Strategies for Improving Protein Production in Sweet Potatoes[1/]

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Abstract

Sweet potato cultivars contain a consistent level of nitrogen in the roots relative to one another over the years. Percentage of nitrogen in the roots is inversely related to fresh wt yield and % N fwb is more closely related than % N dwb. An increase of % N dwb would be expected to increase protein yield. It may be possible to establish a method of selecting for increased nitrogen concentration in the roots by selecting lines on the basis of nitrogen concentration in the leaves. This would facilitate selection and make it relatively more simple to select for both fresh wt yield and N simultaneously.

Introduction

Sweet potatoes have a remarkable potential for contributing to the nutritional needs of the world population. Extrapolating from USDA Handbook 8 (Watt and Merrill, 1975), we find that, on a per calorie basis, sweet potatoes provide at least 90% of the RDA of all nutrients except protein (73%) and Niacin (81%) for a male aged 23-50 yrs old, weighing 70 kg, and 172 cm in height. Substantial contributions to the diet can also be made by the foliage and young stem tips of sweet potato vines.

Sweet potatoes are of tropical origin, and have not received much attention among breeders of tropical crops. Substantial improvements are possible and sweet potatoes may play an increasingly important role in the diets of many people in the tropics.

Since the RDA of protein per calorie was lower than other nutrients, protein production, and the components of protein production were investigated with the hope of determining a strategy for the genetic improvement of protein production.

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Literature Review

Several investigators have studied protein levels in sweet potatoes. Reports vary from 1.73 to 11.8% protein on a dry wt basis (Adolph and Hsi-Chen, 1939); AVRDC, 1977; Cooley, 1948; Crosby, 1964; Darlow et al, 1950; Jurits. 1921; Murthy and Swaminathan, 1954; Purcell et al, 1972). Sweet potatoes with a protein content of 8% dwb provide an adequate protein-calorie ratio (Purcell, et al 1978). Reports of amino acid composition in sweet potato roots (Crosby, 1964; Nagaze, 1957; Purcell et al, 1972; Purcell et al, 1978, Yamamoto, 1953-54) show the protein to be of good quality with chemical indices ranging from 57-98, depending on cultivar and index used. In general sweet potato protein contains an excess of lysine and a deficiency in tryptophan.

Protein content has been reported to be affected by the length of growing season (Purcell et al, 1976; Togari and Shirasawa, 1955) (generally decreasing as harvest is delayed), irrigation (Constantin et al, 1974) (decreased with irrigation), nitrogen fertilizers (Constantin et al, 1974; Li, 1977) (increased with increasing rates of applied N), growing location (Purcell et al, 1978; Ruinard, 1967) and nitrogen distribution within the root (Purcell et al, 1976) (slightly higher concentration at the stem end).

Several authors have reported that trypsin inhibitors are present in raw roots (AVRDC, 1976; Sohenic and Honawan, 1956) and that cooking improves the protein digestibility substantially (Cerning-Bernard and Le Dividich, 1976). It has also been reported (AVRDC, 1976) that the levels of trypsin inhibitors increases as protein level increases but that the heat stability of these inhibitors may vary among cultivars.

Materials and Methods

Replicated plots of 23 to 29 cultivars and breeding lines were grown for 4 years (1975-78) at the University of Maryland Vegetable Research Farm, located at Salisbury, MD (latitude 38° 25' N). The soil type was Norfolk sandy loam with approximately 1% organic matter. Plots received 1680 kg/ha of 5-10-20 fertilizer with 2% MgO. One-third of the fertilizer was broadcast before transplanting, one-third topdressed on the rows 1 month after transplanting and one-third topdressed 2 months after transplanting. Plots were planted between May 20 and May 30 using sprouts and harvested between September 5 and September 27, for a growing season ranging from 108 to 126 days, depending on the year. Spacings were 30 cm between plants and 90 cm between rows.

At harvest, the roots from each plot were graded and weighed. In 1975, one sample of each cultivar was obtained for dry matter and nitrogen determinations. In 1976, 1977 and 1978 one sample was obtained from each plot for dry matter and nitrogen determinations.

Dry matter contents were determined from forced air oven dried samples (70°C) and nitrogen was determined by semi-micro Kjeldahl using selenium and copper catalysts. Protein yield, dry matter (DM) yield and percent N fresh wt basis (fwb) were calculated from the data of fresh wt yield, percent dry matter (DM) and percent N (dwb).

In the 1978 growing season, leaf samples were obtained on July 27, in the mid-afternoon; July 28, early in the morning; August 1, in mid-morning; and September 22, in mid-afternoon. Leaf samples consisting of 10 fully expanded young leaf blades and petioles were taken randomly from each plot. Leaf samples were dried and analyzed for N concentration as described for the root samples. The plots were harvested on September 26.

Standard analysis of variance, correlation and regression procedures were used to analyze the data.

Results and Discussion

Eight cultivars and breeding lines were common to the 3 years (1976-78) for which replicated data are available for all yield variables (fresh wt yield, % DM, % N dwb, % N fwb, DM yield and protein yield). It may be noted from Tables 1 and 2 that all yield variables were significantly affected by years and cultivars. All variables except % N dwb and % N fwb had a significant year x cultivar interaction. On the basis of these data, it would seem that the relative levels of % N dwb and % N fwb are consistent over years and selection for these variables in a single year may be an effective way to increase protein yield.

It has been reported that yield and protein content are inversely related (AVRDC, 1977; Li, 1977). To study the relationship among cultivars with regard to protein yield and its components, correlations were computed based on cultivar means. The results for 4 years (1975-1979) are presented in Table 3. Since the correlation matrices for the 4 years appear similar, the correlation coefficients were tested for homogeneity. Each set of correlation coefficients (i.e. all correlation coefficients for fresh wt yield and DM etc.) was found to be homogeneous and a pooled correlation coefficient was calculated.

Since a linear correlation matrix is identical to a standardized linear regression matrix, one may examine the pooled correlation matrix for indications of effects on the basis of single trait selection on the improvement of protein yield. Selection for high fresh wt yield would probably result to an improvement in protein yield and DM yield, but may also result to a reduction in % DM, % N dwb and % N fwb. Selection for high % DM would probably decrease fresh wt yield, % N dwb, and DM yield, increase % N fwb and not change protein yield. Selecting on the basis of % N dwb would likely result in slight reductions in fresh wt yield and % DM, a somewhat larger reduction in DM yield, an increase in % N fwb and increase in protein yield.

Selecting on the basis of % N dwb has three advantages in addition to improving protein yield; there is no significant year x cultivar interaction, improving % N dwb will result in a more acceptable protein-calorie ratio, and fewer measurements and calculations are required since it is not necessary to measure fresh wt or calculate % DM.

In practice, selection based on % N dwb or % N fwb is cumbersome since nitrogen determinations must follow harvest, and selections are most easily made at harvest time.

It has been reported (Togari and Shirasawe, 1955) that N levels in the leaves and petioles roughly follow N levels in the roots throughout the growing season. If nitrogen concentrations in the leaves were related to nitrogen concentration in the roots it might be possible to obtain leaf sample several weeks before harvest and select for both yield and % N in the roots at harvest time.

In order to investigate the relationship between leaf nitrogen concentrations and root nitrogen concentrations, we obtained leaf samples on 4 dates as previously described. Analysis of variance revealed significant effects for cultivars and sampling dates for % N dwb and % N fwb but no significant interaction effects. This suggests that while nitrogen concentrations in the leaves may vary among dates, the relative level of cultivars remains similar. Correlation coefficients were calculated between nitrogen concentrations in the roots and leaves and are presented in Tables 4 and 5.

Several conclusions seem warranted based on the correlation coefficients. First, % N dwb seems more consistent than % N fwb among sampling dates as can be seen from correlation coefficients between samples. Second, correlation coefficients between leaf samples and root samples increase as the samples are obtained closer to harvest time. This suggests that leaf samples should be obtained as near to harvest time as practical. Third,

both % N dwb and % N fwb in the leaves are related to % N dwb and % N fwb in the roots.

Polynomial regressions were calculated between % N fwb in the roots and % N fwb in the 4th leaf sample, % N dwb in the roots and % N dwb in the 3rd leaf sample and % N dwb in the roots and % N dwb in the 4th leaf sample. Analysis of the regression components revealed that root % N fwb as predicted by leaf % N fwb (4th sample) and root % N dwb as predicted by leaf % N dwb (3rd sample) were linear in effect and that root% N dwb as predicted by leaf % N dwb (4th sample) had significant liner and cubic components (Fig. 1).

It has been reported (Naka and Tanaki, 1957) that up to 25% of the N present in leaf blades and 75-80% of the N present in petioles is non-protein nitrogen. We believe that if leaf nitrogen is divided into nitrate nitrogen and reduced nitrogen we will obtain better models. Work on this phase is continuing.

Rather surprisingly, we found a relationship between % DM in the leaves and in the roots (Table 6). We are not sure of the importance of this finding since it is probably not useful to attempt to select for % DM in roots. However, it does indicate that perhaps some of the genes controlling physiological traits in the above ground portions also have activity in storage roots. This may be explained by the fact that both the source and sink are strictly vegetative organs in sweet potatoes.

Conclusions

Sweet potato cultivars contain a consistent level of nitrogen in the roots relative to one another over the years. Percentage of nitrogen in the roots is inversely related to fresh wt yield and % N fwb is more strongly related than % N dwb. An increase of % N dwb would be expected to increase protein yield. It may be possible to establish a method of selecting for increased nitrogen in the roots by selecting lines on the basis of nitrogen concentration in the leaves. This would facilitate selection and make it relatively more simple to select for both fresh wt yield and % N simultaneously.

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