Potential role of sweet potato to improve smallholder crop-livestock production systems

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Abstract

Sweet potato (*Ipomoea batatas*) is grown for different purposes: human consumption, animal feeding, and industrial products (biofuel). Vines, foliage and un-saleable or damaged roots are frequently used to feed animals in Latin America, Africa and East Asia. Demand for feed, fodder, fuel, and traditional supplements are increasing and competing with human needs. Sweet potato (SP) offers a viable alternative to satisfy different demands by using it as a dual-purpose crop. Nineteen clones were selected on the basis of the roots/vines (R/F) ratio for animal feeding and human or industrial use. A modification of traditional crop management consisting in different cutting frequencies was evaluated. Results have shown that cuts at about 75 days of growth reduced root production by 27% while vine production was increased by 25.1%, increasing total biomass by 11-19.5%. This cutting regime provided biomass to be conserved as silage to be used alone or as a supplement for pig feeding as well as roots for different uses. The utilization of SP stands by grazing/foraging pigs caused no significant effect on soil structure or organic matter content, but brought about significant increments in soil nutrients: nitrogen (25%), phosphorus (50%) and potassium (41%). Grazing/foraging or confined swine fed on SP plus silage and a protein supplement showed no significant difference in weight gain between the grazing/foraging treatments but penned pigs gained 17.5% more weight ($p<0.01$).

Keywords: Sweet potato; cutting regimes; production systems; fattening pigs.

Introduction

Sweet potato (*Ipomoea batatas*) is cultivated throughout several tropical countries and warm temperate regions wherever there is sufficient rainfall to support their growth. Over 95 percent of the global sweet potato crop is produced in developing countries (CIP, 1984). It can be grown in poor soils with little fertilizer and is highly tolerant to pest and diseases, which makes it a major smallholder's staple crop. Because of its versatility and adaptability, SP ranks as the world's seventh most important food crop—after wheat, rice, maize, potato, barley, and cassava. Sweet potato is high in carbohydrates and vitamin A and produces more edible energy per hectare than wheat, rice or cassava and is also a potential source of biofuel production. The tuberous or storage roots of SP are used both for human and animal consumption while the vines are generally used as animal feed along with the crop residues and unmarketable roots, depending on local preferences and customs (Woolfe, 1992). Sweet potato holds comparative utilization advantages over other crops in semi-subsistence farming systems, Figure 1. The diversity of favorable agronomic characteristics of SP includes general hardiness, low input needs (due at least in part to the presence of vesicular-arbuscular mycorrhiza) and fast vine growth response to fertilizer (Tupus, 1983). Sweet potato has the potential for intercropping, ease of propagation, few crop pests and diseases, and good ground coverage for soil

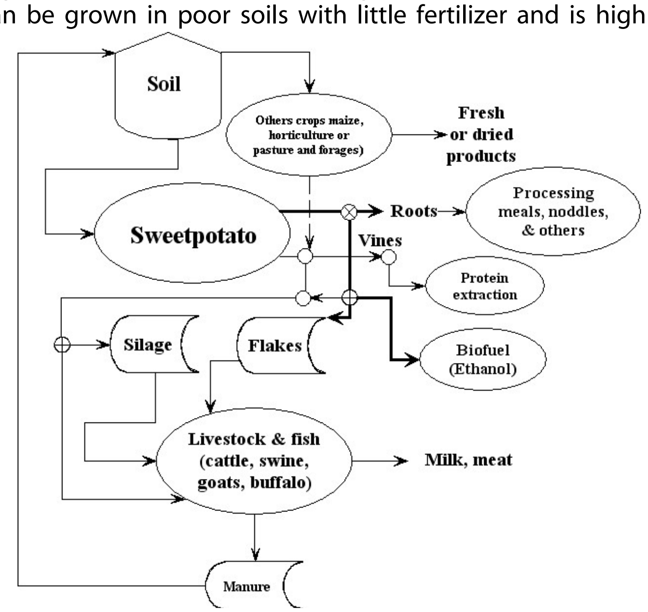

Figure 1. Actual and potential use of sweet potato for human consumption, livestock feeding and industrial purposes

conservation. It has advantageous feeding characteristics in terms of high levels of both energy and protein from the roots and vines, respectively. The vines have high palatability and digestibility for consumption by both ruminants and monogastrics, and due to the low level of enzyme inhibitors in the vines, SP is suitable for its conservation by pre drying or silage (Ruiz, 1982). One major advantage of SP is that besides its use as animal fodder, it may also provide food for human consumption, an optimal integrated crop/livestock management system being able to utilize the sweet potato's good regrowth capacity by continually or sporadically harvesting the vines throughout the growing season before finally harvesting the root (León-Velarde and Gómez, 1996). This management is aimed at enhancing the production of green forage, as harvesting the vines significantly increases the growth rate and yield of the foliage while decreasing root yield.

The aim of the present paper is to summarize the results of the evaluation of SP as a dual-purpose (DP) crop for smallholder's crop-livestock production systems where fresh foliage and roots and the silage of root and vines contributed to the diets for fattening penned or grazing/foraging crossbred pigs. It also presents results of the effects of this crop/livestock system on soil conditions. The results pertain to several experiments conducted by university students under our supervision.

Preliminary results

Preliminary results of SP evaluation suggest that a cutting frequency of 90 days during the crop growing period gave the best balance between forage and root production. A more intensive cutting frequency of 45 days intervals tends to cause a reduced total forage production and nil root harvest. Increasing N fertilization from 0 to 180 kg/ha increased forage production from 6.7 to 9.1t DM/ha (6 cuts at 45 days interval); 6.1 to 8 t DM/ha (3 cuts at 90 days interval) and from 5.4 to 6.2 t DM/ha for one cut at 135 days of growth (Quispe, 1997, Arteaga, 1997). The use of fertilizer is contingent on the cost and marginal production in relation to other forages. As to forage storage, the combination of SP with maize (75% maize without hear-husk and 25% SP) resulted in good quality silage with no reduction of nutritional value (Guerra, 1998). The digestibility of the obtained silage was around 65%. On the other hand, feeding trials in which silage comprised of 75% of SP foliage and 25 % of roots was fed to milking cows showed that milk production was not affected, but feeding costs were reduced (Sanchez, 1995). As to crop management, studies on direct foraging of SP stands are necessary to better link the root and foliage production with livestock rearing in smallholder's crop-livestock farming systems. As to animal feeding, the trypsin inhibitor activity in the vines and roots of some SP varieties, calls for the definition of a more efficient SP utilization by either ruminants or monogastrics. The large number of clones available allows the selection of dual-purpose varieties with characteristics that favor livestock production.

Experimental procedure

Sweet potato varieties

The germplasm collection held at the International Potato Center, CIP, includes a large group of SP clones, varieties and accessions. Breeding efforts are focused on root dry matter and starch content. However, in recent years the demand for forage producing varieties has increased. In this context, research on dual-purpose SP (roots and vines) holds a comparative advantage over research on accessions selected only for roots production. Besides providing food for human consumption, dual-purpose varieties will promote the optimal integration of SP based crop/livestock systems by also providing feedstuff. Dual-purpose varieties could be better utilized by continually or sporadically harvesting the vines throughout the growing season before finally harvesting the roots. Based on previous results of trials on plant density, cutting frequency, fertilization, nutritive value and storage (Quispe, 1997, Arteaga, 1997, León Velarde, et al, 1997), nineteen accessions from a data base, which includes data on root and vines production, were initially selected on the basis of the root/foliage (R/F) dry matter production ratio and the characteristic of the leaves (oval or rounded). They were classified in four probabilistically defined groups over a continuous variation of opposing trends of forage and root production as: forage (11); facultative forage DP (2); DP (2); and, facultative root DP (4). Accessions of high root production were not considered. Observations from two evaluations of around 150 days on plots of ten square meters were analyzed by way of a fixed linear model including group and accession (group); only accessions with at least two observations were included in the analysis (SAS, 1996). The variables measured were forage and root dry matter (total and commercial roots), proportion of commercial and no commercial roots (CR/NCR), root/forage (R/F) ratio and weight of commercial roots. Least square means and standard errors are presented in table 1. Selected varieties were evaluated for fresh and dry mater vines and roots yields, in response to two cutting frequencies (in one case, two cuts at 75 days interval and in the other one single cut at the end of the growing period i.e. 150 days). In both cases, foliage and roots were harvested.

Table 1. Least means square and standard error for main characteristic of dual-purpose sweet potato evaluation on dry matter production; San Ramón, Perú.[1,2,3]

Group variety	Relation		Total forage t/ha	Total Roots t/ha	Commercial Roots	Commercial root weight, g	Relation CR/NCR
	RF	RB					
1. Forage	**0.32±0.08**[a]	0.17±0.18	**4.66 ± 0.20** [a]	**1.36 ± 0.30** [a]	**0.89 ± 0.23** [a]	**187.77 ± 16.72** [a]	**0.35 ± 0.04** [a]
ARB-265	0.00	0.00	6.92 ± 0.56	0.00 ± 0.84	0.00 ± 0.66	-	0.00 ± 0.11
DLP-3548	0.00	0.02	5.61 ± 0.56	0.00 ± 0.84	0.00 ± 0.66	-	0.00 ± 0.11
DLP-1308	0.22	0.15	3.94 ± 0.69	0.71 ± 1.03	0.00 ± 0.66	-	0.00 ± 0.13
ARB-UNAP55	0.00	0.00	3.70 ± 0.56	0.00 ± 0.84	0.00 ± 0.66	-	0.00 ± 0.11
DLP-2481	0.14	0.07	5.72 ± 0.56	0.41 ± 0.84	0.34 ± 0.66	216.65 ± 51.18	0.27 ± 0.11
RCBIN-5	0.14	0.14	3.26 ± 0.56	0.46 ± 0.84	0.46 ± 0.66	151.67 ± 41.79	0.50 ± 0.11
DLP-2448	0.35	0.06	3.24 ± 0.69	1.22 ± 1.03	0.53 ± 0.80	141.95 ± 51.18	0.24 ± 0.13
ARB-158	0.30	0.17	5.85 ± 0.79	1.74 ± 1.19	1.60 ± 0.92	160.43 ± 41.79	0.93 ± 0.15
MOCH	0.79	0.41	2.89 ± 0.97	2.18 ± 1.46	2.17 ± 1.13	315.00 ± 51.18	1.00 ± 0.19
ARB-389	0.73	0.46	5.46 ± 0.61	4.09 ± 0.92	1.96 ± 0.72	149.00 ± 36.19	0.41 ± 0.12
DLP-90052	0.95	0.44	4.65 ± 0.56	4.23 ± 0.84	2.67 ± 0.66	179.62 ± 32.37	0.52 ± 0.11
2. Low dual purpose	**1.13±0.19**[b]	0.37±0.16	**4.28 ± 0.49** [ab]	**4.3 ± 0.73** [b]	**2.84±0.57** [b]	**236.98 ± 25.59** [a]	**0.68 ± 0.09** [b]
DLP-2462	1.04	0.26	4.81 ± 0.79	4.77 ± 1.19	2.94 ± 0.93	218.20 ± 41.49	0.60 ± 0.15
DLP-3525	1.23	0.48	3.76 ± 0.56	3.84 ± 0.84	2.74 ± 0.66	255.77 ± 29.55	0.75 ± 0.10
3. High dual purpose	**1.68±0.15**[c]	0.50±0.01	**3.33 ± 0.40** [b]	**5.62 ± 0.60** [bc]	**4.45 ± 0.46** [c]	**228.85 ± 20.89** [a]	**0.79 ± 0.08**[c]
DLP-275A	1.58	0.51	3.36 ± 0.56	5.38 ± 0.84	3.89 ± 0.66	161.78 ± 29.55	0.71 ± 0.11
ARB-394	1.77	0.49	3.28 ± 0.56	5.86 ± 0.84	5.07 ± 0.66	295.55 ± 29.55	0.87 ± 0.11
4. High-Low roots production	**2.69±0.13**[d]	0.65±0.03	**3.52 ± 0.35** [b]	**9.26 ± 0.52** [d]	**5.96 ± 0.41** [d]	**198.33 ± 18.39**	**0.65 ± 0.07** [d]
ARB-UNAP74	3.13	**0.63**	4.04±0.56	12.48±0.84	8.13 ± 0.66	267.28 ± 29.55	0.68 ± 0.11
SPV55	2.71	0.67	3.67±0.97	9.80±0.84	6.44 ± 1.13	252.55 ± 51.18	0.67 ± 0.19
SR-90323	2.44	0.68	3.27±0.62	7.97±0.92	5.38 ± 0.71	145.16 ± 32.37	0.68 ± 0.12
CC-89213	2.50	0.63	3.13±0.56	6.79±1.49	3.90 ± 0.66	128.33 ± 29.55	0.56 ± 0.11

[2] Least square means of group with the same letter are not significantly different (P<0.01)
[3] Least square means of variety (group) sorter by total dry matter of forage, roots and commercial roots.

Silage

Photo 1. The sequence of sweet potato silage preparation

It is known that working a traditional silo (bunker, aero) in small farms is difficult, a fact that precludes the adoption of silage making practices. To solve this limitation, a modified small silo, large enough to contain the biomass produced in small plots was designed. As shown in Photo 1, the adapted silo is made of two barrels cut by their side and joined by a door hinge (a). The internal wall and the bottom are covered with plastic joined with plastic glue. A large plastic bag in which the plant material is compressed goes into de container. Adequate drainage is provided by a plastic pipeline located at the bottom of the silo (b). In our trial, vines and roots were chopped and mixed at proportions of 75% and 25% respectively; 3 % of molasses was added as starter (c, d). The vines and roots were compressed in layers (15-20cm) until the silo was full to the top (e). After the process of filling the silo was completed, the barrels were separated by removing the pin, making them available for ensiling another load, if needed (f). The silage was used after 45 days. The characteristics of the silage were adequate, as the animals did not reject it.

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Animal response in pig fattening trails

The weight gain of pigs in either confinement or grazing/foraging conditions and fed with different combinations of fresh roots and vines, sweet potato silage and a protein supplement was evaluated:

1. Use of vines and roots. Twelve pigs with initial weight of 30 kg were assigned to three treatments: feeding in confinement with vines and roots *ad libitum* plus a fish meal protein supplement at a rate of 10.58 g/kg (A1); foraging on sweet potato plots plus a fish meal protein supplement at a rate of 10.58 g/kg (A2); and, foraging on sweet potato plots plus a fish meal protein supplement at a rate of 3.5 g/kg (A3) Fish meal was fed twice a day (morning and afternoon) by halves. Data were analyzed as repeated (weekly) measurements over 72 days.

2. Use of silage. Sixteen pigs with an initial weight of 20 kg were assigned to four treatments: confinement with fresh vines and roots *at libitum* plus a protein supplement (30% fish meal and 70% soybean meal) (B1); confinement with SP silage plus protein supplement (B2); semi confinement and limited foraging of fresh SP, plus silage and protein supplement (B3); and, foraging plus protein supplement (B4). The protein supplement was supplied at an average rate of 0.5 kg/day as determined by the estimated total dry matter intake. Data were analyzed as repeated (weekly) measurements over 75 days.

Experimental results

Sweet potato varieties. As mentioned before, the initial selection of nineteen clones of sweet potato was based on the root/forage (R/F) dry matter production ratio and the leaf shape (oval or rounded). Based on the R/F ratio the selected clones were classified in five groups: forage (0-1), facultative forage DP (1-1.5), DP (1.5-2.0), facultative root DP (2.0 –3.0) and, high root production (3.0), (León-Velarde, 1997, 2001). Table 1 shows the evaluation of varieties within groups. There was a significant difference among groups (P<0.01) for total forage and root dry matter, total of commercial roots and R/F ratio. Significant differences among accessions within groups on total forage dry matter and commercial roots indicate that there is variability within groups, which gives room for a selection process. The least square means for forage dry matter yield were 4.66 ± 0.20, 4.28 ± 0.49, 3.33 ± 0.40 and 3.52 ± 0.35 t/ha for groups 1, 2, 3 and 4 respectively. Total root production was 1.36 ± 0.32, 4.31 ± 0.73, 5.62 ± 0.60 and 9.26 ± 0.52 t/ha for groups [1], [2,] [3 and [4] respectively. The total commercial roots produced by groups [2] and [3] were 2.84 ±0.46 and 4.45 ± 0.46 t/ha, which is 68.7% more root production than group [1] and 25.3% less yield than group [4] opening the opportunity for income generation from root production plus forage availability. The average weights of commercial roots vary from 187 to 228 with no significant difference among groups. The classification of the clones within groups was also analyzed with regard to the total dry matter of vines and roots (Figure 2).

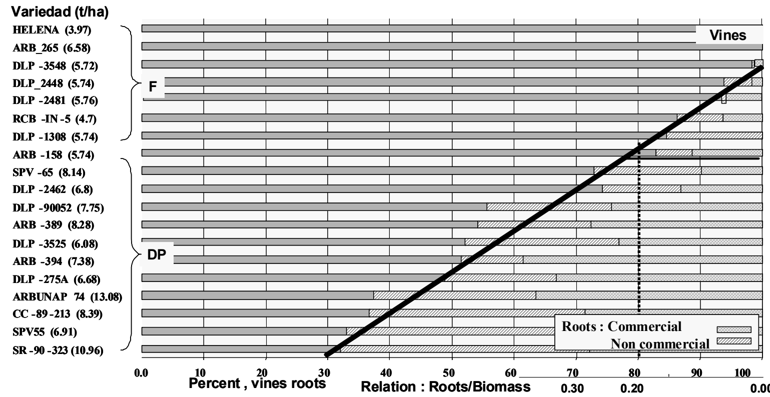

Figure 2. Clones of dual-purpose sweet potato categorized by root-vines and root-biomass ratio

Following the above tests, it was noticed that some clones within groups could not be pigeon holed unambiguously as in some cases the classification based on the ratio of roots to vines did not appropriately place some clones. Thus, it was suggested that the ratio of roots dry matter to total biomass [R/(R+V)] would be more appropriate. When it was done, the number of categories was reduced from five to two: varieties for only forage (F), [0<R/B≤0.20], and dual purpose, [R/B > 0.20]. This classification gives a better definition of dual-purpose sweet potato in the context of crop-livestock production systems where it is necessary to increase or maintain dry matter availability all year round. Based on this classification of forage and dual purpose SP, a set of clones was evaluated under two crop management practices, Table 2.

Table 2. Vines and roots production at two crop management practices; t/ha of dry matter

Clones	Relation R/B	Crop management					
		Vines harvested at two cuts (t/ha)				Vines harvested at one cut (150 days)	
		at 75 days	At +75 days	Total vines	Total Roots	Total vines	Total roots
Forage[1] (F)	0.03±0.02	1.70±0.14	3.08±0.21	4.77±0.24	0.07±0.05	4.15±0.56	0.15±0.12
Dual purpose (DP)	0.36±0.12	1.53±0.49	3.34±0.77	4.87±1.01	1.62±0.97[b]	4.76±1.07	3.00±1.74[a]

[1] Total dry matter (DM) expressed in t/ha.
[1] DLP-2448, ARB-158, DLP-2481, DLP-3525, ARB-394
[2], SPV-65, DLP-275A, ARB, 389, ARB-UNAP74, DLP-2462, SR-90323, CC-89213

Crop management practices

Traditionally SP roots are harvested at the end of the cropping season leaving the vines in the field for any post harvest use. Usually, roots are weighted and marketed for human consumption and the vines are derived for animal feeding purposes. This management is generally applicable to different common varieties but for a dual-purpose variety grown in crop-livestock production systems, a different crop management is required. The novel approach we propose takes into account the total biomass production, which includes roots and vines. Based on previous results of continuous harvest at 45 days interval, it was determined that cutting intervals of at least 60 days are required for obtaining roots (León-Velarde, et al, 1997; Quispe, 1997). Therefore a modified cutting regime consisting of a harvest of vines at the middle of the growing period was tested. Twelve sweet potato clones classified, as either of the forage or dual-purpose type were included in a test of biomass production as affected by two different managements, table 2. The figure 3 shows the production of vines and roots under the two cutting regimes. On average, the yield of vines was similar on both managements; however, the cut of vines at the middle of the growing period tended to increase the production of vines by 15% while reducing roots yield by 27.1% (P<0.05). The total biomass increased by 11% and 19.5% for forage and dual purpose SP, respectively, Table 2.

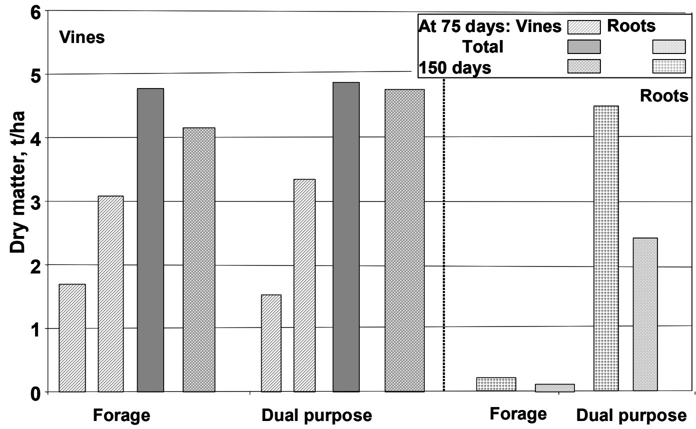

Figure 3. Effect of two cutting regimes on the yield of vines and roots of forage only and dual-purpose varieties

Figure 3 shows the clones evaluated as divided in two groups: forage, and dual purpose. A cut over 75 days tends to reduce by 19.5% the root production of dual-purpose varieties (P<0.05). For varieties classified as forage producers the root production is nil but the yield of vines was increased by 15%.

Other aspect of SP management is that vines are traditionally used in a short period of time, due to the problems of conserving them as fresh biomass, which leads to the necessity of preserving them as silage.

Animal response in pig fattening trials

Figure 4 shows the weight gains of penned pigs fed fresh roots and vines, and foraging pigs, both receiving fishmeal as supplement. There was significant difference (P<0.05) in weight gain of penned pigs (0.620±0.190 kg/day) compared to foraging pigs fed 1/3 of fish meal (0.503±0.132 kg/day) and foraging pigs receiving the full amount of fish meal (0.488±0.021).

The level of fishmeal was enough to cover the protein requirements. Thus, the foraging group with 1/3 of fishmeal allowance showed similar weight increments that the group with full protein supplementation, indicating that the level of protein from sweet potato was enough to obtain adequate weight gain. Incidentally, it happened that fishmeal supplementation was too high as it caused a slight fish odor in the meat.

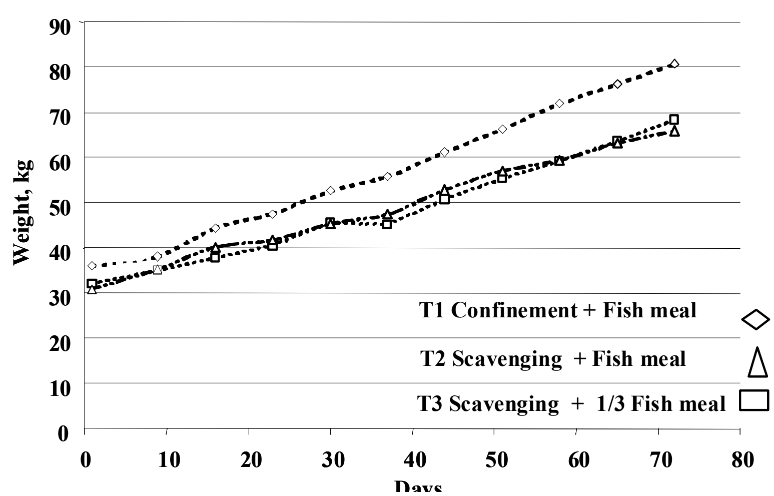

Figure 4. Live weight gain of penned and foraging swine fed sweet potato and protein supplementation

The effect of cut and carry and foraging of SP on the soil was evaluated. Results showed that either management has no significant effect on soil structure and organic matter content (Figure 5). However, foraging caused significant increments in soil nitrogen, phosphorus and potassium, improving residual soil fertility for subsequent crops like maize.

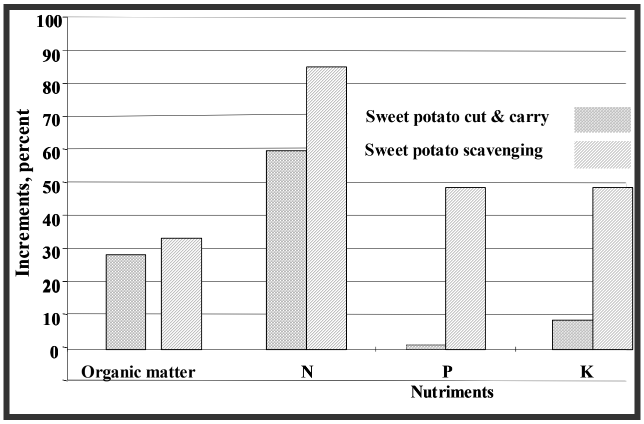

Figure 5. Effect of foraging and cut and carry of SP on soil structure

Figure 6 shows the results of feeding fresh roots and vines to penned and foraging pigs, some of them supplemented with SP silage and protein (fish meal and soybean). The weight gain (0.551±0.150 kg/day) of the penned pigs fed fresh sweet potato and the protein supplement showed no significant difference with the weight gain (0.524±0.140 kg/day) of the foraging pigs. On the other hand, the weight gain (0.444±0.125 kg/day) of penned pigs supplemented with SP silage and protein was significantly higher ($P<0.05$) than the weight gain (0.361±0.105 kg/day) of semi confined pigs receiving the same diet. Semi confining management was cumbersome for the continuous back and forth movement between the field and the pen.

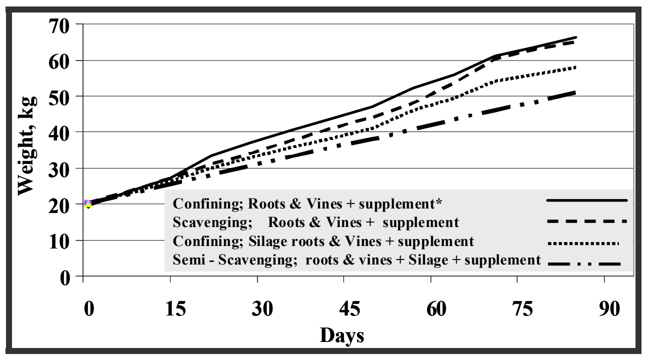

Figure 6. Live weight gain of penned and foraging swine fed on fresh sweet potato, silage and a protein supplement

Concluding remarks

- Sweet potato varieties can be classified by the ratio of root biomass to total biomass, which provides a useful tool for the identification of dual-purpose varieties suitable for crop/livestock systems.
- Weight gain of penned and foraging pigs fed on the same diet of fresh vines and roots and adequate protein supplementation was similar.
- It was feasible to produce good quality sweet potato silage for the feeding of penned pigs as a supplement or when fresh sweet potato is scarce.
- Foraging of SP fields by pigs improves soil nutrients condition.

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