Y = 0 provides a preliminary estimate of the threshold top growth required for initiating bulb formation for all equations.

Yield. Total marketable bulb yields increased with an increase in transplant size (Table 1). "White Grano" normally produces few large bulbs and the few large bulbs produced in this study were classified as mediums to facilitate size grading. As transplant size increased, the yields of small onions declined and the yield and percent of medium sized onions increased. These results agree with those reported by Jones (4). The average size of mature bulbs declined as the severity of pruning increased. This resulted in an increase in yields of small bulbs and a decrease in the yield of medium bulbs. These results are similar to those reported by Hawthorne (3) and Davis and Jones (1).

Economic evaluation. The net dollar return/ha was significantly decreased by all pruning treatments compared to the control (Table 1). Returns were similar among the pruned treatments. Net returns were also reduced with a decrease in transplant size. The small and mixed transplants produced a net return significantly lower than the other 2 transplant sizes. The reduction in dollar value as a result of transplant pruning provides an estimate of one of the major costs of preparing transplants for mechanized transplanting. It also may indicate real costs to producers who have workers that prune transplants unnecessarily to facilitate handling and transplanting. A trade-off in reduced yields and crop value against reduced planting costs is therefore involved in the evaluation of the effects of transplant pruning. Transplant size accounted for 52% of deviations from the net returns' mean compared to 38% due to pruning. Large and medium size transplants produced above average returns while small transplants produced a below average return (Table 1).

Literature Cited


Resistance of Sweet Potato to Virus Complex

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Additional index words. Ipomoea batatas, plant breeding

Abstract. A core-graft transmission method has been used successfully for rapid screening of sweet potato (Ipomoea batatas (L.) Lam) for resistance to sweet potato virus complex (SPVD). Field test scores of resistance to SPVD were significantly correlated with core-graft test scores (r = 0.60). A high broad sense heritability estimate of 0.95 ± 0.02 for resistance to SPVD was computed based on the core-graft test for 24 cultivars tested in one year, while a lower broad sense heritability (h² = 0.48 ± 0.02) was estimated based on the field test for the same cultivars (except one) conducted at four locations for three years. Broad sense heritability estimates from diallel crosses ranged from 0.82 ± 0.02 to 0.98 ± 0.19. 'TIS 2498,' 'TIS 3228,' 'TIS 3053,' 'TIS 2544' and 'TIS 2534' sweet potato were resistant to SPVD.

Sweet potato virus disease complex (SPVD) is widespread throughout the world (4, 5, 7, 9), especially in Africa (1, 7, 11, 12). Schaefers and Terry (11) reported on a sweet potato virus disease complex in Nigeria consisting of 2 components, one of which was a virus (SPVD) causing vein clearing in Ipomoea setosa Ker, transmitted by aphids in a non-persistent manner and found to be latent in sweet potato in the absence of a second component. The other was a presently unidentified virus-like agent, transmitted by white flies (Bemisia tabaci Genn.). It was found to cause chlorotic stunt symptoms in Ipomoea setosa but was also latent in sweet potato in the absence of the aphid transmitted component. The two disease agents in combination produced severe disease symptoms of various combinations of leaf strapping, vein clearing, puckering and stunting in sweet potato and Ipomoea setosa. Although no etiological evidence was given, Mukibi (7) reported on the basis of symptoms that there are 10 synonyms used in reference to SPVD as described by different authors on different cultivars. Mechanical transmission of the aphid component of SPVD from infected plants to I. setosa has only been achieved with difficulty (3).

In Africa the yield of fresh storage roots from plants showing SPVD symptoms was reduced by 57 to 80% (1, 2, 6). Reduced root yield was associated with smaller photosynthetic organs due to severe stunting and strapping (1).

The core-graft method of Nusbaum has been used for rapid screening for resistance to internal cork virus (8, 14). Terry (13) reported that this method was very efficient in transmitting the SPVD agents and in screening sweet potato for resistance to the disease. The leaves of the sweet potato sprouts which arise from storage roots challenged with the core tissues from the virus-carrying storage roots, developed the characteristic SPVD symptoms usually within 11 to 13 days.

There are no reports of resistance of sweet potato to SPVD and none on breeding of sweet potato for resistance to the disease in Africa. This paper reports the screening methodology, cultivar differences in resistance to SPVD, and heritability of resistance to the disease.

Field test. A total of 23 IITA improved cultivars were planted for yield trials at 4 locations with different soils and climatic conditions within Nigeria from 1976 to 1978. A randomized complete block design was used with 4 replications. Each plot consisted of 2 rows 10 m long and 1 m apart. Planting space between plants within rows was 30 cm. Cuttings (slips) as planting material were obtained from the top 30 cm of shoots of plants which had been exposed to SPVD in the field at IITA for the previous 6 to 8 years. Resistances of cultivars to the disease under the field conditions were scored on an 0-5 basis taking into account both disease incidence and severity: class 0 = no visible SPVD symptoms on all plants in a plot; class 1 = very mild symptoms on 5% plants; class 2 = mild symptoms on 10% plants; class 3 = moderate symptoms on 25% plants; class 4 = severe.
were symptoms on 50% plants; and class 5 = very severe symptoms on more than 75% plants.

The average SPVD scores for 23 cultivars ranged from 0.9 to 3.2 (Table 1). Since these cultivars were selected on the basis of field performance for 6 to 8 years, and average disease scores of 4 locations and years were used, differences among the cultivars in the score were, as expected, not as distinct as in the case of unselected seedlings. However, unselected seedlings showed a range from 0 to 5.

Core-graft test. Storage roots of the 23 cultivars used for the field test plus one additional cultivar were challenged using the core-graft method of Nusbaum (8, 14) and core tissues from the storage roots of the SPVD susceptible cultivar, TIS 1499 which was naturally infected. Twelve storage roots from each cultivar were challenged, each storage root receiving one core tissue, and were divided into four lots to make replications. The challenged storage roots were planted in the nursery bed in a randomized complete block design with four replications. Resistance was scored as for field test on the basis of severity only. The average SPVD scores of the 3 storage roots of each cultivar were used for statistical analysis.

The average SPVD scores tested by the core-graft method ranged from 1.0 to 5.0 which was greater than with the field test (Table 1). Some cultivars had a low score in both tests. To relate the field test scores with core-graft scores, a correlation coefficient was calculated as $r = 0.60$, which is significant at 1% level and indicates that core-graft results agree well with field results.

At IITA, screening sweet potato breeding material for resistance to SPVD has been based on phenotypic expression of symptoms severity and incidence in the field relying upon natural infection by viruliferous vectors. The field transmission efficiency of the SPVD agents by vectors is quite low. Vector population size fluctuates with years. For this reason, it normally takes 1 to 3 years before seedlings show pronounced SPVD symptoms under field conditions. Field screening of seedlings for resistance to SPVD at IITA has thus been very slow and not very efficient. Attempts to rear the 2 vectors for rapid and mass screening of seedlings for resistance to SPVD have been made under controlled conditions without success. The core-graft technique overcomes this difficulty and is efficient in screening large numbers of seedlings from the sweet potato breeding program. Symptom development after inoculation is quite rapid: 11-25 days after inoculation. Selected plants can be tested further for resistance to SPVD and other horticultural characters.

The significant correlation ($r = 0.60$) between field scores and positive core-graft test scores indicates that resistance of sweet potato to SPVD may not depend on resistance to vectors. However, since the plants of 23 cultivars had been grown in the field for long periods of time (6 to 8 years) there is a chance that the plants were already infected by SPVD. This may have contributed to high correlation between field scores and core-graft test scores. Terry (13) reported that when individual plants of the resistant cultivar TIS 2498 were challenged by the core-graft method only 10% of plants from it showed positive responses compared with 85 to 90% for susceptible cultivars. It is thus assumed that the nature of resistance appears to be associated with resistance to infection (13). There were differences in cultivars in recovery and in time of symptom expression after they were challenged.

The fact that resistant cultivars showed significantly low SPVD severity ratings and small percentages of disease infected plants for the previous 6 to 9 years under relatively heavy disease pressure in the field, suggests that the rate of disease spread is limited in plantings of resistant cultivars. This indicates that another dimension to resistance is resistance to spread of disease agents within the planting. Resistance of sweet potato to vectors play a part, which needs further investigation.

**Diallel crosses.** Two diallel crosses (one set of F$_1$s, neither parents nor reciprocal F$_2$s were included): 6 x 6 and 8 x 8 were made in 1974 and 1975 respectively, using parents ranging from susceptible to resistant to SPVD. For the 6 x 6 diallel cross, 50 seedlings for each of 15 cross combinations were divided into 2 groups consisting of 25 seedlings to make 2 replications. For the 8 x 8 diallel cross, a total of 22 seedlings from each of 36 cross combinations were raised in the nursery and 3 cuttings were made from each seedling to make 3 replications. Two field tests were planted each year, one in the rainy season and one in the dry season. Each plot of the 1974 resistance trial consisted of 2 rows of 25 seedlings of a cross and that of 1975 trial consisted of 22 seedlings. Randomized complete block designs are used with 2 replications for the 1974 resistance trial and 3 replications for the 1975 trial. Since the test plants in the dry season showed a higher incidence of virus symptoms, which may be due to longer exposure to virus infection in the field, only the SPVD score data taken in the dry season trials were used for estimation of heritability of resistance.

**Heritability.** Broad sense heritabilities for resistance to SPVD were estimated by variance component methods using the data of the field test, core-graft test and diallel crosses. For field tests with 4 replications of each cultivar tested at 4 locations for years, the phenotypic variance was estimated by

$$\sigma^2_p = \sigma^2_v + \sigma^2_{yj} + \sigma^2_{vl} + \sigma^2_{yl} + \sigma^2_{e}$$

where $\sigma^2_v$, $\sigma^2_y$, $\sigma^2_{vl}$, and $\sigma^2_e$ are the cultivar, year, location and family variance components obtained from the combined analysis of variance. For the core-graft test with 4 replications of each cultivar tested in 1 year, the phenotypic variance was estimated by

$$\sigma^2_p = \sigma^2_v + \sigma^2_{yl} + \sigma^2_{vl} + \sigma^2_{e}$$

For diallel crosses, the phenotypic variance components were estimated by

$$\sigma^2_p = (\sigma^2_v + \sigma^2_{yl} + \sigma^2_{vl} + \sigma^2_{e})$$

where $\sigma^2_v$, $\sigma^2_y$, $\sigma^2_{vl}$, and $\sigma^2_e$ are the family, family x year, location and family x year location variance components and $r$ is number of replications. Heritability was obtained by dividing the estimate of cultivar or family variance by the appropriate phenotypic variance. Standard errors of the heritability estimates were obtained following the method described by Pesek and Baker (10).

Heritabilities of resistance to SPVD on a mean basis and their standard errors which were estimated using the virus score data from 2 sets of diallel crosses and varietal trials in the field with a natural and core-graft tests are presented in Table 2. Higher heritability estimates were obtained from the field tests of unselected families than from selected clones as expected.

### Table 1. Average sweet potato virus scores of replicated field trials at four locations for three years and of a core-graft test with four replications in one year.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Field test scorea</th>
<th>Core-graft transmission test scorea</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIS 2534</td>
<td>0.9a</td>
<td>2.0b</td>
</tr>
<tr>
<td>TIS 2498</td>
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<td>1.0a</td>
</tr>
<tr>
<td>TIS 3328</td>
<td>1.0a</td>
<td>1.0a</td>
</tr>
<tr>
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<td>1.2ab</td>
<td>1.5ab</td>
</tr>
<tr>
<td>TIS 3053</td>
<td>1.4ab</td>
<td>1.0a</td>
</tr>
<tr>
<td>TIS 2532</td>
<td>1.6bce</td>
<td>2.0be</td>
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<tr>
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<td>2.0be</td>
</tr>
<tr>
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<td>2.5cd</td>
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<td>3.00</td>
</tr>
<tr>
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<td>2.5cd</td>
</tr>
<tr>
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<td>1.9bcf</td>
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</tr>
<tr>
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<td>4.0ef</td>
</tr>
<tr>
<td>TIS 2153</td>
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<td>3.3de</td>
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<td>5.0g</td>
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<td>2.2elg</td>
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</tr>
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<td>TIS 1499</td>
<td>2.8hij</td>
<td>5.0g</td>
</tr>
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<td>2.8c</td>
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</tr>
<tr>
<td>TIS 1145</td>
<td>3.2j</td>
<td>4.3fg</td>
</tr>
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Large volumes of water are used to cool various industrial processes. Spent cooling waters usually exit the industrial process at about 38°C. Heat in the water is dissipated via spray ponds, cooling towers, or cooling lakes to eliminate the effects of thermal pollution before the water can be returned to native water resources. Electrical power plants are a major source of this reject heat. For example, a 1,000 mega-watt plant produces about 40,000 liters per second of waste heated water. Boersma et al. (1) reported soil warming could be used to enhance the growth of corn, tomato, strawberry, snap bean, and several other crops. In the southeastern U.S., summer soil temperatures may not be favorable for production of many crops and with the addition of soil warming this effect is magnified (4). This study was instituted to determine if sweet potatoes could be successfully grown in the high soil temperature regime resulting from soil warming and to determine the influence of soil warming on growth and development, root quality and skin color.

'Jewel' and its red skin mutant, 'Copper Skin Jewel' sweet potato were planted 30 cm within the row and 106 cm between the rows on June 6, 1974, at the Central Crops Research Station, Clayton, N.C. Each plot was a single row 6 m long, and the center 3.6 m was harvested for yield and quality. Plants were fertilized with 30 N–25 P–24.9K kg/ha at planting sidedressed with 50 N–P–99.6K kg/ha at final cultivation on July 18.

Eight treatment combinations were compared as follows: soil warming (38°C water, circulating 50 cm deep in 2.5 cm polyethylene pipes spaced 50 cm apart); evaporative cooling irrigation (20 mm per hr between 1100-1200 and 1400-1500 daily); subirrigation (15 mm water per day directly at the soil warming pipe level); no treatment; and all combinations of the above (4). These environmental modifications constituted a 2 x 2 factorial design and the 2 cultivars were treated as subplots in an overall split-plot design with 2 replicates. Because of funding limitations this study was conducted for only 1 year and the results should be considered as preliminary.

Plots were harvested on October 11 following a frost on October 4 which killed the tips of some leaves in most treatments. The foliage material in a 3.6 m long section of row was removed and weighed. Subsamples of the foliage were taken for dry weight determinations. The roots were graded according to USDA guidelines as jumbo, U.S. #1 large, U.S. #1 small, canners, and culls. The sweet potatoes in each grade were weighed and 2 subsamples of 10 roots each removed from U.S. #1 large small roots. A set of samples was used for immediate determination of raw product quality, and other stored. The stored samples were held for 1 week at 21°C, cured for 1 week at 30° and 90% relative humidity, then stored at 15° and 90% relative humidity for 3 more weeks.

Quality factors were determined on both raw and stored roots. Epidermis color intensity was rated on washed roots.