Using Competing Traits to Select Dual-Purpose Sweetpotato in Native Germplasm

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Eighteen accessions of sweetpotato (*Ipomea batata* L.) were selected using the ratio of root/forage dry-matter production (R/F) and classified into four groups: (1) forage, (2) low dual-purpose, (3) high dual-purpose, and (4) low forage-high root production. Roots and vines produced between 120 and 150 days on plots of 10 square meters were evaluated over two years and analyzed in a fixed linear covariance model, including group, accession (group), and days as covariables. There was a significant difference among groups ($P < 0.01$) for total forage and root dry matter, total commercial roots, and root to forage dry matter. Significant differences of accessions within groups on total forage dry matter and commercial roots indicate that there is enough within-group variability among the accessions to allow a process of selection. The least-squares means for dry-matter forage production ranged from 6.07 ± 0.27 kg/10m^2 for group 1 to 4.43 ± 0.38 kg/10 m^2 for group 4. Total root production dry matter (DM) ranged from 2.04 ± 0.54 kg/10 m^2 for group 1 to 8.22 ± 0.50 kg/10 m^2 for group 4. The total commercial root produced was 2.99 ± 0.60 kg DM/10 m^2 for group 2 and 3.32 ± 0.55 kg/10 m^2 for group 3. This represents 132% more root production than group 1 and almost 36% less than group 4. The average weight of commercial root ranged from about 144 g to 259 g, with a significant difference between groups. The results show that a number of accessions have potential as dual-purpose sweetpotatoes. These are DLP-3548, DLP2481, ARB265, and ARB-158, defined as forage in group 1; DLP-3525 and DLP-2462, defined as low dual-purpose; and ARB-394 and DLP-275A, defined as high dual-purpose.

Sweetpotato (*Ipomea batata* L.) is one of the 12 main plant species used as human food throughout the world (Woolfe, 1992). Sweetpotato roots are used for both human and animal consumption, whereas vines are generally used for animal feed along with crop residues and unmarketable roots, depending on local preferences and customs (Woolfe, 1992). When grown for animal fodder, the sweetpotato has several advantages over other feed crops in semi-subsistence farming systems. One major advantage is that it may also provide food for human consumption. An optimally integrated livestock-management system can use the sweetpotato's ability to regenerate by continually or sporadically harvesting the vines throughout the growing season before finally harvesting the root (León-Velarde and Gomez, 1996). The emphasis in this practice is on green forage production; cutting the vines significantly increases the yield and

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growth rate of the aerial part of the plant, while decreasing the yield of the root.

The germplasm collection held at CIP includes multi-use sweetpotato varieties, clones, and accessions. However, recent breeding efforts have concentrated on dry-matter content for flour and starch. But in recent years, the demand for varieties that produce forage has increased.

In mixed crop-livestock production systems, one limitation on productivity is the year-round requirement for feed. The sweetpotato can help to overcome this limitation without environmental damage. It can also contribute to the family's nutrition and household income. Previous studies have demonstrated that a group of accessions have both forage and root production that can help small farmers to increase their income as well as the availability of fodder (Arteaga, 1997; Gomez and Quesada, 1996). The favorable agronomic characteristics of these accessions include general hardiness, low input needs (due at least in part to the presence of vesicular-vascular mycorrhiza), and rapid vine growth in response to fertilizer (Tupus, 1983).

Sweetpotato has potential for intercropping, is easy to propogate, has few crop pests and diseases, and provides good ground cover for soil conservation. In addition, the sweetpotato has desirable characteristics as fodder because of its high levels of both energy and protein from the roots and vines, and its palatability. The vines are highly digestible for consumption by both ruminants and monogastrics, and the generally low levels of enzyme inhibitors in the vines make it suitable for pre-drying or silage (Ruiz, 1982).

A dual-purpose sweetpotato would have a comparative advantage over accessions and clones selected only for roots or forage production. It would provide food for human consumption, and an optimally integrated livestock-management system could utilize the sweetpotato's ability to regenerate by continually or sporadically harvesting the vines throughout the growing season before finally harvesting the roots.

To test this hypothesis, preliminary studies were done to evaluate a selected group of accessions (León-Velarde, 1999). The evaluation was done on management effects and use (digestibility and conservation). Cutting frequency, plant density, and level of fertilization were the main management effects considered. The variety Helena (ARB-UNAP55) was evaluated in San Ramon, Oxapampa, Huachipa, and Cajamarca. Five accessions were evaluated in Oxapampa and Huancamba. These included DLP-3548, ARB-265, ARB-142, RCBIN-5, and Helena. The five accessions produced an average of 12.5 ± 2.5 t/ha of total forage and 2.3 ± 0.9 t/ha of total root dry matter. A cut frequency of 90 days during crop growth gave the best balance between forage and root production. A cut frequency of 45 days tended to reduce regeneration, resulting in lost forage production and nil root production. A level of fertilization from 0 to 180 kg of N increased Helena's forage production from 6.7 t DM/ha to 9.1 t DM/ha (six cuts at 45-day intervals), from 6.1 t DM/ha to 8 t DM/ha (three cuts at 90-day intervals), and from 5.4 t DM/ha to 6.2 t DM/ha at a cut interval of 135 days (Quispe, 1997; Arteaga, 1997).

Use of sweetpotato as forage depends on its cost and marginal production in relation to other forages. Sweetpotato can be used in silage with maize (75% maize without ear-husk and 25% sweetpotato) as a form of storage that does not diminish nutritional value (Guerra and León-Velarde, 1998). The digestibility of the silage is around 65% in this combination, decreasing to 48% when sweetpotato proportions were increased. Silage using 75% sweetpotato forage and 25% roots did not affect milk production in dairy cows, and feeding costs were reduced (Sanchez, 1995).

Although, several studies have indicated the sweetpotato's potential for animal feed, additional studies are necessary to link root and foliage production in crop-livestock farming systems. Limiting factors, such as the activity of the trypsin inhibitor in the vines and its effect on ruminants and monogastrics, need to be defined. The research on the sweetpotato as a dual-purpose crop reported here evaluated alternatives for assessing its more effective use in crop-livestock production systems.

Materials and Methods

Considering the numbers of clones available in the CIP collection at the San Ramon experiment station, future selections for dual-purpose varieties could include characteristics that favor livestock production.

Clone selection

The first step in the research reported here was to analyze the germplasm, considering the ratio of total dry matter of roots to vines (R/F), and to classify it into five groups: forage (R/F of 0–1), low dual-purpose (R/F >1–1.5), high dual-purpose (R/F >1.5–2.0), low root production (R/F >2.0–3.0), and high root production (R/F >3.0) (León-Velarde et al., 1997). Based on this classification, 18 accessions were selected and reclassified into four groups as follows: group 1, forage (9 accessions); group 2, low dual-purpose (2 accessions); group 3, high dual-purpose (2 accessions); and group 4, low forage-high root production (5 accessions). Accessions classified as high root production were not included.

Statistical analysis

Four evaluations from years 1999 and 2000, carried out between 120 and 150 days on plots of 10 square meters were analyzed according to a fixed linear covariance model:

$$Y_{ijk} = \mu + \upsilon_i + \delta_{ij} + \beta(x_{ij} - \bar{X}_{ijk}) + \varepsilon_{ijk}$$

where υ_i is the group effect, δ_{ij} is the accession (group) effect, and β is the regression effect of the covariate. Only accessions with at least three observations were considered (SAS, 1996). The variables: total dry matter for forage, proportion of commercial and non-commercial roots (CR/NCR), and ratio of root to forage (R/F) were analyzed, with 137 observations for each. Total root dry matter production (107 observations) and commercial (100 observations) were analyzed; and 98 observations of commercial root weight. Least-squares means and standard errors are presented in Table 1.

Results and Discussion

Table 1 shows the evaluation done on 18 accessions classified into four groups. There was a significant difference ($P < 0.01$) among groups for total dry matter of forage and roots, total dry matter of commercial roots, and CR/NCR ratio as well as R/F ratio. The covariate (days) was not significant for total dry matter of forage and roots, commercial weight, or R/F ratio; it was significant for commercial weight and proportion of commercial and non-commercial roots ($P < 0.05$). This is related to the large differences found among groups for commercial root weight, which ranged from 140.27 g to 258.87 g. The information presented in Table 1 was sorted by total dry matter of forage then by total and commercial root dry matter in order to observe the relative importance of the dual-purpose sweetpotato. The results obtained indicate that the classifications fit the selected accessions. Nevertheless, there was a significant difference ($P < 0.01$) of accessions (group) because of the variability and characteristics of each selected accession, particularly in group 1. Further evaluation of the results showed the possibility of subdividing this group based on the CR/NCR ratio. A subgroup of forage sweetpotatoes without roots was then defined and evaluated. The other subgroup within group 1 can be considered mainly for forage but with some root production. It

Table 1. Least-squares means and standard error for the evaluation of the main characteristics of dual-purpose sweetpotato, San Ramón, Peru.

Group	Variety	Total forage DM	Total root DM	Commercial root DM	Commercial root weight, g	Ratio CR/NCR	Ratio R/F
1. Forage		6.07 ± 0.27 a	2.04 ± 0.54 a	1.36 ± 0.40 a	143.79 ± 15.50 a	0.27 ± 0.03 a	0.32 ± 0.10 a
	DLP-3548	7.26 ± 0.80	0.32 ± 2.14	0.22 ± 1.51	-	0.14 ± 0.08	0.01 ± 0.29
	DLP-2481	7.09 ± 0.80	2.51 ± 1.52	1.50 ± 1.07	220.09 ± 44.32	0.24 ± 0.08	0.25 ± 0.29
	ARB-265	7.00 ± 0.80	0.06 ± 2.31	-	-	0.00 ± 0.08	0.01 ± 0.29
	ARB-158	6.69 ± 0.80	3.71 ± 1.23	2.16 ± 0.87	157.99 ± 35.91	0.46 ± 0.08	0.58 ± 0.29
	HELENA	6.47 ± 0.80	-	-	-	-	0.00
	DLP-2448	5.88 ± 0.80	3.00 ± 1.23	2.25 ± 1.07	139.90 ± 44.22	0.27 ± 0.08	0.50 ± 0.29
	ARB-389	5.25 ± 0.80	2.62 ± 1.07	1.42 ± 0.81	118.25 ± 33.28	0.35 ± 0.08	0.61 ± 0.29
	DLP-90052	5.05 ± 0.80	2.04 ± 1.07	0.94 ± 0.81	102.52 ± 33.29	0.33 ± 0.08	0.45 ± 0.29
	RCBIN-5	3.90 ± 0.93	2.07 ± 1.23	1.06 ± 0.87	124.16 ± 35.91	0.64 ± 0.09	0.48 ± 0.42
2. Low dual-purpose		5.77 ± 0.59 a	4.93 ± 0.84 b	2.99 ± 0.60 b	258.87 ± 24.47 b	0.52 ± 0.06 b	0.94 ± 0.21 b
	DLP-325	6.24 ± 0.80	4.07 ± 1.23	2.35 ± 0.87	253.71 ± 35.91	0.47 ± 0.08	0.66 ± 0.29
	DLP-2462	5.29 ± 0.85	5.78 ± 1.14	3.65 ± 0.81	264.03 ± 33.23	0.57 ± 0.09	1.21 ± 0.31
3. High dual-purpose		5.08 ± 0.59 ab	4.99 ± 0.78 b	3.32 ± 0.55 b	183.00 ± 22.75 ac	0.57 ± 0.06b	1.27 ± 0.21 b
	ARB-394	5.28 ± 0.80	4.50 ± 1.07	3.41 ± 0.75	225.74 ± 31.08	0.63 ± 0.08	1.14 ± 0.29
	DLP-275A	4.87 ± 0.85	5.47 ± 1.14	3.27 ± 0.81	140.27 ± 33.23	0.50 ± 0.09	1.41 ± 0.31
4. Low forage-high root production		4.43 ± 0.38 b	8.22 ± 0.50 c	4.29 ± 0.36 b	178.03 ± 14.73 ac	0.49 ± 0.04 b	2.31 ± 0.14 c
	SPV-65	6.36 ± 0.85	7.32 ± 1.14	4.38 ± 0.80	218.52 ± 35.28	0.54 ± 0.09	1.31 ± 0.31
	CC-89213	4.69 ± 0.80	5.07 ± 1.07	2.40 ± 0.81	112.41 ± 33.23	0.34 ± 0.08	1.38 ± 0.29
	ARB-UNAP74	3.99 ± 0.93	10.06 ± 1.23	5.22 ± 0.87	226.15 ± 35.91	0.52 ± 0.10	2.64 ± 0.33
	SR-90323	3.91 ± 0.80	8.50 ± 1.06	3.76 ± 0.75	140.45 ± 31.08	0.48 ± 0.08	2.28 ± 0.29
	SPV55	3.22 ± 0.80	10.17 ± 1.07	5.74 ± 0.75	192.68 ± 31.08	0.57 ± 0.08	3.94 ± 0.29

Total dry matter (DM) is expressed in kg/10 m2; CR/NCR = commercial and non-commercial roots; R/F = root to forage. Least-squares means of groups with the same letter within a column are not significantly different ($P \leq 0.05$). Least-squares means of variety (group) are sorted by total dry matter of forage, roots, and commercial roots.

is necessary to mention that in group 1, four accessions had previously been evaluated in Oxapampa and Huacho: namely, ARB-265, DLP-3548, RCBIN-5, and ARB-UNAP55 (Helena) (Fonseca, 1996). Results showed that there is some potential for forage and roots; however, the change in production between sites indicated a possible genotype x environment interaction, which needs to be considered for diffusion and use in other areas. Helena, which has an RF ratio of 0, is considered a forage variety. However, in certain places, such as Oxapampa, Peru, and Africa, Helena has been found to produce some roots (Ted Carey, pers. comm.). This could be evidence of a genotype x environment interaction.

The accessions suited mainly for forage are DLP-3548, DLP-2481, ARB-265, and ARB-158. For dual-purpose use, DLP-2448, ARB-389, and DLP-3525 present a range of total dry-matter forage from 5.25 kg/10m^2 to 6.24 kg/10m^2 and commercial roots ranging from 1.42 kg/10m^2 to 2.35 kg/10m^2, with a weight of 118.25 g to 253.71 g/root.

Some accessions in group 1 produced a similar quantity of dry-matter forage to that produced by accessions in group 2; however, the main difference is the consistent commercial root production and the ratio of CR/NCR. Possible dual-purpose selections would be accessions DLP-2462 and ARB-394. Similarly, in group 4, which had high root production but less forage dry matter, accession ARB-UNAP74 needs further evaluation since it shows high root production with forage production similar to that of groups 2 and 3.

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