The Potential of the Winged Bean *(Psophocarpus Tetragonolobus* (L.) DC as a Root Crop

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Abstract

Root crops feeding over half the World's population are cassava, yams, cocoyam and potatoes. These are however regarded as inferior to cereals because of their low protein contents. The Winged Bean plant contains high protein in all parts including the roots, therefore, efforts should be concentrated to improve its root production. The potential of the winged bean as a root crop in comparison with other root crops are discussed. Breeding for development of male sterility types will create self-pruned plants and offer high sink strength for desirable tuber formation.

Introduction

Root crops have played a major role in the dietary needs of the inhabitants of the tropics especially the wetter tropics. They serve mainly as a source of carbohydrate. Although root crops are of immense local importance, most of them have not entered into world trade like the cereals. Root crops are easily adapted to low agricultural technology, and since their consumption has been associated with countries described as "developing" they generally are regarded as food for poor people. The fact that root crops were among the earliest crops to be domesticated (Coursey and Haynes, 1970) and provide the basic staple of more than half of the world population has always been overlooked.

Root crops have, received little attention from research workers, and most has been centered on *Solanum tuberosum* (Irish potatoes) being a primary staple in Western Europe and North America.

Among the dozen or so crops on which most of the world's populations are fed, are five root crops, namely: cassava, (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* (L) Lamb), yams *(Dioscorea* spp) and Aroids *(Colocasia* and *Xanthosoma* spp). Table 1 gives the estimated production of the major tropical root crops.

Apart from these major root crops, numerous other tropical root crops are grown in particular regions, where they are of local importance. Among these are two leguminous root crops, the African yam bean (*Sphenostylis stenocarpa*) and the winged bean (*Psophocarpus tetragonolobus*), the later is by far the more important, and has been intensively cultivated in Burma for its tuberous roots (Burkill, 1906).

General Features and Uses of the Winged Bean

The winged bean has the potential for improving human diet. No other crop offers such a variety of foods which, taken together, make up an impressively nutritious and palatable diet; a backyard "nutrition supermarket" with a range of products for selection and variation. Its green pods, leaves and seeds are all rich in protein and vitamins.

An interesting feature of the winged bean is that it produces tuberous roots (Figure 1). The tubers are said to have a pleasant and slightly sweet taste, ivory white flesh and firm texture resembling an apple (NAS, 1975). Tuber development is fully attained at ten to twelve months of growth. If allowed to grow beyond one year, tubers become stringy and insipid.

The use of winged bean tubers as food appear to be restricted to Burma and the Papua New Guinea Highlands, although there are occasions when tubers are used in other countries during famine, as is the case in Northern Ghana (Karikari, 1978).

There is variation in the preparation of the tubers for consumption. In the Highlands of Papua New Guinea, the roots are usually served wrapped in banana leaves or in bamboo, steamed in the "mum" oven or in an oil drum. The tuber is a very popular and highly acceptable food among the village population (Khan and Claydon, 1975). In Burma, cooked tubers are peeled and eaten like potatoes by children, often with a sauce made from vegetable oil and salt (NAS, 1975). In Northern Ghana, the tubers are roasted in fire and eaten with fish (Karikari, 1978). The tubers are rarely cooked.

Yields

Tuber yields have not been measured in large plantings. In small plots at IITA, Ibadan, Nigeria (Rachie, 1974), yields from 600 to 1,300 kg of fresh tubers per hectare were obtained. In similar research plots at Kade, Ghana, three varieties of winged beans gave consistent and reliable tuber yields averaging about 830 kg per hectare (Karikari, 1978). The maximum tuber exceeding 4 tons per season has been reported from Burma (Burkhill, 1906).

Table 2a shows the maximum yields of various root crops which have recently been reviewed by de Vries et al. (1967). Additional figures for winged beans have been provided (Karikari, 1977). According to Coursey and Haynes (1970) the figures are higher than values obtained under normal conditions. Nevertheless, they show what can be achieved with materials that in most cases, except sweet potato, represent only selections rather than hybrids. In the case of winged beans however, tuber yields are from unselected plants in mixed cropping. In addition to the tubers produced, about one ton per hectare of dry seeds could also be obtained.

Materials and Methods

Agronomic response to tuber yield has been studied under experimental conditions at Kade, where three experiments have been carried out to investigate methods that enhance tuber formation. Three tuber-forming varieties among the Kade collection, namely 10/6, 27/4 and 6/16 were studied for tuber yield under the following treatments:

1. Variation in vine support length (Figure 2)
2. Planting on mounds, ridges and flat (Figure 3), and
3. Flowering and deflowering (Figure 4)

In the first experiment, stakes of varying lengths – 120, 150, 180, 210, 240, 270 cm were used to support the vines as against the control of "no staking" in randomized complete block design. Tables 3 and 4 show the mean yields of tuber and vegetative matter twelve months after planting. Tuber yield increased progressively from 4.5 gm per plant at control H_0 to 34.9 gms per plant at H_{240} cm. The difference between the control H_0, H_{120}, and H_{180} were all highly significant (P = 0.01). At H_{180}, H_{120} and H_{240} however, the difference was not significant even at the 5% level. At H_{270} there was a drastic drop in tuber yield, tuber yield at this level being 5.0 gms per plant and almost as low as yield H_0 (Table 3). On yield of vegetative matter, it was found that vegetative matter, progressively increased from control at 5.6 kgs per plant to 8.9 kgs per plant on the support length of 270 cms. The difference between the control and all other treatments was highly significant (P =0.01) but the difference at H_{120} to H_{150}, were not significant even at the 5% level. Yield of vegetative matter, increased from H_{180} to H_{240}. The yield at H_{240} and H_{270} was however the same (Table 4).

The second experiment, involved planting the beans in three different kinds of soil preparation. The land was plowed and planting was done on mounds, ridges and flat (control). Table 5 shows the effect of soil preparation on mean yield of tubers, twelve months after planting. Tuber yield increased as soil aeration improved. Planting on mounds and ridges yielded significantly. Varieties also showed different responses to soil treatment. The yield of variety 27/4 was significantly different from 1/2 (P = 0.05) but the difference in yield of varieties 10/6 and 27/4 was not significant.

In the third experiment, the effect of pruning (flower removal) of 50% flowers (i.e. plucking off every other flower), 100% flower removal, and control (no flower removal) on tuber yield was studied. Tubers were harvested twelve months after planting. Using the LSD test, it was found that flower removal increased tuber yield significantly (P = 0.05), and the higher the flower removal, the greater the yield (Table 6).

Discussion

Table 7 and Figure 5 shows the composition of nutrients of winged bean tubers as determined by Claydon (1975) in comparison with other conventionally known tubers as determined by FAO (1972). The protein content of the winged bean is at least five times higher than that of yam and taro and ten times higher than that found in cassava and sweet potatoes. According to NAS (1975), in some cultivars, as much as 15% protein was found in the roots calculated on fresh weight basis.

Not only is the protein high but the tuberous roots are also rich in carbohydrate 30.5 gm per 100 gm as compared with 27.1 in sweet potatoes, 21.0 in taro, 25.1 in yam and very close to cassava which has 32.4 (Figure 5). Among the root crops, the winged bean contains the least amount of moisture (Table 7). It contains a comparatively high proportion of fat (0.4 gm) as compared with 0.1, 0.2 and 0.3 gm of yam, cassava, and sweet potatoes, respectively. Its energy value in terms of calories is very high (150), as compared with 135 for cassava, 115 for sweet potatoes, 108 for yam and 94 for taro. Although the values for minerals of the winged bean roots are lower, generally, the values for calcium, phosphorous and iron is comparable with those found in most tropical tubers.

A more valid comparison between winged bean tubers and other root crops is yield of protein per acre, i.e. tuber yield x percent protein. Table 2b shows that winged bean yields 82.7 t/ha of protein per annum which is higher than cassava (71.1) and sweet potatoes (78.2).

The only investigation on amino acid composition of the winged bean tuber is probably that of Choo (1975). As can be seen in Table 8, the winged bean tuber, although very rich in crude protein, appears to have an amino acid profile that cannot be regarded as satisfactory. The amino acids appear to be present in inadequate amounts. However, this range of values in individual amino acids in root crops can be very large, for example in cassava, the range of methionine is between 31 and 179 mg/g and that of cystine between 25 and 154 mg/g (FAO, 1972). Therefore, according to Cerny (1978), a single analysis of the amino acid composition of the winged bean tuber protein as was done by Choo (1978) cannot be regarded as representative.

Conclusion

In terms of production, concrete figures on winged bean tubers are difficult to come up with. The crop is grown for both seeds and tubers in only a few countries, it is only in Burma where the crop is grown mainly for its tubers. In South East Asia, cultivation is largely done by subsistence farmers cultivating small irregular and scattered plots, usually with much inter-cropping and under shifting cultivation. Thus, it is very difficult to collect and interpret statistics. It can thus be seen that yield figures of winged bean tubers is very variable, and the 8.0 tons/ha/yr represents only a good average. This average yield is currently well below the level which can be produced, because in most cases the plant has not undergone any selection for tuber yield.

With agronomic improvement, tuber yield could be higher than 8 tons/ha/yr. So far the response to tuber yield stimulation has been very encouraging. For instance varieties show varying responses on tuber yield to various support lengths of the vines. Generally, unsupported plants produced significantly less tubers than the supported plants. As staking height increased from 0 to 240 cms, the yield increased to a maximum of 240 cm and then declined sharply with further increase of 30 cm in the staking length (Table 2). The increase in tuber yield is associated with increase in yield of vegetative matter in similar manner (Table 3). The association of the two could stem from the fast expansion in tuber size resulting from storage of excess photosynthate. Increasing staking height appears to expose greater photosynthetic area to the sun resulting in higher photosynthesis.

Improvement in soil structure also improved tuber yield. In an experiment to compare tuber yield under various soil structures, tuber yields were higher for planting on ridges and mounds than planting on the flat (Table 4).

In a dual purpose winged bean crop, four sinks may be identified as the various seeds, pods and tubers, and the vegetative matter (stem & leaves). Their functions appear to be competitive in storing the excess photosynthate. The removal of flowers could result to translocation of all the excess photosynthate into the tubers whereas partial removal could enhance the yields of the remaining seeds and the tubers, (Table 5). Choo (1978) observed an increase in tuber yield in plots where the pods were harvested as green succulent pods for vegetable than those harvested for dry seeds.

Having considered the above available information, it can now be seen that with research, the winged bean can become a significant root crop in Central and South America, the Caribbean, Oceania and Asia where protein deficiency is high.

The seeds of winged beans have a very high protein content. However, the plant requires staking to produce high yields of seeds. Moreover, the seeds produced are not as palatable as other legumes like cowpeas, groundnuts and bambarra beans. As a result, it appears that the winged bean may not rival other legumes in terms of utility of seeds. Its utility as a tuber crop may perhaps make more contribution in meeting food needs, especially since it is grown in regions where people depend on edible root and tubers such as cassava, yams, sweet potatoes and cocoyams which are so low in protein. In these regions, food shortages are very prevalent and people depend increasingly on plants rather than animals for protein in their diet. Most sources of plant proteins are very expensive. In Ghana for instance, cowpeas cost as much as meat, while most root crops are comparatively cheap. It therefore appears that a root that has high protein content can be very useful in many of the tropical areas where protein deficiency is a serious problem.

The potential of winged bean as a root crop has not been fully explored. The crop is utilized as a multi-purpose crop, its fresh pods, dry seeds, and tubers, all being nutritious.

However, there are several important tropical legumes and vegetables which are better preferred to the winged bean in these aspects. The potential of the winged bean therefore appears to lie in its use as a root crop. This could be possible with breeding and selection and agronomic improvement for high tuber yield. The plant has high heritability values which could be utilized for tuber production. Reproductive and off-season effects all have influence on tuber yield, and if male sterility types could be developed, it may create a self-deflorating crop. It has been observed that at certain day lengths, flowering does not occur at all in daylength sensitive cultivars. Perhaps in each day length, winged bean could be grown solely for tubers. Experiments on tuber improvement in winged bean are in progress at the Kade Research Station.

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Table 1. Estimated Production of Tropical Root Crop (Million Metric Tons)*

	Cassava	Yams and Sweet Potatoes	Potatoes	Total
Latin America and Caribbean	29.86	3.81(1)	5.07(2)	28.74
Tropical Asia and Oceania	18.36	9.58	5.22(3)	33.16
Africa	29.37	23.05	2.02	54.44
Total	77.59	26.44(4)	12.31	126.34

Figures derived from FAO Production Yearbook, 21 100-117 (1967).

(1) These two crops are not distinguished in FAO statistics. According to Coursey (1967), 41% of the total represents yam production, and the remaining 59%, sweet potato.

(2) This figure excludes the production of Argentina, Chile and Uruguay, where potatoes are produced under nontropical conditions. The total production of these countries is 2.3 million tons.

(3) This figure excludes Cyprus and Turkey but included the remainder of the Near East. Australia and New Zealand have been excluded from the total for Oceania.

(4) Sweet potatoes, although essentially a tropical crop, are also produced in warm temperate countries, notably USA, Japan, Korea, Spain, Italy and New Zealand to the extent of 8-5 million tons.

*From Coursey and Haynes (1970).

Table 2a_ Maximum Known Yields of Some Tropical Root Crops (Adapted from Coursey and Haynes (1970)

Crop	Yield tons/ha/year*
Cassava	71.1
Sweet Potato	65.2
Yam	93.3
Colocasia	47.0
Winged Bean	8.0

* This method of excpressing yields, although makes the comparison between different crops easier, tends to give rather falsely high impression of total yield, when the crop occupies the ground for only part of the year. It is not always possible to grow the same, or any crop for the remainder of the year, unless irrigation and other facilites are available. Nevertheless, the yields given are extremely high.

Table 2b Protein Yield (t/ha) of some Tropical Root Crops

Crop	Protein Yield t/ha (i.e. Tuber Yield x per cent Protein)
Cassava	71.1
Sweet Potato	78.2
Yam	186.6
Colocasia	103.4
Winged Bean	87.2

Table 3 Effect of Staking on Yield of Tuber (gm/plant)

Stakes Lengths (cm)	Varieties 10/6	27/4	6/16	Mean
0	4.5	3.8	4.0	4.1
120	15.3	16.5	17.1	116.3
150	22.9	20.2	18.6	20.6
180	31.6	30.4	28.4	30.1
210	33.4	31.1	30.03	31.9
240	34.9	35.1	32.1	34.0
270	6.4	7.7	21.4	11.8
Means	21.3	20.8	21.7	–

LSD (5%) for stake lentgth = 2.1

LSD (5%) for varieties = 1.0

Table 4 Effect of Staking Length on Yield of Vegetative Matter (kg/plant)

Stakes Lengths (cm)	Varieties 10/6	27/4	1/2	Means
0	6.21	5.60	4.85	5.56
120	5.96	7.35	7.02	7.11
150	7.55	7.65	7.71	7.64
180	7.93	8.08	8.31	8.11
210	8.62	8.88	8.57	8.69
240	8.75	8.90	8.88	8.84
270	8.82	8.90	9.22	8.98
Means	7.8	7.9	7.8	–

LSD (5%) stakes lengths = 1.6

LSD (5%) Varieties = 1.2

Table 5. Effect of Soil Preparation on the Yield of Tuber (gm/plant)

Soil Preparation	Varieties			Means
	10/6	27/4	1/2	
Flat	32.3	34.6	29.5	32.1
Mounds	38.4	41.3	33.6	37.8
Ridges	42.5	46.1	33.0	40.5
Means	37.7	40.8	32.0	–

LSD (5%) Planting methods = 3.0

LSD (5%) for varieties = 1.0

Table 6. Effect of Deflowering on Yield of Tuber (gm/plant)

Flowering Treatment	Varieties			Means
	10/6	27/4	1/2	
Number picking of flowers	33.6	41.2	38.9	37.9
50% picking of flowers	44.7	46.5	38.1	43.1
100% picking of flowers	52.3	56.1	37.1	48.6
Means	43.5	47.9	38.0	

LSD (5%) varieties = 5.6

LSD (5%) flower treatment = 5.0

Table 7 Composition of the Winged Bean Tuber (in 100g edible portion)

	%	Winted Bean a/	Cassava b/	Sweet Potatoes b/	Taro b/	Yam b/
Moisture	%	56.5	65.5	70.7	75.4	71.8
Calories		150	135	115	94	108
Fat	g	0.4	0.2	0.3	0.4	0.1
Crude Protein	g	10.9	1.0	1.2	2.2	2.0
Carbohydrate	g	30.5	32.4	27.1	21.0	25.1
Fiber	g	1.6	1.0	0.8	0.8	0.5
Ash	g	1.7	0.9	0.7	1.0	1.0
Calcium	mg	25	26	36	34	22
Phosphorus	mg	30	32	56	62	39
Iron	mg	0.5	0.9	0.9	1.2	1.0
Manganese	mg	10	–	387	267	–
Zinc	mg	1.3	–	2.0	–	1.1

a/ Choo (1975), recalculated to mg/g N.

b/ FAO (1970)

Table 8 Amino Acid Composition of the Wineged Bean Tuber Protein (mg/g/N)

Amino Acid	Winged Bean a/	Cassava b/	Sweet Potato b/	Taro b/	Yam b/
Isoleuchine	171	175	230	219	234
Luecine	229	247	340	460	404
Lysine	ND	259	214	241	256
Methionine	48	83	106	84	100
Cystine	14	90	69	163	72
Total S. Cont.	62	173	175	247	172
Phenylalanine	106	156	141	316	300
Tyresine	72	100	146	226	210
Threonine	195	165	236	257	225
Tryptophan	ND	72	ND	88	80
Valine	150	209	283	382	291
Arginine	ND	129	84	110	118
Histidine	ND	683	307	552	477
Alanine	113	235	298	344	265
Aspartic Acid	594	406	825	788	691
Glutamic Acid	406	1009	541	732	777
Clycine	137	160	234	231	220
Proline	106	172	219	276	249
Serine	171	204	255	413	330

a/ Choo (1975), recalculated to mg/g N

b/ FAO (1970).