Studies on Tuber Production in Winged Bean (*Psophocarpus tetragonolobus* (L) DC)

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Abstract

Various aspects of tuber production in winged bean have been studied at the University of Papua New Guinea. Although much of this work is preliminary, it indicates the potential of the winged bean as a valuable, high protein tuber-producing crop for the tropics. Yields of 11 tons of fresh tubers per hectare and protein contents of up to 10.9 percent of fresh weight have been obtained. Further screening of available germplasm for desirable tuber characteristics and evaluation in both lowlands and highlands should be carried out, together with studies to confirm and add to existing data.

Introduction

The winged bean (*Psophocarpus tetragonolobus* (L) DC) is a potentially important tuberous root crop which has received considerable attention over recent years, mainly because of its versatility as a subsistence food crop: young pods, flowers, mature seeds, leaves and tubers are all a valuable source of highly nutritious human food, (Anon, 1975; Claydon, 1975; 1978; Cerny, 1978 and Ekpenyong and Borchers, 1978).

To date, however, attention has been directed towards the development of winged bean as a "commercial" grain legume crop. In many ways this is unfortunate since winged bean could be more widely exploited as a source of high protein food in developing tropical countries where there is a need for a protein supplement for the largely carbohydrate diet. Fresh tubers of winged bean contain up to 11 per cent crude protein (Claydon 1975). Winged beans, with a tuber yield of only 1 t/ha still compare favorably with sweet potato (1% protein; US. Dept. H. E. W., Nutrition Program, Center for Disease Control, Health Services and Mental Health Administration and FAO 1972) in terms of protein yield.

In the Highlands of Papua New Guinea, the winged bean is grown primarily for its tubers which are highly prized as a flavorsome and nutritious food (Khan, Bohn and Stephenson, 1977). To encourage tuber development, continuous pruning is carried out on both vegetative (tender shoot tips and young leaves) and reproductive (flowers and young pods) plant parts. All these parts are consumed as vegetables thus providing a valuable protein supplement for 2-3 months from the stage of flowering onwards. Burkill (1906) also pointed out the importance of traditional winged bean tuber production in Burma.

Because of the importance of winged bean tubers in the Highlands of Papua New Guinea and the general lack of information, researchers at the University of Papua New Guinea commenced studies on various aspects of tuber production. This report summarizes the results.

Nutritional aspects of winged bean tubers

A dietary survey was conducted in 1978, in one of the main tuber producing areas in Papua New Guinea. The contribution of winged bean parts to the diet of Kumbagl people in the Wahgi Valley of the Western Highlands Province was assessed.

The methods used in the food intake surveys were those used in the Yobakogl nutritional study (Lambert, 1975). The experimental design was derived from Jeliffe (1966). Two or three representative-families were selected from each village or community and all their meals and daytime snacks for 6 days, weekened included, were weighed, ingredient by ingredient after cooking. Nutrient intakes were calculated using the latest FAO food composition table (FAO, 1972). The percentage energy, protein and vitamin C intakes were calculated separately for adult men, adult women and children from Kumbagl and, for all groups, over sixty per cent of the protein intake was provided by winged bean tubers. Tubers also contributed from 30 to 50 percent of the daily energy intake, as well as supplying considerable vitamin C.

Chemical analyses of winged bean tubers harvested in different environments in different years and from different varieties were carried out and compared with those reported by Wong, Kai Choo (1976) from Malaysia. Considerable variation in crude protein contents, from 3 to 10.9%, has been recorded. This variation may be associated with varietal differences, plant husbandry, seasonal and/or soil nutritional differences, regional climatic differences (eg. cold nights), tuber age and possibly with the food preparation processes. Accordingly, a more detailed programme of study is needed to investigate the influence of these factors on protein contents.

Regional variety tuber yield trials

In 1978, ten varieties, selected primarily on the basis of seed yield were planted in five randomized blocks each at seven locations throughout Papua New Guinea, at various altitudes from the Lowlands to the Highlands. Both mature seed and tuber yields were measured. Meaningful tuber yield data was recorded at four sites only. No specific treatments were given to encourage tuber development.

Plots were 5 m in size and consisted of two 50 cm rows, with 25 cm between plants within the rows. Plants were supported on "A" frame trellisses 1 m high. A basal dressing of 12-12-17 fertilizer was applied by hand at the rate of 500 kg/ha.

Considerable variation in tuber yield with both variety and location was shown, tuber yield being correlated to both tuber number ($r = 0.816$) and tuber size ($r = 0.961$), particularly in the four highest tuber-yielding varieties (UPS 122, UPS 121, UPS 62 and UPS 47).

Overall, the best variety was the dual purpose type, UPS 122, which gave the highest seed yield (2.5 t/ha) in the lowlands and the highest tuber yield (11.7 t/ha) at Kuk (1537 m) near Mt. Hagen in the Western Highlands Province where 234, 800 tubers with a mean size of 50 g were produced per hectare. The second highest mean tuber yield was 7.6 t/ha (214,000 tubers with an average size of 35.8 g) for UPS 62 at Wapenamanda (1615m) in the Enga Province of the Highlands. Tuber yield from UPS 121 at Kuk was 7.7 t/ha (235,600 tubers with an average size of 32.4 g). Tuber yield for all other varieties

at all sites did not exceed 5 t/ha.

At Laloki, a lowland site near Port Moresby, the best tuber yields obtained were 2.6 and 2.5 t/ha for UPS 122 and UPS 62, respectively. The latter produced 187,200 tubers per hectare averaging 13.4 g compared with 145,600 tubers of 17.8 g for the former.

Although these tuber yields may be low compared to other tuber-producing crops, they were essentially a by-product of a grain legume crop. If the crop is managed to promote tuberization, yields could be comparable with those from established tuberous crops.

The effects of pruning and mulching on tuber production

In the Highlands of Papua New Guinea, crops of winged beans grown for tubers are traditionally pruned. Experiments were carried out during a wet and dry season to determine the extent to which this practice enhance tuberization, if at all. A mulching sub-treatment was superimposed in an attempt to lower soil temperature and assess the effect of this on tuber yields.

There were three pruning treatments and an unpruned control; vegetative pruning (leaves and shoots), reproductive pruning (flowers and young pods) and a combined vegetative/reproductive pruning treatment. Pruning was carried out at seven day intervals commencing at first flowering.

Grass mulch, 10 cm thick was applied to one-half of the area, the remaining half receiving no mulch.

Three varieties were selected for these trials; UPS 121 was a high tuber-yielding type whereas USP 31 produced low (if any) yields of tubers and UPS 62 was intermediate. Experiments were conducted at Waigani in a high clay vertisol soil to which 50 g of 12:12:17 fertilizer had been applied per meter of row in a band beneath the seed at the time of planting. Seedlings were raised in jiffy pots in the glasshouse and then transplanted, when the first trifoliate leaf had expanded, 50 cm apart, on ridges 20 cm high and 1 m apart. Plot size was 6 m x 1 m.

Combined yields of roots plus tubers were recorded, mainly because of the difficulty in separating tubers from the roots of UPS 31.

Although all tuber yields recorded were low, pruning increased yield from 10 g (unpruned plants) to 50 g (mean weight of tubers from all pruning treatments) per plant. Tubers from pruned and unpruned plants bulked slowly up to 16 and 17 weeks, respectively. Thereafter, tubers from pruned plants bulked over the following five weeks whereas those from unpruned plants did not change significantly.

Mean leaf area of pruned plants was greater than that of unpruned plants after the commencement of bulking. The larger leaf area maintained over the tuber bulking period probably contributed to the greater rate of tuber growth on pruned plants. Pate (1975) also increased leaf area duration by pruning peas and Moorby and Milthorpe (1974) pointed out that increased yields would be realized if leaf area could be maintained for longer periods after the tubers in potatoes had started bulking.

Tuber production was, for all varieties, restricted in the wet season compared with the dry season. Reproductive and the combined reproductive plus vegetative pruning treatments gave significantly higher tuber yields during the dry season, particularly from the tuber-producing variety, UPS 121 (169.1 g and 165.7 g/plot, respectively). In contrast, during the wet season the vegetative pruning treatment tended to promote higher tuber yields (16.8 g/plot compared with 5 g from unpruned plants), although differences were not significant. These results agree with those obtained by Herath and Fernandez (1978).

Mulching gave significant higher yield of roots plus tubers in both wet (8.9 g/plot) and dry (123.8 g/plot) seasons compared with corresponding yields from unmulched plots of 4.7 g and 75.7 g/plot, respectively. Yields in the dry season were 15 times greater than those in the wet season.

It would be desirable to confirm these findings by repeating similar experiments in a Highlands environment.

The effects of temperature on tuber production

Since tuber production appears to be greater in the Highlands than in the Lowlands, low temperature may be responsible for stimulating tuberization. These studies were carried out in controlled environment chambers to determine the optimum day and night temperatures for tuber production. The winged bean variety UPS 122 was chosen because of its ability to produce tubers in the field. It was grown under various thermoperiods. 20°C day/10°C night, 24°/13°, 25°/15°, and 30°/22°C, with a daytime relative humidity of 91 to 94 percent and a 12/12 hour day/night cycle. These temperatures represent the annual mean maximum/minimum air temperatures from various locations in Papua New Guinea where winged beans are grown.

Single plants were grown in 30cm pots containing alluvial soil mixed with peat moss. Because of the limited capacity of the chambers, 15 cm cylinders of chicken wire, 60cm high were used to support the plants. The main stem and branches of plants were trained, spirally, around the cylinders and, when they had reached the top, were pruned. All flowers were removed as soon as they appeared.

The most vigorous early vegetative growth occurred under the 30°/22°C thermoperiod, followed by 25°/15° and 24°/13°C. Under the 20°/10° regime, vegetative growth was very slow. The high temperatures which promoted vigorous vegetative growth (30°/22°C) appeared to inhibit tuberization. Under the 25°/15°C condition an average of 8 tubers weighing 14.3 g dry weight per plant was produced whereas under the 24°/13°C regime, an average of 13 tubers weighing 22.9 g and under the 20°/10°C regime, an average of 7 tubers weighing 9.7 g dry weight per plant were produced. Further work is required to determine critical temperatures for the promotion of tuberization. The optimum lies between 20° to 25° day and 10° to 15°C night temperatures.

Genetics of tuber production

In order to determine whether or not tuber yields could be improved by breeding, the following study was carried out.

Two pure lines UPS 31 and UPS 122, representing low and high tuber-producing ability, respectively, were crossed to raise F_1, F_2, BC1, and BC2 (BC = back cross) populations. Together with the parents, all six populations were grown in 1977 in the Waigani Garden, University of Papua New Guinea. At the time of harvest, underground yield (root and tubers), haulm yield and number of tubers were recorded and the results were expressed as dry weight per plant.

A variance component analysis was used to partition the total phenotypic variance and estimates of additive, dominance and environmental variances for each character were calculated. From these components estimates of heritability were also made.

The analysis indicated that the tuber yield is controlled by polygenes. The F1 and backcross populations, as expected, were intermediate between their respective parents and the F2 populations showed greater variation than the parents with certain exceptions.

The mean haulm yield of the F1 (133.9 g) exceeded the better parent, UPS 122. This could be attributed to the manifestation of hybrid vigor. Another anomaly was the reduced variance shown by the F2 for the root plus tuber yield (SD in F2 = 5.2, SD in P1 = 5.9).

The heritability estimates indicate that the additive genetic variances were higher than either dominance or environmental variance. The narrow sense estimates of root plus tuber yield, number of tubers/plant and haulm yield were 0.45, 0.64 and 0.64, respectively. Phenotypic correlations between these three characters were greater than + 0.74 and were significant. This showed that correlated responses to selection for high tuber yield are possible.

Tuber production could be enhanced by manipulating the sink-source relationship. Alternatively, genotypes with a hereditary potential for higher tuber yield could be selected. The results of the present experiments based on a narrow genetic base of two pure lines indicate that it may be possible to increase tuber yield by genetic manipulation. However, further detailed studies are necessary before embarking upon a selection programme.

Conclusion

Winged bean tuber is an important and popular food in the Highlands of Papua New Guinea. Traditionally, plants are pruned regularly by removing shoot tips, leaves, flowers and young pods, all of which are eaten. Data presented herein indicate that, in a lowland environment, pruning and mulching promote tuber production and it is reasonable to anticipate that pruning might have a similar effect on tuber yields in the Highlands. If so, tuber yield potential for winged beans would be considerably greater than 11.7 t/ha recorded at Kuk. Such yields may be comparable with those from established tuberous crops. Moreover, based on a mean crude protein content of 7 per cent in fresh tubers, the winged bean tuber crop could be expected to be more valuable, nutritionally, than most others.

Because of the variation which is evident in the germplasm collection at the University of Papua New Guinea, more specific screening for tuber production, preferably in both highland and lowland environments should be carried out. Specific tuber yield trials for varieties showing potential for tuber production should also be carried out at a number of locations over a number of seasons. In both the screening and the yield trials, plants should be pruned regularly to promote tuberization.

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