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The Effect of Trellis Support on the Productivity of Winged Bean Grown for Tubers in Tada-U Township, Myanmar

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Abstract

In Myanmar, the tubers of winged bean (*Psophocarpus tetragonolobus (L.)* DC.) are popular protein-rich snacks traded in small quantities throughout the country. The tubers are mainly produced on untrellised fields in irrigated plains such as around Tada-U township south of Mandalay. However, seed for the tuber crops is produced in trellised fields 150 km to the northeast, in the hills of Shan State. The purpose of the field trial reported here, was to investigate the possibility of producing quality seed in Tada-U, in the middle of a conventionally irrigated tuber crop using a simple 2 m high trellis to promote flower and pod set. The trial had a randomised block design with four replications comparing Trellis and No-Trellis treatments. To facilitate irrigation and interrow cultivation of weeds, the trellises were not erected until 56 days after planting. Throughout the vegetative phase from Day 30 to Day 128, the number and dry weight of nodules per plant in both untrellised and untrellised plots was substantial, confirming winged bean's reputed potential for nitrogen fixation. By Day 94, trellised plants had significantly surpassed untrellised plants in the number of main stem nodes; average internode length, particularly in the first five internodes; total leaf number; number of open flowers; and total dry matter of plants, particularly the leaves. However, by Day 149 when plots were harvested for tubers, the trellised plots had only 120 g dry mater of tubers per plant (about 1100 kg ha-1) compared with 163 g dry matter of tubers per plant (1800 kg ha-1) in the untrellised plots. Moreover, both trellised and untrellised plots had produced negligible yields of fruit (no more than 300 kg dry matter of pods ha-1) and seed by Day 185 when the trial was terminated. For farmers in the central plains who might wish to produce seed locally for tuber production, further research will need to be carried out to identify niches and trellising practices more favourable to high seed yields than are the high-water table riverine flats of Tada-U.

Keywords: Myanmar; *Psophocarpus tetragonolobus*; Tuber Production; Trellis Support; Winged Bean

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Introduction

For centuries past, winged bean (*Psophocarpus tetragonolobus* (L.) DC.), has been grown as a garden vegetable plant throughout tropical Asia and Melanesia and as a minor field crop for tuber production in parts of Myanmar and Papua New Guinea [1-4]. In Myanmar, on the riverine plains around Tada-U town (21°48'58" N, 95°58'12" E) 10 km southwest of Mandalay, the sweet, proteinaceous tubers are produced without trellising under irrigation and are sold in small quantities to markets across the country. Farmers manage their fields in ways that stimulate tuber set and growth. In 2018, about 1,200 ha of winged bean were planted in the Tada-U township administrative area, while about 4,000 ha were planted to rice and 20,000 to other crops such as chickpeas, sunflower, sesame, mungbean and orchards (unpublished data from the Tada-U township Department of Agriculture). There is good circumstantial evidence that winged bean for tuber production benefits soil (particularly its organic matter and nitrogen content) for subsequent crops [1].

The seed sown to produce these tuber crops comes from the Shan State in north-eastern Myanmar where environmental conditions and the trellising provided by farmers favour seed production over tuber production. However, in recent years the price of this seed has been rising steeply. Tada-U farmers could produce their tubers more economically if seed of the tuberous variety could be produced locally. The farmers are very familiar with the practices of trellising and judicious reproductive pruning for other crops such as oriental melons (*Cucumis melo* Makuwa Group) grown for export. The reason they continue to produce winged bean tubers in fields adjacent to these high value melons is because the tuber crop is a low-risk alternative. The market for winged bean tubers though small is relatively stable and profitable for farmers with the know-how to grow them. In contrast to abundant, potentially hazardous, use of pesticides in the melon crops [5], there is minimal use of expensive chemical inputs other than fertilisers in the production of winged bean tubers (Figure 1).

This paper describes a trial that we conducted in an irrigated field of Tada-U town to examine the effects of trellising on winged bean growth, and on the yield of tubers, pods and mature seed. The aim of the trial was two-fold: (1) to examine whether it is feasible to produce seed of the tuber-producing variety locally rather than having to purchase it from Shan State; and (2) to learn more about the traditional production methods of experienced farmers. Field trials in Southeast Asia and Africa have shown potential benefits of trellising on seed

Figure 1: Winged bean cropping system. A. In Tada-U, a tuber crop with a trellised melon crop in the background; B. Edible winged bean tubers; C. In Tada-U, a mulched, trellised, melon crop; D. Near Bant Bway in Shan State, a lightly trellised, winged bean crop for seed production.

production and of trellising coupled with reproductive pruning on tuber production [6,7], but previous observations suggest that this might not be the case in the tuber cropping systems of Myanmar [1]. Apart from possible practical benefits of the trial described here, measurement of carbon and nitrogen fixation and of their partitioning within a legume-based cropping system is of broad interest [7-9].

Materials and Methods

Study site

The trial was carried out in a field of farmer U Win Myint (21°48’27” N, 95°57’20” E, 60 m asl), 1 km west of the Tada-U railway station. Tada-U is situated on a meander floodplain derived from the confluence of the incoming Myitnge River with the major Irrawaddy drainage system. The better soils of the stable riverine plains are described as Dark Compact Soils (Vertisols) with good water-holding capacity in contrast to surrounding lighter textured soils known as Red Brown Savanna Soils [10]. Typically, these are characterised by a clay content of 30% or more, with a neutral to alkaline pH (7-8.5). However, the soil of U Win Myint’s winged bean field was somewhat lighter in colour and texture, with a higher sand content and more variable pH than a classic Vertisol.

The climate of Tada-U is classified as Tropical Savanna (Aw). Thirty-year climate data (1961-1990) from the nearby city of Sagaing (21°52’56”, N 95°58’43” E) records an annual mean temperature of 27.5^0C, and a total annual precipitation of 798 mm on average, 89% of which falls between the beginning of May and the end of October (Table 1). Evidence is that June-July rainfall in the Central Dry Zone of Myanmar has been declining since the 1950s, emphasising the somewhat bimodal pattern of the rainy season [11, 12].

Planting details

In early July 2019, the farmer, U Win Myint ploughed the field using animal traction in preparation for planting winged bean. A basal application of manure preceded the ploughing. After ploughing, row positions were marked out 60 cm apart. Then, in late July, winged bean seed from Shan State purchased in Pyin U Lwin was planted by hand at a spacing of 45 cm between planting-points within the rows. At each planting-point 4-5 seeds were sown at a depth of about 3 cm. On 25 July, the field was trickle-irrigated. This was followed by an immediate heavy rainfall event which ensured good germination. On 3 August (i.e., Day 9), when the seedlings were at the two-unifoliate leaf stage, the field was inter-row cultivated with a cattle-drawn rig and an area 19.2 m (32 rows) wide by 15 m (32 planting-points) wide was marked out within the field for conduct of the trial (Figure 2).

Trial design

The trial was designed initially to evaluate two treatment factors in a split-plot arrangement with four replications in a randomised block configuration. The main-treatment factor compared trellis support with no trellis support, while the sub-treatment factor was intended to compare management for tuber production versus management for seed production. As the trial progressed, however, it was recognised that there was no purposeful difference in the management for tubers versus management for seed. Thus, for statistical analysis, the two subplots were considered as systematic samples of the eight main treatment plots, rather than as sub-treatment plots.

Management of trial area and construction of trellis treatments

The winged bean field including the trial area was irrigated and sprayed twice during August with an application of foliar fertiliser (30 N: 20 P_2O_5: 10 K_2O) and post-emergent herbicide (Active Ingredient Quizalofop-P-Ethyl) for controlling grass weeds. By 24 August (Day 30), plants were well established at about the seventh trifoliate leaf stage. On Day 45, the field was interrow cultivated by animal traction (Figure 2). Subsequently, weeds within plant rows were removed by contracted day-labourers. To facilitate construction of trellising, the field was not irrigated in mid-September and, without rain, the field was looking quite dry by 19 September (Day 56). Subsequently, the field was irrigated as needed and October-November rains ensured adequate growth and ground coverage up until termination of the trial after final tuber harvest in January 2020 (Day 185).

On Day 56, trellises were constructed in the four relevant main-plots. Each plot received four adjacent tripod-style trellises, 3.75 m long and 2m high (Figure 2). Within each plot, the innermost four plant rows were reserved for measurement of final seed and tuber yields, while the outermost four rows were used for progressive plant sampling (for growth analysis).

Sampling and measurement of variables of plant performance

On 3 August, soon after plant emergence, the number of planting points within a 15 m length of row and the number of seedlings within each of twelve randomly sampled planting points were counted in an area of the field adjacent to the trial area. Four random planting points were again dug up for analysis on 8 September.

Then, from the time of trellis-construction onwards, systematic sampling for plant growth analysis was carried out within the trial area on five occasions – 19 Sep (Day 56); Day 74; Day 94; Day 115; 30 Nov (Day 128). On these occasions, each experimental plot was sampled; one planting point was randomly selected from the outer four rows of each experimental plot and all growing plants from within that selected planting point clump were disentangled and the following variables were determined in the laboratory: number of plants per clump; height (cm) of each plant in the clump; number of leaves per plant; length of the longest root (cm); number of visible root nodules per plant; number of open flowers per plant; dry weight (g) of leaves per plant; dry weight (g) of stem per plant; dry weight (g) of root per plant; and dry weight of nodules per plant. On six occasions between Day 30 and Day 115, internode lengths (cm) for all mainstem internodes of all sampled plants were measured.

On Day 149 and Day 185, in which the focus was on final yield, the sampling method changed; five single, randomly sampled plants from the innermost four rows of each sub-plot were harvested and taken to the laboratory to determine total dry weight (g) of fruit, tubers, leaves and stems.

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max temp (0C)	28.8	31.9	36.0	38.2	35.7	33.7	33.0	32.5	32.5	32.3	30.4	28.3
Min temp (0C)	14.3	16.4	20.6	24.8	25.7	26.2	26.2	26.0	25.6	24.7	20.4	15.9
Rainfall (mm)	1.0	4.6	5.0	39.4	142.6	99.0	69.8	126.1	153.0	119.5	32.0	6.0

Table 1: Climate averages for Sagaing, Myanmar (https://worldweather.wmo.int/en/city.html?cityId=2155, accessed September 2022).

Figure 2: Planting details. A. Irrigating up on 25 July after hand planting; B. Emerged seedlings on 3 August (9 Days after planting); C. Established plant clumps on Day 30; D. Inter-row cultivation on Day 56; E. One month after imposition of trellis treatments (Day 74); F. Two months after imposition of trellis treatments (Day 115).

Data analysis

For the seven occasions between 24 August and 30 November, on which planting point clumps were sampled for growth analysis, clumps varied in the number of established plants. Thus, for analysis of the effect of trellising on depended variables (leaf number per plant, dry weight of roots per plant etc.), the plant number per clump was regarded as an independent random variable. For all measured variables, mean plant values were determined for each sampled clump (by dividing total clump values by the number of plants in the clump). Then analyses of variance on these mean plant values were carried out using the General Linear Model analysis function within IBM's SPSS statistical package. Differences between main treatments (trellis vs no-trellis) were regarded as fixed effects while differences between replicate blocks were regarded as random effects. For each measured variable, standard errors for the treatment means were determined from the treatment x replicate variance components, and F-tests were carried to assess the significance of differences between Trellis and No Trellis treatments.

Results

Plant density

On 3 August, nine days after planting, when emerged seedlings were at the two-unifoliate-leaf stage, there were an average of 27 plant clumps per 12-metre length of row. The number of seedlings per clump ranged from 1 to 5 with a mean of 3.8 plants per clump. The rows were 60 cm apart. So, at this time, the plant population for the field as a whole (Figure 2) was determined to be approximately 140,000 seedlings per hectare (i.e., 14 m^{-2}). On subsequent sampling occasions, there was a slight declining trend in average number of plants per clump: 19 Sep (Day 56) - 3.6 plants; Day 74 - 3.6; Day 94 - 3.5; Day 115 - 3.3; and Day 128 - 3.2 plants.

Analysis of plant architecture

For more than forty days after installation of trellising on Day 56, there was no significant difference in the length of the main stem between the trellised and untrellised plots, but at measurement on Day 115 and Day 128, the total length of the main stem was greater ($p<0.05$) in trellised plants than in the untrellised plants (Table 2). The difference in mean main stem length from plants in Trellis and No Trellis treatments on Day 128 was due not only to a significant difference in the number of main stem nodes but also to difference in their average internode length, more particularly in the first five internodes than in the upper internodes. On the earlier sampling occasions, Day 74 and Day 94, plants from trellised and untrellised treatments did not differ significantly either in node number or average internode length. On no sampling occasion did plants from trellised and untrellised treatments differ in the mean number of main stem branches, but on Day 115 and Day 128, number of leaves on trellised plants was double that of untrellised plants.

No flower buds were observed in any plot on 24 August (Day 30) but by 7 October (Day 74) open flowers were recorded in fifty percent of main plots, with a greater number of open flowers in the trellised than untrellised treatment. By Day 115, plants from the trellised treatments had significantly more open flowers than plants in the untrellised treatment (Table 2).

	Measurement Occasion			
	17 November (Day 115)		30 November (Day 128)	
	Trellis	No Trellis	Trellis	No Trellis
Total mainstem length (cm)	317 + 20	203 + 20*	311 + 11	184 + 17*
Number of mainstem internodes	30 + 2	21 + 1*	na	na
Length of N1-N5 (cm)	33.6 + 4.9	18.5 + 1.2*	na	na
Length of N6-N10 (cm)	55.7 + 4.6	49.9 + 3.3 NS	na	na
Number of open flowers per plant	8.3 + 1.6	0.2 + 0.1*	na	na
Total number of leaves per plant	48 + 5	26 + 4*	52 + 7	19 + 2*

Table 2: A comparison of plants in trellised and untrellised treatments in the length of the main stem, number of main stem nodes, the length of their internodes, and the number of flowers per plant, recorded on 17 November; and total number of leaves recorded on 17 and 30 November. Values are expressed as means + standard errors of plants in clumps from four replicates. For internode length recorded on 17 November the values are expressed as the average across all main stem internodes and as the total length of the first five internodes (N1-N5) and of the second five internodes (N6-N10).

Note: * These mean values for the Trellis treatment differ significantly from those for the No Trellis treatment (at $p<0.05$).

Root development and nodulation

From the time of the first plant measurement on 24 August (Figure 3) through until 30 November healthy root nodules were observed in all plant clumps, but on no measurement occasion was there a significant difference in the number or dry weight of root nodules per plant between trellised and untrellised plants (Table 3).

Mean number of nodules per plant reached a peak on Day 94 and declined somewhat after that occasion, but total dry weight of nodules did not decline. There was no difference between trellised and untrellised plants in the mean length of the longest root on any measurement occasion.

Figure 3: Winged bean nodules, tubers and pods: A. Root nodules on 24 August (Day 30); B. Tubers harvested from one Untrellised plot on Day 149; C. Tubers harvested from one Trellised plot on Day 149; D. Pods harvested from one Trellised plot on Day 149.

Measurement Occasion	Length of Longest Root (cm) Per Plant	Number of Visible Nodules per Plant	Dry Weight (g) of Visible Nodules per Plant
Day 30 - 24 Aug	12.9	11.0	0.09
Day 56 - 19 Sep	20.7 + 1.3	13.9 + 2.5	0.28 + 0.05
Day 74 - 7 Oct	22.5 + 0.6	30.2 + 3.7	0.48 + 0.14
Day 94 - 27 Oct	24.6 + 0.7	33.0 + 5.1	0.64 + 0.09
Day 115 -17 Nov	25.5 + 0.7	25.9 + 4.2	0.55 + 0.10
Day 128 - 30 Nov	22.0 + 0.5	9.7 + 1.4	0.60 + 0.20

Table 3: The mean length of the longest root, number of visible root nodules and dry-weight of nodules per plant determined between 24 August and 30 November 2019.Values are expressed as means + standard errors of plants in clumps from four replicates determined independently for each measurement occasion.

Plant dry matter growth and its partitioning

Total dry matter of plants increased steadily between Day 30 and 3 Day 128). After 27 October (Day 94), growth of total dry matter of trellised plants outstripped that of untrellised plants (Figure 4). The most significant contribution to this difference in total dry matter came from the leaf portion rather than from stem or roots (Table 4).

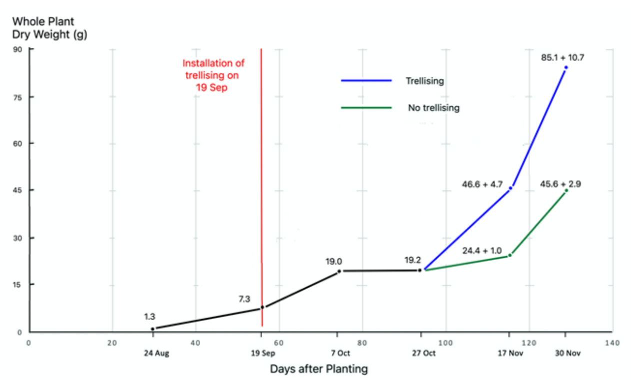

Figure 4: The increase in the total dry matter (g) of winged bean plants (leaves + stems + roots + nodules) from Day 30 to Day 128 in response to trellising. Values shown are means + standard errors of plants in clumps sampled from four replicates. There was no significant difference in total plant dry matter between Trellis and No Trellis treatments on 7 October and 27 October.

	Dry Weight (g) of Plant Parts					
Measurement	Leaves		Stems		Roots	
Occasion	Trellis	No Trellis	Trellis	No Trellis	Trellis	No Trellis
Day 30 - 24 Aug		0.5		1.1		0.1
Day 56 - 19 Sep	3.7 + 0.8	5.0 + 0.5	2.1 + 0.3	1.7 + 0.2	1.0 + 0.3	0.6 + 0.1
Day 74 - 7 Oct	13.1 + 1.3	8.2 + 0.2	8.4 + 1.4	4.3 + 0.7*	1.7 + 0.4	1.3 + 0.4
Day 94 - 27 Oct	8.8 + 0.8	7.8 + 0.9	9.4 + 1.2	7.8 + 0.8	1.7 + 0.3	1.6 + 0.1
Day 115 - 17 Nov	18.3 + 3.1	4.8 + 0.9*	15.9 + 2.1	9.6 + 1.1	11.9 + 1.1	9.4 + 1.1*
Day 128 - 30 Nov	38.1 + 7.5	8.5 + 1.0*	22.6 + 2.7	17.7 + 1.3	24.2 + 4.2	18.5 + 2.2

Table 4: The change over time in dry matter of individual plant components (leaves, stems and roots) from Day 30 to Day 128. Values are expressed as means + standard errors of component parts of plants in clumps from four replicates determined independently for each measurement occasion.

Note: * These mean values for the Trellis treatment differ significantly from those for the No Trellis treatment (at $p<0.05$).

Up until Day 94, the fibrous root systems of plants consisted largely of dispersed mats of thin adventitious roots but, from then on, the primary and major lateral roots thickened visibly, resulting in the substantial increase in root dry matter per plant recorded on 17 and 30 November for both trellised and untrellised plots (Table 4).

Final yields of tubers and pods

Although, root dry matter per plant was slightly higher in the Trellis than No Trellis treatments between September and November, this did not result in higher root tuber yields on Day 149 and Day 185 (Table 5). On Day 149, the yield of tubers per plant in the No Trellis treatment plots was significantly higher than in the Trellised plots (Table 5, Figure3). On the other hand, the Trellis plots had higher dry matter of fruits than did the No Trellis plots.

Subsequent to the 21 December measurement, farmer U Win Myint harvested tubers from his field including from the No Trellis plots in the trial area. Thus, on the 26 January, only trellised plots were available for sampling. By this time, there had been an increase in leaf drop from the plants; a decline in remaining stem, leaf and tuber dry matter; but an increase in fruit dry matter. Whereas no mature seed had been produced in the No Trellis plots by the time of the final tuber harvest, a very small (unmeasured) yield of mature seed was obtained from the Trellised treatment at the time of termination of the trial on 26 January.

If we assume that the average plant density of the field had declined over time (see section on Plant Density, above) from 140,000 plants ha^{-1} at Day 9 to 110,000 plants ha^{-1} by the end of the trial, then the dry matter of tubers on Day 149 equated to about 1800 kg ha^{-1} in untrellised plots and to 1100 kg ha^{-1} in trellised plots. At trial's end on Day 185, the yield of pods in trellised plots equated to 300 kg dry matter ha^{-1}; a very low yield compared to pod and seed yields routinely reported in the international literature [2,7,13].

Dry Weight (g) of Plant Parts	Day 149 - 21 December		Day 185 - 26 January
	No Trellis	Trellis	Trellis only
Leaves	28.5 + 4.2	37.8 + 2.6#	9.4 + 1.2
Stems	63.5 + 24.2	64.4 + 13.3	41.6 + 2.4
Root Tubers	162.7 + 16.0	102.4 + 11.0*	92.0 + 9.8
Fruits	3.1 + 0.7	6.0 + 2.0#	28.0 + 3.8
100-Seed Wt	na	na	37.3 + 0.5

Table 5: The dry matter of individual plant components (leaves, stems, root tubers, and mature green fruits) on 21 December 2019 and 26 January 2020. Values are expressed as means + standard errors of component parts of five plants sampled plants randomly from plots in each of four replicates determined independently for each of the two measurement occasions.

Note: * These mean values for the Trellis treatment differ from those for the No Trellis treatment at a significance level of $p<0.05$).

These mean values for the Trellis treatment differ from those for the No Trellis treatment at a significance level of $p<0.10$).

Discussion

The results of this trial support the local contention that environmental conditions and existing winged bean cropping practices on the irrigated plains of Tada-U township are more favourable for tuber production than they are for seed production. Writing in the early years of the twentieth century, Shwe Zan Aung [1] recorded: "While much of the quality [of tubers] depends upon the selection of seeds, the difference between plants grown from Shan seed and locally saved seed may still further be ascribed to the fact that in spite of the more abundant rainfall in the Shan States, the hilly country is not exactly waterlogged as the plains are; for it will be noticed that the excess of moisture in the ground materially affects the yield" It is still common practice today to purchase seed from the Shan states for planting tuber crops in Tada-U and surrounding areas. Local seed is considered to be inferior for tuber production, compared with seed purchased in Pyin Oo Lwin obtained from crops grown with trellising in the scattered hill farms of Shan State.

An interesting question arises from this: what is the feedback loop that ensures trellised winged bean planted for seed production in Shan State retains the genetic potential for good quality tuber production in the very different environment and agronomic practices of the irrigated flood plains? The crops grown in Shan State do produce tubers – again quoting from Burkill [1]: "Sometimes the Shans dig the root up and eat it, but more generally they leave it to produce beans which are gathered young except those intended to set seed… The tuber is said to be much larger than is produced in Burma (i.e., on the Central plains)". It is likely that, from time to time, seed collected from the tuber fields on the plains makes its way back to the seed growers in the Shan State, which would provide a genetic infusion from the plains to the hills. The seed for the tuber crops has a cream colour testa and is large (100-seed weight 36-37 g) compared to the tan coloured seed of winged bean varieties grown for vegetable pod production in Southern Myanmar (100-seed weight 31 g); moreover, trellised winged bean plants of the Shan tuber variety produce more branches (7) in the first ten main-stem nodes than do the southern varieties (5) grown for vegetable pod production [14]. A high number of branching stems from the lower nodes is of benefit to untrellised tuber crops, allowing for a more rapid leaf coverage of the ground. In contrast, winged bean varieties planted with staking support for tuber production in Papua New Guinea have much less branching from the lower mainstem nodes.

Many studies in other parts of the world have consistently obtained greater pod and seed yields from trellised winged beans than from untrellised plants [15]. With a robust trellis structure, Wong [16] achieved a cumulative green pod yield of 35 t ha^{-1} from a Malaysian winged bean variety. Trellised winged bean plots had seed yield up to ten-fold and tuber yields three-fold those of untrellised plots. For seed yield, a 1.8-meter-high trellis out-yielded a 1.2 m high trellis. With this kind of semi-permanent trellis, the Malaysian team went on to obtain a cumulative seed yield of 6.26 t ha^{-1} by growing a first crop through to 19 weeks after planting, followed by two additional ratoon cycles of seed production [7]. The benefits of trellising and ratooning apply particularly to varieties with strong branching tendencies [17]. With such varieties, researchers in Java have found that the optimum plant density for trellised green pod and dry seed yield is below 75,000 plants/ha and often much lower [18,19]. In a recent variety trial in North East Thailand [13] estimated fresh pod and tuber yields of around 20 t ha^{-1} to 15 t ha^{-1}, respectively, were obtained from two dual-purpose winged bean accessions, planted with 2 m high trellises at a spacing of 20,000 plants ha^{-1}. In a second, less favorable season, the yields were half those obtained in the previous season.

In this paper we have focussed on the agronomy of tuber production. Shwe Zan Aung cited by Burkill [1], "reported that "The [financial] margin left to the bone fide cultivators after trouble and expenses would by itself not be encouraging, but the cultivators in Singaing township generally grow a bumper crop of sugar-cane after [winged beans]. It is said that the cane crop, if preceded by (winged bean) yields half as much again as usual". Our trial confirmed the reports of other workers [2,7,20] of substantial healthy nodulation of the winged bean root system in a variety of soil types.

Thu et al. [21] working in dryland cropping systems of Magway Region in Central Myanmar, showed a significant increase in subsequent crop yields by incorporating various crop residues into the soil as mulch. In that context the major benefit came from an increase in water use efficiency. Nevertheless, with such residue incorporation practices there are likely to be additional long-term benefits arising from improvements in soil organic matter status; including soil nitrogen in the case of leguminous residues. In Myanmar, there has been good research on the effectiveness of various rhizobial strains for growth and productivity of major leguminous crops such as chickpea [22] but very little work on nodulation and nitrogen-fixation in winged bean. Circumstantial evidence suggests that winged beans grown for tubers in the irrigated plains of Tada-U make a positive contribution to soil organic matter including nitrogen, despite the fact that at time of harvesting the tubers crop residues are removed for feeding livestock. Further research is required to substantiate this.

Conclusion

For farmers in the irrigated plains of Kyaukse and Tada-U, there would be a double benefit if seed for their tuber crops could be produced locally; not only would cost be reduced, but there would arise a more direct genetic relationship between factors controlling yield and quality of tubers and the factors involved in seed production. However, as tradition suggests and this trial confirms, fields susceptible to water-logging in the Tada-U plains are not ideal for trellised seed production. Research should be undertaken to identify nearby locations that are less flood-prone where trellised seed production could be conducted more conveniently. Further research, both technical and social, is also required to assess the economic sustainability of winged bean tuber production in the Kyaukse–Tada-U triangle and the long-term effects of this enterprise on soil properties of the area.

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