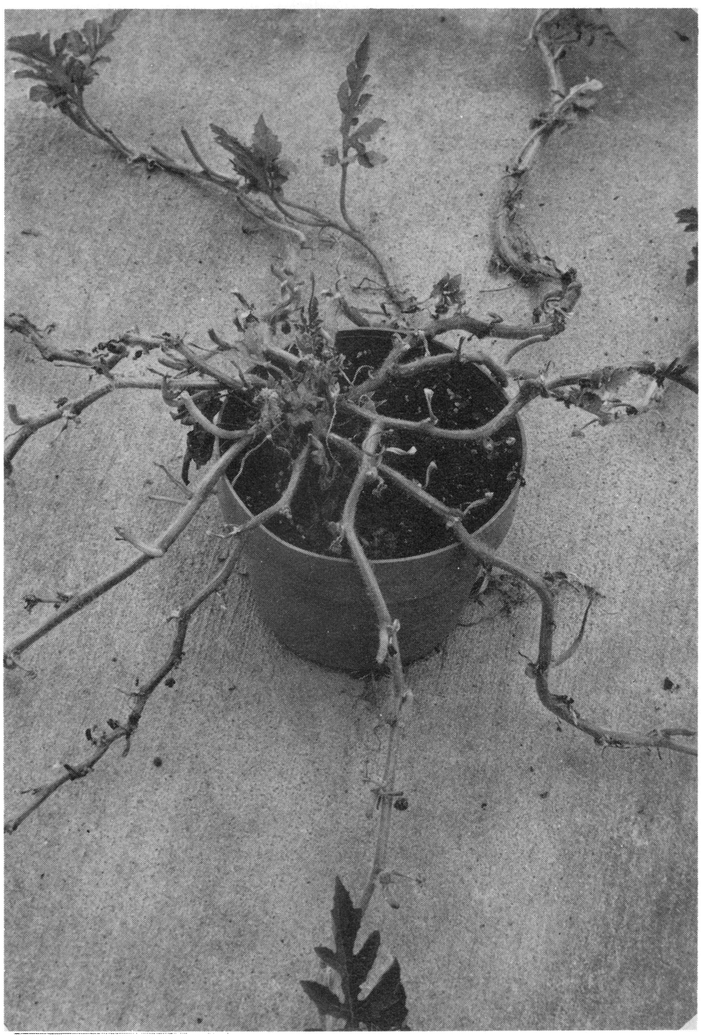

Fig. 2. Plant of AYB (leaves removed) illustrating the crown branching characteristic. While the internodes are shorter than those of vines they are much longer than those of double recessive (see Fig. 3).

early maturity from that cultivar. As expected, the F_1 of this outcross was all vine-type and the F_2 generation segregated with good conformance to the expected 9:3:3:1 dihybrid ratio with respect to plant type. Continuous evaluation of outcrosses, segregating lines and inbred lines covering 10 growing seasons has given consistent verification of the existence of these 2 major genes controlling dwarfing.

The "double dwarf" (double recessive) plants exhibit morphological characteristics of both the single gene dwarf parents. The "naked bud" character, expressed as a pleiotropic effect of the gene dw_1 (6), is present in the double dwarf. Crown branching, found to be associated with AYB, is present in all double dwarfs (Fig. 3). Hypocotyl length of the double dwarf is approximately half that of normal vines (Table 2).

When mature (fruiting) plants grown under the same conditions were compared, it was found that internode lengths of a dw_1 line

Table 1. Segregation data for F_2 progeny of a cross between AYB Japanese dwarf ($dw_2\,dw_2$) and W-45, 'Desert King Bush' type ($dw_1\,dw_1$).

Year	Observed Phenotypes					
	Vine (+ +)	W-45 ($dw_1\,dw_1$)	AYB ($dw_2\,dw_2$)	Double dwarf ($dw_1\,dw_1$ $dw_2\,dw_2$)	X^2 (9:3:3:1)	P
1965	101	42	31	13	2.09	.70–.50

Table 2. Hypocotyl measurements of month old watermelon seedlings of double dwarf and vine types.

	Double recessive dwarf	Vine
No. of seedlings	25	25
mean length (mm)	38.28	83.44
range (mm)	26–64	64–102

t – 14.21, P < 1%

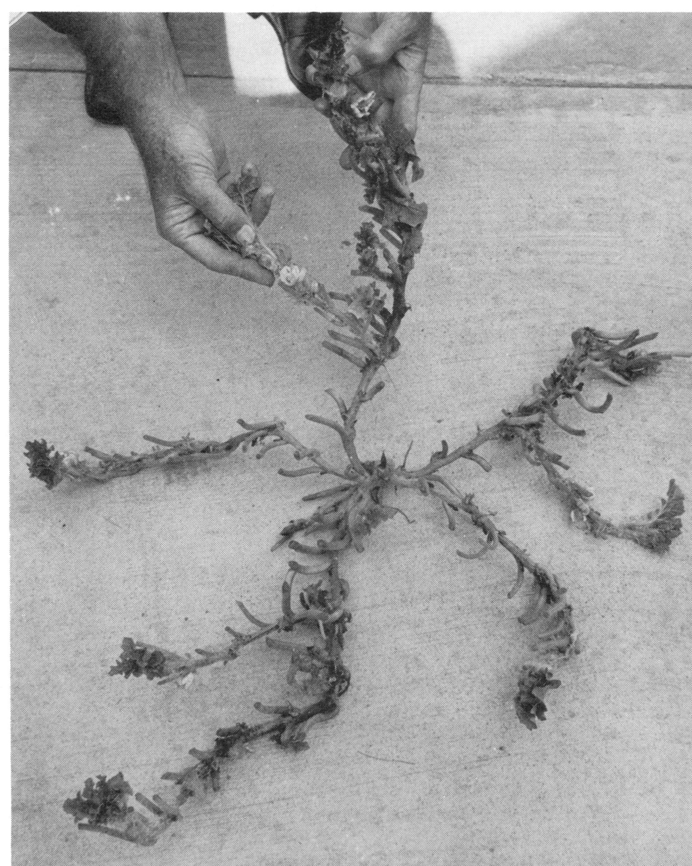

Fig. 3. Plant of double recessive dwarf (leaves removed) showing crown branching inherited from AYB and the intensification of the short internode characteristic.

Fig. 4. Experimental plot of double dwarf plants grown on plastic mulch. Plants resemble bush squash in size and form. They should immediately be acceptable for home gardens, eventually for commercial high density plantings.

ranged from 2.5 to 4 cm, of a dw_2 line from 3.5 to 5 cm, of a vine from 12–15 cm, and the double recessive dwarf produced internodes averaging only 1 cm long (Figs. 1, 2 and 3). The average number of nodes produced by these plants was 80 for the $dw_1 dw_1$ genotype, 160 for the $dw_2 dw_2$ genotype and 137 for the $dw_1 dw_1$, $dw_2 dw_2$ genotype.

The late maturity of the double recessive dwarf segregants that were obtained from the F_2 of the W-45 × AYB cross may be partially accounted for by the characteristically late maturity of both parents. However, the fact that plants of the other phenotypes in the F_2 were earlier than the double recessive dwarfs indicates that there is an inherent tendency to delayed maturity associated with the double recessive. The success in establishing lines of earlier maturity through outcrossing to 'New Hampshire Midget' conforms to results obtained with BDK (6).

The origin of numerous branches from the crown of the plant in AYB is a hitherto unreported characteristic. It is heritable, but the mode of inheritance has not been determined. It may be a pleiotropic effect of the gene dw_2, or may be closely linked with it. All double recessive lines obtained during the past 10 years have exhibited this characteristic, although the number of branches originating from the crown is different in different lines.

The short-hypocotyl characteristic permits elimination of vine segregants in segregating seedling populations. It also contributed to the compact growth of dwarf seedlings produced in pots or Jiffy 7's, a characteristic of much value in the production of transplants. Double dwarf plants remain in a condition suitable for setting out for several weeks, whereas vine types become overgrown within a few days.

Potential horticultural values of the double recessive dwarf are numerous. The plant, being comparable in size and form to bush squash (Fig. 4), should be readily accepted for home gardens. It is adapted to much closer spacing than the vine type and, thus, to intensive culture and large per acre yields. Studies on optimum spacing, fertility levels, etc. need to be conducted as soon as cultivars suitable for commercial use are available. The double recessive plant type also offers promise of contributing to development of a mechanized harvest system, should this become desirable in the future.

Literature Cited

1. Holm, E. 1969. Effects of two dwarfing genes in barley crosses. *Hereditas* 62:214–220.
2. Jodon, N. E. and H. M. Beachell. 1942. Rice dwarf mutants and their inheritance. *J. Hered.* 34:155–160.
3. Liu, P. B. W. and J. B. Loy. 1972. Inheritance and morphology of two dwarf mutants in watermelon. *J. Amer. Soc. Hort. Sci.* 97:745–748.
4. Mohr, H. C. 1956. Mode of inheritance of the bushy growth characteristic in watermelon. *Proc. Assoc. South Agr. Workers* 53:174.
5. ______. 1958. Bush Desert King Watermelon. Texas Agr. Expt. Sta. Leaflet 397.
6. ______. 1963. Utilization of the genetic character for short internode in improvements of the watermelon. *Proc. Amer. Soc. Hort. Sci.* 82:454–459.
7. ______. 1964. Vegetable breeding. 77th Ann. Rept., Ky. Agt. Expt. Sta. pg. 65.
8. ______. 1966. Developing varieties of the short-internode type in the cultivated *Cucurbitaceae*. Proc. of the XVII Internat'l, Hort. Cong. Vol. 1, pg. 61.
9. ______. 1970. Breeding dwarf watermelons. 83rd Ann. Rept. Ky. Agr. Expt. Sta. pg. 90.

Interaction of Planting Date and Powdery Mildew on Pea Plant Performance[1]

E. T. Gritton and R. D. Ebert[2]
Department of Agronomy, University of Wisconsin, Madison

Abstract. In weekly plantings of peas, *Pisum sativum* L., later plantings emerged faster and required less time to reach bloom and harvest stages than early plantings. Later plantings, however, required slightly more heat unit accumulation to reach the harvest stage than early plantings.

Powdery mildew (caused by *Erysiphe polygoni* D.C.) was severe in later planted plots 1 year. Unprotected plots yielded only 44 to 71% as much as protected plots. From those planting dates where powdery mildew affected yields, fungicide-sprayed plots had lower tenderometer values at harvest than unsprayed plots.

Yields of an early cultivar showed no particular trend with planting date except for drastic reductions in unprotected late planted plots 1 year. Yields of the late cultivar tended to decrease with delayed planting, with especially sharp reductions in unprotected late planted plots 1 year.

Peas for canning and freezing are planted over a period of time to separate the harvests and thus lengthen the processing period. Planting normally commences in spring as soon as the soil can be prepared, and continues as long as profitable yields can be expected, or until projected harvests interfere with processing of a later crop such as sweet corn. Growing conditions are generally more favorable for earlier plantings, while progressively later plantings are subjected to higher temperatures, drier soils, and greater incidence of insects and diseases.

[1] Received for publication March 6, 1974. Contribution from Dept. of Agronomy, WI Agr. Exp. Sta., Madison. Research supported by the College of Agricultural and Life Sciences, University of Wisconsin, Madison.
[2] Associate Professor and former specialist, respectively.