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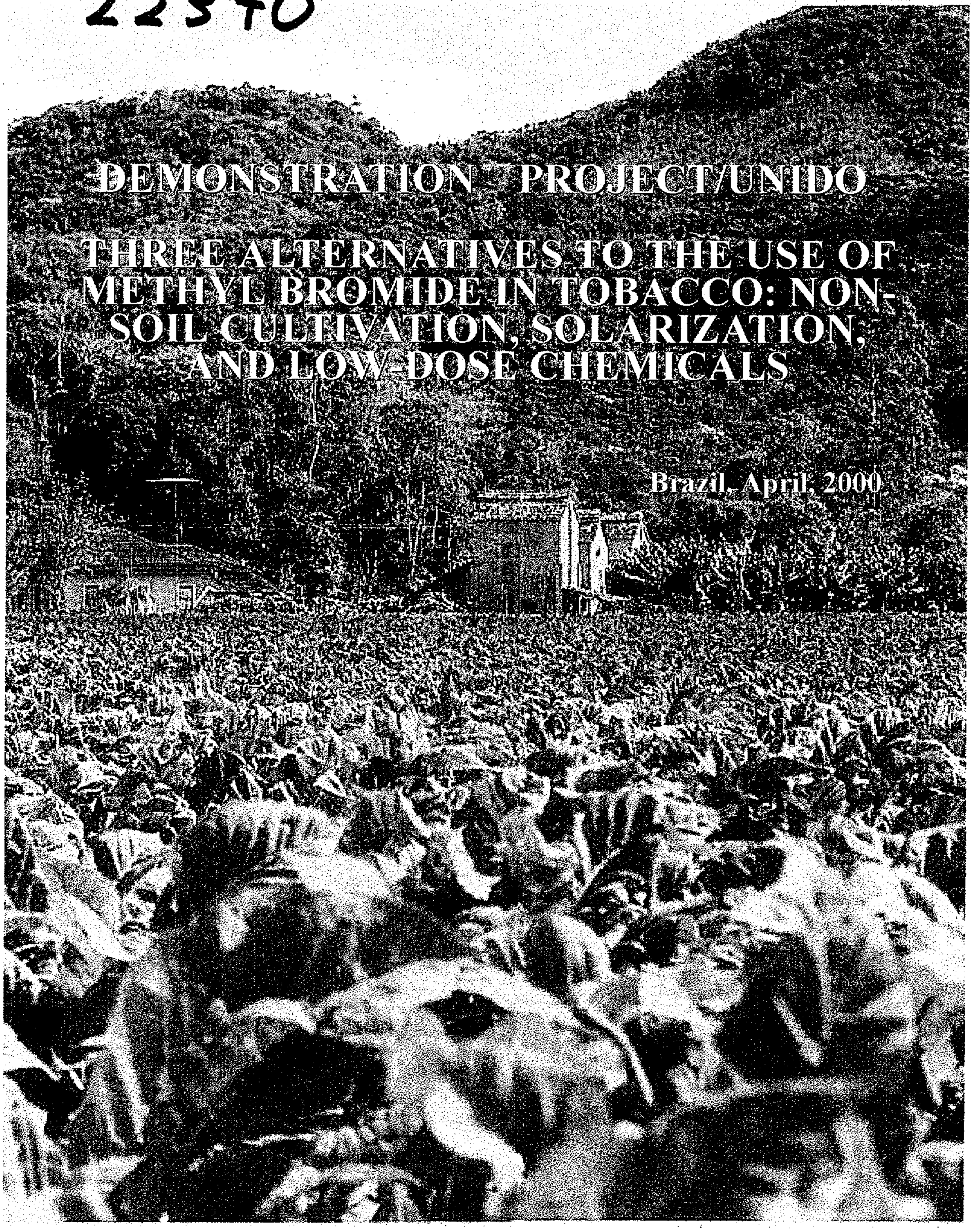

DEMONSTRATION PROJECT/UNIDO

THREE ALTERNATIVES TO THE USE OF METHYL BROMIDE IN TOBACCO: NON-SOIL CULTIVATION, SOLARIZATION, AND LOW-DOSE CHEMICALS

Brazil, April, 2000

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DEMONSTRATION PROJECT - UNIDO

THREE ALTERNATIVES TO THE USE OF METHYL BROMIDE IN TOBACCO: NON SOIL CULTIVATION, SOLARIZATION AND LOW DOSE CHEMICALS

FINAL REPORT

1998-2000

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SUMMARY

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DEMONSTRATION PROJECT ON ALTERNATIVES TO THE USE OF METHYL BROMIDE: NON-SOIL CULTIVATION, SOLARIZATION AND LOW-DOSE CHEMICALS IN BRAZIL

ABSTRACT

Methyl bromide, a broad-spectrum pesticide, has been used in Brazil for more than five decades in the control of pest insects, nematodes, weeds and soil pathogens. Most of this pesticide is used in the tobacco sector for seedbed fumigation, which accounts for more than 95% of the amount used in Brazil, totaling, in 1998, approximately 700 tons. The objective of the project "Alternatives to the use of methyl bromide" is to demonstrate the technical and economic feasibility of alternative methods to the use of methyl bromide for production of tobacco seedlings.

The fieldwork was carried out at three different sites in the Rio Grande do Sul and Santa Catarina states. Different floating systems in high and low tunnels, as well as different chemical treatments of seedbeds, solarization, and other alternatives were applied and evaluated. The outcome encourages the use of the floating system, especially in low tunnel, due to the low cost, and the use of Metam sodium and solarization in seedbeds. Seedling production in solarized seedbeds was the lowest cost alternative, however, its technical success depends on meteorological conditions. The price of the growth media and of the tunnel structure determines the higher cost of the alternative bed of substrate, particularly in the high tunnel.

In the field phase, the yield of tobacco plants developed from seedlings produced by using the floating systems and solarization, demonstrated the suitability of these methods for producing tobacco seedlings.

I - INTRODUCTION

Methyl bromide, a broad-spectrum pesticide, has been used in Brazil for more than five decades, in the control of pest insects, nematodes, weeds and soil pathogens. Originally used for controlling leaf-cutting ants and disinfectant of stored products, it is used today primarily as a soil fumigant. Soil sterilizer has been primarily used in greenhouses and nurseries to prevent the spreading of nematodes and soil diseases. In Brazil, most of this pesticide is used in the tobacco sector, for seedbed fumigation, which accounts for more than 95% of the total application. Methyl bromide is not manufactured in Brazil, and is therefore imported mainly from the United States and Israel, which accounted for a total import in 1997 of around 1,700 tons.

Brazil is the fourth largest tobacco producer in the world, with approximately 540,000t/year. The main area of coverage is the south, where the States of Rio Grande do Sul, Santa Catarina and Paraná represent around 90% of the total production in the country. In this region, around 158,000 farmers, distributed in more than 650 municipalities, are involved in the tobacco production. The average size of the family-run farm is 20 hectares, out of which 1.5 to 2.0 hectares are generally dedicated to tobacco cropping.

The Brazilian Government proposed in 1995 to phase-out the non-essential use of methyl bromide, by the year 2006. A demonstration project, with alternatives to substitute methyl bromide in tobacco sector, was submitted and approved at the 22nd Meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol. The objective of this project is to conduct demonstration trials in order to evaluate the technical and economical feasibility of alternative methods to the use of methyl bromide in the tobacco seedling production. Two technical State Institutions are involved in the project implementation, EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), and EPAGRI (Empresa de Pesquisa Agropecuária do Estado de Santa Catarina).

The fieldwork was carried out in the Rio Grande do Sul and Santa Catarina states. In the first State, two municipalities were targeted, namely Pelotas in the 1998-1999 growing season, and Vera Cruz in the following year. In the second State, the municipalities of Aurora and Ituporanga were earmarked for this activity. The differences of the floating tray systems in high and low tunnels, as well as the different chemical treatments of seedbeds, solarization and other alternatives were evaluated.

II - METHODOLOGY

In Rio Grande do Sul, during the first year of the project, the demonstration trial was conducted in Pelotas, at the "Centro de Pesquisa Agropecuária de Clima Temperado" of EMBRAPA. In the second year, trials were carried out in the most important region for tobacco production in Rio Grande do Sul, namely the "Depressão Central" region, at the municipality of Vera Cruz. In Santa Catarina State the trial was conducted at two municipalities: Aurora, with Virginia type tobacco, and Ituporanga, with burley type tobacco, located at Alto Vale do Itajai region, a major Santa Catarina tobacco producing area.

Description of the alternatives tested:

Traditional seedbed with methyl bromide

This is the traditional system, where methyl bromide at a rate of $50cm^3/m^2$ was applied over the well-prepared soil in seedbed. The soil was covered with a plastic film for a duration of four days. Thereafter, the plastic sheet was removed and sowing took place at a rate of 3,5 g of seeds/seedbed ($45m^2$).

Seedbed with no treatment (as a control mechanism)

The procedure in this system was the same adopted in the previous one, except for the application of methyl bromide. The weed control was done manually. This system was included for evaluation purposes, in order to compare all possible effects of the other seedbed treatments on the seed development.

Seedbed using Dazomet

Dazomet[1], a chemical soil sterilizer used in seedling nurseries, was applied to the well-prepared soil in seedbed at a rate of $50g/m^2$ and incorporated up to 20 cm deep

[1] commercial name - Basamid

in the soil. The treated area was irrigated and covered with polyethylene sheet. To prevent phytotoxicity, the soil was aerated prior to planting.

Seedbed using Metam sodium

Metam sodium[2], a broad-spectrum soil fumigant, was applied to the seedbed at a rate of 75 ml/m^2. The seedbed soil was well prepared, and covered after application with polyethylene sheet for a period of five days. Prior to the application, soil moisture was increased by irrigation.

Solarized seedbed

In the solarization system, a layer of clear UV protected plastic film was applied to the soil prior to planting, in order to trap solar radiation and heating of the soil. The plastic was left in place during the summer months, up to the sowing date. Soil was well prepared to provide an even surface. In order to improve heat transportation in the soil profile, irrigation was performed prior to the application of the plastic sheet. After applying the solarization, and before sowing, the soil was revolved only superficially, to avoid reinforcement from sub superficial layers.

Bio-fumigated seedbed

Bio-fumigation was accomplished by applying 7 kg/m^2 of fresh cow manure. The manure was incorporated up to 20cm deep in the seedbed soil. After the manure application, the seedbed was covered with transparent plastic sheet until the sowing date.

Floating in low tunnel

In the floating system, expanded polystyrene trays (0.34 x 0.68 x 0.06 m) with 200 cells, were filled with commercial substrate and placed to float on a water film of

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[2] commercial name - Bunema

0.08m inside a pool of 1.40 x 5.25m. Above the pool a small micro-tunnel was installed, using 100-micra transparent UV protected plastic sheet. Fertilizers were applied directly on the water, during the sowing time. A copper solution was used in the water to prevent alga development and restrict root growth around the bottom of the cells.

Floating in high tunnel

The system previously described was installed under a high tunnel. In the 1998-1999 growing season a metallic structure was used. In the following season, in order to lower the cost, a high tunnel with a PVC structure was installed covering the floating system.

Suspended trays in high tunnel

Expanded polystyrene trays (0.34 x 0.68 x 0.06 m), with 200 cells were filled with commercial substrate and suspended under a high metallic tunnel, and irrigated as needed. The fertilizers were dissolved and applied through water irrigation.

Bed of substrate in low tunnel

Small plastic pool, of 12 cm height, were filled with an 8cm layer of commercial substrate. Above the pool, a small micro-tunnel was installed by using 100-micra transparent, UV protected plastic sheet. Un-coated seeds were used at a rate of 0,077g/m^2 and irrigation was conducted by using a drip system. The fertilizers were dissolved in water and applied over the substrate.

Bed of substrate in high tunnel

In this alternative, a similar method was used as with the previous one. However, instead of a micro tunnel, a high PVC tunnel was used to protect the substrate bed. The remaining procedures were the same applied in the low tunnel system.

III -TECHNICAL RESULTS

A -SEEDLING STAGE

In Santa Catarina State, on Aurora farm, extreme cloudy conditions favored snail occurrence, possibly *Vaginula* sp. In spite of control practices adopted and applied, the snails could not be controlled, thereby destroying the seedlings in seedbeds. The results at Aurora therefore only correspond to seedlings produced under low and high tunnels.

Chemical alternatives

Dazomet, a chemical soil sterilizer used in seedling nurseries, is a technically feasible chemical alternative to methyl bromide. It is effective against nematodes and weeds, with the advantage of being non-persistent in the environment and is not considered to be an ozone depleting substance. However, in conducting the trials, some kind of plant toxicity was detected. In Rio Grande do Sul, the area treated with Dazomet resulted in very low seed germination (Table 1). Dazomet controlled most of the weeds very well. On average, only 2.2 weeds/m^2 were observed in the treated plot (Table 2). The application must be done in the absence of wind, otherwise, most the product would be drifted away from the seedbed area.

Metam sodium is a broad-spectrum soil fumigant used to control nematodes and weeds, and because it is safer and easier to use than methyl bromide, it is a potential alternative to this chemical. Metam sodium showed a good weed control, and had no effect on seed germination. On average, 120 tobacco seedlings/m^2 (Table 1) have developed in the treated beds. Moreover, uniform application of Metam sodium was extremely easy to obtain.

The demonstration plot treated with methyl bromide, in the 1998-1999 season, compared to the other chemicals, produced on average the highest number of seedlings per area, around 204 seedlings/m^2 (Table 1). This product controlled most of the weeds satisfactorily in both of the growing seasons. The seedbeds treated with methyl bromide produced high dry weight seedlings (Tables 4 and 5).

In Santa Catarina, on both farms, *Amaranthus* sp. (broad leaf) and *Cynodon* sp. (narrow leaf) species were the main weeds found. On the demonstration area located at Aurora, one of the most effective weed controls was provided by methyl bromide (Table 3). In Ituporanga, all chemical products proved to be effective in weed control. Methyl bromide, Dazomet and Metam sodium, produced seedlings with the highest dry weight, compared to the other alternatives tested in the 1998-1999 growing season (Table 6). Although Dazomet-treated seedbed was subject to a 26-day interval, before sowing and soil revolving, the germination test applied has shown some kind of plant toxicity, affecting the seedling quality. In the 1999-2000 growing season, methyl bromide at Aurora, and solarization at Ituporanga, were the alternatives which produced the highest seedling dry weight (Table 7).

In both States, Rio Grande do Sul and Santa Catarina, seedlings produced in seed beds had the highest total dry weight, particularly those from methyl bromide, Dazomet and Metam sodium-treated plots. However the data of dry matter production, should be interpreted with care. Dry matter of seedlings was highly affected by the intensity of leaf pruning. Since the pruning was done at the same time for all alternatives, those in which the seedlings developed faster, had a more drastic pruning.

Table 1. Number of tobacco seedlings/m^2 in plots disinfested with soil fumigants, and controlled in Rio Grande do Sul, Brazil, 1998-1999

System	Number of seedlings/m^2
Methyl Bromide	204
Dazomet	16
Metam Sodium	120
Control	111

Table 2. Number of weeds/m^2 in plots disinfested with soil fumigants, and controlled in Rio Grande do Sul, Brazil, 1998-1999

Systems	Number of weeds/m^2*
Methyl Bromide	11.1
Dazomet	2.2
Metam Sodium	24.4
Control	403.0

*Predominance of broad leaves

Table 3. Dry weight of weeds/m^2 in plots disinfested by soil fumigants, solarization, bio-fumigation, and controlled in two municipalities at Santa Catarina, Brazil, 1998-1999

a) Aurora

Systems	Dry weight (g/m^2)		
	Broad leaves	Narrow leaves	Total
Methyl Bromide	0	0	0
Dazomet	1.36	0	1.36
Metam Sodium	38.50	26.60	65.10
Solarization	0.08	0	0.08
Bio-fumigation	32.00	69.90	101.90
Control	68.30	76.80	145.10

b) Ituporanga

Systems	Dry weight (g/m^2)		
	Broad leaves	Narrow leaves	Total
Methyl Bromide	0	0	0
Dazomet	0	0	0
Metam Sodium	0	0	0
Solarization	0	0	0
Bio-fumigation	0	0	0
Control	19.00	253.40	272.40

Table 4. Dry weight of shoots, roots, and total of tobacco seedlings produced in different systems at Rio Grande do Sul, 1998-1999

Systems	Dry weight (g)		
	Roots	Shoots	Total
SEEDBEDS			
Methyl bromide	0.22	3.93	4.15
Metam sodium	0.21	3.81	4.02
LOW TUNNEL			
Floating	0.29	2.26	2.55
Bed of substrate	0.19	1.66	1.85
HIGH TUNNEL			
Floating	0.30	1.90	2.20

Table 5. Dry weight of shoots, roots, and total, and stem diameter, of tobacco seedlings produced in different systems at Rio Grande do Sul, 1999-2000

Systems	Dry weight (g)			Stem diam. (mm)
	Roots	Shoots	Total	
SEEDBEDS				
Methyl bromide	0,63	6,34	6,97	0,53
Without methyl bromide	0,67	5,35	6,02	0,53
Solarization	0,37	4,29	4,66	0,51
LOW TUNNEL				
Floating	0,17	1,43	1,60	0,39
Bed of substrate	0,12	1,70	1,82	0,39
HIGH TUNNEL				
Floating	0,30	2,95	3,25	0,52
Bed of substrate	0,17	2,15	2,32	0,44

Table 6. Dry weight, height, number of leaves, and stem diameter of seedlings produced in different systems, in two municipalities, at Santa Catarina, Brazil, 1998-1999

a) Aurora

Systems	**Dry weight (g)**			**Height (cm)**	**Leaves (n°.)**	**Stem diam.(mm)**
	Root	**Leaf**	**Total**			
LOW TUNNEL						
Floating	0.66	2.36	3.02	14.75	4.56	4.28
HIGH TUNNEL						
Floating	0.46	1.69	2.15	13.50	5.43	4.15
Suspended trays	0.35	2.22	2.57	12.07	4.85	4.45

b) Ituporanga

Systems	**Dry weight (g)**			**Height (cm)**	**Leaves (n°.)**	**Stem diam.(mm)**
	Root	**Leaf**	**Total**			
SEEDBEDS						
Methyl bromide	0.45	8.96	9.41	16.19	4.07	4.93
Dazomet	0.41	7.00	7.41	16.65	4.35	4.93
Metam sodium	0.51	6.89	7.40	20.10	5.06	5.96
Solarization	0.41	5.43	5.84	17.80	4.66	5.96
Biofumigation	0.45	5.51	5.96	14.40	4.10	5.32
LOW TUNNEL						
Floating	1.06	3.63	4.69	15.68	4.37	5.34
HIGH TUNNEL						
Floating	0.91	3.52	4.43	21.31	4.43	4.65
Suspended trays	0.78	0.72	1.50	9.18	4.00	4.32

Table 7. Dry weight, height, number of leaves and stem diameter of tobacco seedlings, produced in different systems, in two municipalities at Santa Catarina, 1999-2000

a) Aurora

System	Dry weight (g)			Height (cm)	Leaves (n°.)	Stem diam. (mm)
	Root	Leaf	Total			
SEEDBEDS						
Methyl bromide	1.69	15.27	16.96	21.30	5.25	5.55
Solarization	0.87	10.12	10.99	23.19	4.85	4.75
LOW TUNNEL						
Floating	0.90	5.38	6.28	20.71	4.70	3.95
Bed of substrate	1.34	6.14	7.48	13.23	4.80	3.60
HIGH TUNNEL						
Floating	1.20	4.24	5.44	17.13	4.45	3.20
Bed of substrate	0.53	4.80	5.33	15.82	4.65	2.90

b) Ituporanga

System	Dry weight (g)			Height (cm)	Leaves (n°.)	Stem diam. (mm)
	Root	Leaf	Total			
SEEDBEDS						
Methyl bromide	1.00	16.90	17.90	20.67	4.90	6.60
Solarization	2.20	17.20	19.40	22.50	5.25	6.35
LOW TUNNEL						
Floating	1.20	5.70	6.90	15.09	3.50	3.90
Bed of substrate	2.00	10.30	12.30	16.76	4.05	5.00
HIGH TUNNEL						
Floating	1.10	6.40	7.50	20.08	3.60	3.85
Bed of substrate	1.60	8.00	9.60	15.84	3.70	4.65

Solarization

Solarization can be a viable alternative to methyl bromide in the control of soilborne pathogens and weeds, in tobacco seedling production, when applied as a pre-plant soil treatment. By using this technique the solar radiation was trapped by heating the soil to a temperature high enough to eliminate a broad spectrum of soil pests, resulting in a process that left no toxic residues.

The results from the region of Vera Cruz in Rio Grande do Sul, and Ituporanga and Aurora in Santa Catarina State, showed that solarization was effective against a broad spectrum of weeds present in the demonstration area. In Santa Catarina, weed control was very close to 100%. In Vera Cruz, in the 1999-2000 growing season, no weeds were observed in the solarized plots. Seedlings produced in the solarization system on both growing seasons, in the two states, presented good quality, based on data collected having a total dry weight and stem diameter.

Bio-fumigation

Bio-fumigation was performed only in the 1998-1999 growing season, in the Santa Catarina State. Bio-fumigation is a safe alternative method in the control of soilborne pathogens and weeds, when applied as a pre-plant soil treatment. In this technique fresh manure was incorporated to the soil. The gases produced during the manure decomposition process affected a broad spectrum of soil pests.

A big difference was observed related to weed control at the two sites where this alternative was tested (Table 3). At Aurora, the weed control was very poor, with a high number of broad and narrow leaves developing in the treated area. On the other hand, at Ituporanga, the bio-fumigation was very effective controlling all the weed species present, thereby showing similar results to the chemical alternatives used. The seedlings produced in bio-fumigated area resulted in good quality (Table 6).

Seedbeds with no treatment (as a control mechanism)

During the 1998-1999 season in Rio Grande do Sul, a large number of weeds developed in the area in seedbeds without treatment (control), thereby reducing tobacco seedling development significantly. For this reason this treatment was not further evaluated. In the following year, the weed control was done manually. A large number of weeds that initially developed in the area, impaired seed germination, and reduced the number of seedlings available for transplantation. However, the low number of seedlings produced was of high quality. In Santa Catarina there was no weed control, and the large number of weeds developed in the area dramatically reduced the seedling development, impairing any further evaluation.

Bed of substrate in low and high tunnel

The results obtained with seedling production in the bed of substrate (Tables 4, 5 and 7) showed that this alternative is technically viable, with low application of chemicals, and fungicides necessary for disease control. In the 1998-1999 growing season at Rio Grande do Sul, and the 1999-2000 in Santa Catarina, the irrigation was done manually. However, the lack of uniformity in this process impaired seedling development, and produced un-uniform transplants. At Vera Cruz in 1999-2000, water was provided by drip irrigation, and the system produced homogenous seedlings. As for the seedling quality, no differences were observed between the low and high tunnel, and it was similar to the floating tray system.

Suspended trays

This alternative showed different results, when the two sites tested were compared. At Aurora, good quality seedlings were produced, with a large stem diameter (Table 6), however at Ituporanga, possibly due to un-uniform irrigation, the seedlings produced resulted in reduced dry weight and height.

Floating in low and high tunnel

This soilless system has the advantage of low input of chemicals, and adequate water supply without the need for frequent irrigation. As a general observation, the floating system produced the most uniform seedlings, and the highest percentage of useful seedlings, compared to the other treatments. Approximately 95% of the seedlings, in average, were suitable for transplantation. In the 1998-1999 growing season, at Aurora, the highest seedlings were those produced under high and low tunnel floating systems (Table 6). In the same period, at Ituporanga, the high tunnel floating system also produced the highest seedlings. With regards to the floating, no significant differences were observed in the final weight, between seedlings produced in the high or low tunnel. However, the seedlings developed a little faster in the high tunnel than in the low tunnel, which was possibly due to better thermic isolation. The seedling stress caused by the transplantation from the seedbed to the open field was less pronounced in the floating system, compared to the other alternatives tested. This fact is due to the portion of substrate that remains adhered to the roots, protecting them against the water stress that normally occurs after transplanting.

B - FIELD STAGE

In the Rio Grande do Sul State, in the 1998-1999 growing season, a severe drought occurred in the region where the trial was carried out. The stress induced by the low levels of precipitation, affected plant height and the number of leaves, thereby reducing the yield by more than 50%, compared to that generally obtained from normal growing seasons (Table 8). Small differences regarding plant height and number of leaves were observed among the alternatives tested. The seedlings produced in the bed of substrate presented some nutrient deficiency, which affected dry weight and possibly the yield in the field stage. Transplants produced in the float systems had lower total dry weight, compared to seedbeds; however this fact had no effect on the yield in field conditions, where those systems presented similar yields. In the 1999-2000 growing season (Table 9) seedlings produced in methyl bromide and solarization systems showed in the open field a slightly higher yield, compared to the other alternatives. Plants developed from seedlings produced in bed of substrate presented intermediary yields, yet slightly higher than those obtained from the floating system.

Table 8. Average height, number of leaves and yield of tobacco plants developed from seedlings produced in different systems at Rio Grande do Sul, Brazil, 1998-1999

Systems	Height (cm)	N° of leaves	Yield (Kg/ha)
SEEDBEDS			
Methyl bromide	57	20,6	1.250
Metam sodium	62	20,3	1.350
LOW TUNNEL			
Floating	56	18,4	1.367
Bed of substrate			1.000
HIGH TUNNEL			
Floating	60	18,2	1.267

Table 9. Average height, number of leaves, and yield of tobacco plants developed from seedlings produced in different systems at Rio Grande do Sul, Brazil, 1999-2000

Systems	Height (cm)	N° of leaves	Yield (Kg/ha)
SEEDBEDS			
Methyl bromide	82,8	19,9	3,234
Without methyl bromide	85,5	20,2	2,699
Solarization	87,3	20,7	3,284
LOW TUNNEL			
Floating	78,4	18,9	2,701
Bed of substrate	82,2	19,4	3,078
HIGH TUNNEL			
Floating	73,5	18,2	2,825
Bed of substrate	74,0	19,6	3,190

At Santa Catarina, in the 1998-1999 growing season, burley tobacco plants originated from plots treated with Metam sodium, presented the highest yield, followed by methyl bromide, solarization and bio-fumigation treatments (Table 10). For the Virginia type tobacco, the highest production resulted from the suspended tray-system. In the following growing season, high tunnel float and methyl bromide were the most productive systems for the Virginia type tobacco (Table 11). In the burley type tobacco, small differences were observed among treatments, except for the bed of substrate system, which yielded around 10% less than the other treatments.

Table 10. Average height, number of leaves and yield of Virginia and burley tobacco plants developed from seedlings produced in different systems at Santa Catarina, Brazil, 1998-1999

Systems	Height (cm)		N° of leaves		Yield	
	Virginia	Burley	Virginia	Burley	Virginia	Burley
SEEDBEDS						
Methyl bromide		88		15.0		3,067
Dazomet		91		15.7		2,510
Metam sodium		100		15.5		3,217
Solarization		101		15.8		3,067
Biofumigation		84		14.7		3,067
LOW TUNNEL						
Floating	93	92	19.1	16.2	3,656	2,883
HIGH TUNNEL						
Floating	83	84	17.5	15.2	3,212	2,767
Suspended tray	85	83	18.5	15.3	4,010	2,767

Table 11. Average height, number of leaves, and yield of Virginia and burley tobacco plants developed from seedlings produced in different systems at Santa Catarina, Brazil, 1999-2000

Systems	Height (cm)		N° of leaves		Yield	
	Virginia	Burley	Virginia	Burley	Virginia	Burley
SEEDBEDS						
Methyl bromide	69,2	72,0	17,1	13,1	3,002	2,666
Solarization	55,8	71,5	16,0	14,5	2,793	2,666
LOW TUNNEL						
Floating	60,3	81,0	16,6	13,1	2,470	2,666
Bed of substrate	46,8	78,0	15,6	12,7	1,722	2,333
HIGH TUNNEL						
Floating	57,1	89,5	15,8	14,3	3,024	2,417
Bed of substrate	40,1	78,5	14,4	13,6	2,321	2,583

IV - ECONOMICAL ANALYSIS

The calculation of the cost of the different alternatives tested was based on the exchange rate of 1,75 Real for US$1. However, it is important to note that major fluctuations frequently occur in Brazil, which affects the final cost of the different systems. For instance, an alternative tested may have its cost unaltered in Brazilian currency, but in US dollars this cost may increase or decrease, depending on the exchange rate at a particular time. Another point is the cost of materials, such as polystyrene trays, which depends on the international price of oil polymers, and therefore oscillates according to the market.

The difference in cost between Rio Grande do Sul State and Santa Catarina were negligible, and for this reason they are not presented separately.

In general, the seedbeds presented the lower cost, compared to the other alternatives, (Tables 12 to 17) and solarization showed the lowest cost, followed by bio-fumigation. Solarization proved to be a technically feasible and cost-effective non-chemical alternative to methyl bromide. The costs of seedlings produced using methyl bromide, was equivalent to seedbeds without this chemical, due to the high cost of labor to control weeds manually. The systems where Dazomet was applied presented an intermediary cost, very similar to the floating system in low tunnel. The float in micro tunnel was approximately 50% more expensive than the cheapest alternative, namely the soil solarization.

Regarding the alternatives tested in high tunnel (float and suspended trays), the cost was extremely high when a metallic structure was used (Tables 20 and 21). By using the PVC structure, the cost was reduced, with float in high tunnel (Table 19) arriving to only 21% higher than the cost of the micro tunnel (Table 18).

The high amount of substrate used in the beds of substrate system (Tables 22 and 23), substantially increase the seedling production cost. Although this growth medium had been considered useful for three years, with little input (approximately

10%) of new material each year, this system presented good technical results. However, it will become economically viable, only with a substantial reduction in the substrate price. The operational cost of this alternative was very low, but the capital cost contributed to a high final cost. The most expensive alternative was the bed of substrate in high tunnel, where, besides the substrate, the cost of the tunnel structure contributed to the increase of the cost of this system.

In Rio Grande do Sul State, in the 1999-2000 growing season, the high income and profit of methyl bromide and solarization alternatives (Table 24) resulted in a high yield obtained through these systems. Although there is a slightly higher income of bed of substrate, when compared with the floating system, these alternatives presented similar returns, due to the large amount and high cost of substrate used in the first one.

The difference in the production cost at Santa Catarina State, when comparing the two growing seasons (Tables 25 and 26), is mostly due to the difference in the exchange rate of US$ dollar. In the 1998-1999 growing season, the best financial returns (Table 25) were offered by floating low tunnel and suspended trays, for the Virginia type tobacco, and by bio-fumigation, methyl bromide, Metam sodium and solarization, in the burley type tobacco (Table 26). In the following growing season the floating systems in high tunnel and methyl bromide showed the highest profit for the Virginia type tobacco. The low yield and high production cost in the bed of substrate systems, allowed these alternatives to present the lowest income and profit. In the burley type tobacco, small differences were observed related to the financial returns, except for the alternative bed of substrate in low tunnel, which presented around 35% lower profit compared to the others.

The qualitative rate - values from 1 to 100 in tobacco leaf grading, under the Ministry of Agriculture legislation - in the 1988-1999 growing season at Santa Catarina, varied from 42,3 (float high tunnel) to 59,3 (floating low tunnel) for the Virginia tobacco (Table 25). These values are considered good in addition to having high quality. For the burley type, the qualitative rate varied from 84.5 to 92.5 (Table 26), and these values ranked as optimal. The best qualitative rate was scored with bio-fumigation. In the following growing season, slight variation in the qualitative rate was recorded for burley type tobacco (Table 28), and as for the Virginia type, the best rate was scored by the floating systems (Table 27). Generally, the burley type showed better qualitative rate than the Virginia type tobacco

Table 12. Cost per open field hectare of tobacco seedlings produced in traditional seedbeds with methyl bromide (in US$)

Capital costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Plastic sheet	m^2	143	2	0,2057	14,71
Plastic f/ seed covering	m^2	143	2	0,0629	4,49
Total					**19,20**

Operating costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Methyl bromide	can	5	1	3,8971	19,49
Fertilizers	kg	25	1	0,2171	5,43
Seeds	envel.	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Confidor	envel.	0,5	1	8,6229	4,31
Labor	w/h	75,6	1	0,6857	51,84
Total					**95,86**

Total	**115,06**

Table 13. Cost per open field hectare of tobacco seedlings produced in seedbeds without treatment (control) (in US$)

Capital costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Plastic f/seed covering	m^2	143	2	0,0629	4,49
Total					**4,49**

Operating costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Fertilizers	kg	25	1	0,2171	5,43
Seeds	envel.	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Confidor	envel.	0,5	1	8,6229	4,31
Labor	w/h	127,6	1	0,6857	87,50
Total					**112,03**

Total	**116,52**

Table 14. Cost per open field hectare of tobacco seedlings produced in seedbed using Dazomet (in US$)

Capital costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Plastic sheet	m^2	143	2	0,2057	14,71
Plastic f/seed covering	m^2	143	2	0,0629	4,49
Total					**19.20**

Operating costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Dazomet	kg	5,625	1	8,61	48,43
Fertilizers	kg	25	1	0,2171	5,43
Seeds	envel.	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Confidor	envel.	0,5	1	8,6229	4,31
Labor	w/h	76,6	1	0,6857	52.52
Total					**125.48**

Total	**144.68**

Table 15. Cost per open field hectare of tobacco seedlings produced in bed using Metam sodium (in US$)

Capital costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Plastic sheet	m^2	143	2	0,2057	14,71
Plastic f/seed covering	m^2	143	2	0,0629	4,49
Total					**19,20**

Operating costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Metam sodium	l	8,43	1	1,8285	15,41
Fertilizers	kg	25	1	0,2171	5,43
Seeds	envel.	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Confidor	envel.	0,5	1	8,6229	4,31
Labor	w/h	76,6	1	0,6857	52.52
Total					**92,46**

Total	**111,66**

Table 16. Cost per open field hectare of tobacco seedlings produced in bio-fumigated seedbeds (in US$)

Capital costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Black polyethylene sheet	m^2	143	2	0,3371	24,10
Plastic f/seed covering	m^2	143	2	0,0629	4,49
Total					**28.59**

Operating costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Fertilizers	kg	25	1	0,2171	5,43
Seeds	envel.	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Confidor	envel.	0,5	1	8,6229	4,31
Labor	w/h	78,1	1	0,6857	53,55
Total					**78.08**

Total	**106.67**

Table 17. Cost per open field hectare of tobacco seedlings produced in solarized seedbeds (in US$)

Capital costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Plastic sheet	m^2	143	2	0,2628	18,79
Plastic f/seed covering	m^2	143	2	0,0629	4,49
Total					**23.28**

Operating costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Fertilizers	kg	25	1	0,2171	5,43
Seeds	envel.	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Confidor	envel.	0,5	1	8,6229	4,31
Labor	w/h	74,0	1	0,6857	50,74
Total					**75.27**

Total	**98.55**

Table 18. Cost per open field hectare of tobacco seedlings produced in the floating system in micro tunnel (in US$)

Capital Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Expanded polystyrene trays	un	100	5	1,6800	33,60
Manual seeder	un	1	10	51,2000	5,12
Galvanized steel arches	un	16	5	1,1429	3,66
Polyethylene sheet UV protected	m^2	47	2	0,2629	6,18
Elastic bidders	un	16	2	0,3486	2,79
Lumber	m	38	3	0,3714	4,70
Nails	kg	0,5	3	1,0286	0,17
Total					**56.22**

Operating Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Black polyethylene sheet	m^2	42,3	1	0,3371	14,26
Substrate	kg	165	1	0,1771	29,23
Seeds	un	21.700	1	0,0006	12,40
Fertilizers	kg	4	1	0,2171	0,87
Copper	kg	0,12	1	4,1486	0,50
Dithane	kg	0,04	1	9,7371	0,39
Rovral	kg	0,016	1	54,6743	0,87
Labor	w/h	48	1	0,6857	32,91
Total					**91.43**

Total	**147.65**

Table 19. Cost per open field hectare of tobacco seedlings produced in the floating system in high PVC tunnel (in US$)

Capital Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
PVC arches	un	7	5	9,60	13,44
PVC tubes	un	14	5	1,79	5,00
Lumber stakes	pieces	4	3	0,715	0,95
Galvanized wire	kg	1,2	5	0,98	0,24
Stretchers	un	4	5	2,74	2,19
Polyethylene sheet UV protected	m^2	123	2	0,26	16,17
Plastic strips	m	70	2	0,20	7,00
Expanded polystyrene trays	un	100	5	1,6800	33,60
Manual seeder	un	1	10	51,2000	5,12
Lumber	m	38	3	0,3714	4,70
Nails	kg	0,5	3	1,0286	0,17
Total					**88.58**

Operating Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Black polyethylene sheet	m^2	42,3	1	0,3371	14,26
Substrate	kg	165	1	0,1771	29,23
Seeds	un	21.700	1	0,0006	12,40
Fertilizers	kg	4	1	0,2171	0,87
Copper	kg	0,12	1	4,1486	0,50
Dithane	kg	0,04	1	9,7371	0,39
Rovral	kg	0,016	1	54,6743	0,87
Labor	w/h	46,9	1	0,6857	32,14
Total					**90,66**

Total	**179.24**

Table 20. Cost per open field hectare of tobacco seedlings produced in the floating system in high metallic tunnel (in US$)

Capital Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
High tunnel	un	1	10	3,582.36	358,23
Expanded polystyrene trays	un	100	5	1.6800	33,60
Manual seeder	un	1	10	51.2000	5,12
Lumber	m	38	3	0.3714	4,70
Nails	kg	0,5	3	1.0286	0,17
Total					**401,82**

Operating Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Black polyethylene sheet	m^2	42,3	1	0,3371	14,26
Substrate	kg	165	1	0,1771	29,23
Seeds	un	21.700	1	0,0006	12,40
Fertilizers	kg	4	1	0,2171	0,87
Copper	kg	0,12	1	4,1486	0,50
Dithane	kg	0,04	1	9,7371	0,39
Rovral	kg	0,016	1	54,6743	0,87
Labor	w/h	46,9	1	0,6857	32,14
Total					**90.66**

Total	**492.42**

Table 21. Cost per open field hectare of tobacco seedlings produced in suspended trays in metallic high tunnel (in US$)

Capital Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
High tunnel	un	1	10	3,582.36	358.23
Trays support	m	78	5	0,3714	5.79
Expanded polystyrene trays	un	100	5	1,6800	33,60
Manual seeder	un	1	10	51,2000	5,12
Total					**402.74**

Operating Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Substrate	kg	165	1	0,1771	29,23
Seeds	un	21.700	1	0,0006	12,40
Fertilizers	kg	4	1	0,2171	0,87
Dithane	kg	0,04	1	9,7371	0,39
Rovral	kg	0,016	1	54,6743	0,87
Labor	h/H	59	1	0,6857	40.45
Total					**84.21**

Total	**486.95**

Table 22. Cost per open field hectare of tobacco seedlings produced in bed of substrate in micro tunnel using drip irrigation (in US$)

Capital Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Substrate	kg	4.680	3	0,1771	276,34
Galvanized steel arches	un	72	5	1,1429	16,46
Polyethylene sheet UV protected	m^2	211,6	2	0,2629	27,81
Black polyethylene sheet	m^2	192,3	3	0,3371	21,61
Elastic bidders	un	72	2	0,3486	12,55
Lumber	m	183	3	0,3714	22,65
Nails	kg	0,5	3	1,0286	0,17
Irrigation hoses	m	320	3	0,19	20,72
Total					**398,31**

Operating Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Fertilizers	un	9	1	0,2171	1,95
Seeds	kg	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Labor	w/h	49,7	1	0,69	34,06
Total					**50.80**

Total	**449,11**

Table 23. Cost per open field hectare of tobacco seedlings produced in bed of substrate in PVC high tunnel using drip irrigation (in US$)

Capital Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
PVC arches	un	21	5	9,6000	40,32
PVC tubes	un	42	5	1,7857	15,00
Lumber stakes	pieces	4	3	0,715	0,95
Galvanized wire	kg	3,81	5	0,9829	0,75
Stretchers	un	4	5	2,7429	2,19
Polyethylene sheet UV protected	m^2	304,42	2	0,2629	39,88
Plastic strips	m	213	2	0,2000	21,30
Black polyethylene sheet	m^2	172,8	3	0,3371	19,42
Substrate	kg	4.680	3	0,1771	276,34
Lumber	m	144	3	0,3714	17,83
Nails	kg	1	3	1,0286	0,34
Irrigation hoses	m	320	3	0,19	20,72
Total					**455.04**

Operating Costs

Item	Unit	Quantity	Duration	Unit cost	Total cost
Fertilizers	kg	9	1	0,2171	1,95
Seeds	un	2,5	1	1,7143	4,29
Rovral	kg	0,112	1	54,6743	6,12
Dithane	kg	0,45	1	9,7371	4,38
Labor	w/h	48,6	1	0,6857	33,33
Total					**50.07**

Total	**505.11**

Table 24. Production cost, gross income, and profit of one hectare of Virginia tobacco plants, developed from seedlings produced in different systems at Rio Grande do Sul, Brazil, 1999-2000 (in US$)

Systems	Production cost		Gross income	Profit
	Seedlings	Total		
SEEDBEDS				
Methyl bromide	115,06	1,894.51	4,356.00	2.461.49
Without methyl bromide	116,52	1,895.97	3,616.57	1,720.60
Solarization	98,55	1,878.00	4,392.57	2,514.00
LOW TUNNEL				
Floating	147,65	1,927.10	3,627.42	1,700.32
Bed of substrate	408,40	2,187.85	4,154.86	1,967.01
HIGH TUNNEL				
Floating	179,24	1,958.69	3,782.85	1,824.25
Bed of substrate	505,11	2,284.56	4,154.86	1,870.30

Table 25. Production cost, gross income, profit and qualitative rate of one hectare of Virginia tobacco plants, developed from seedlings produced in different systems at Santa Catarina, Brazil, 1998-1999 (in US$)

Systems	Production cost	Gross income	Profit	Qualitative rate
LOW TUNNEL				
Floating	2,719.00	4,588.00	1,869.00	59.30
HIGH TUNNEL				
Floating	2,809.00	3,427.00	618.00	42.30
Suspended trays	2,807.00	4,571.00	1,764.00	48.60

Table 26. Production cost, gross income, profit and qualitative rate of one hectare of burley tobacco plants, developed from seedlings produced in different systems at Santa Catarina, Brazil, 1998-1999 (in US$)

Systems	Production cost	Gross income	Profit	Qualitative rate
SEEDBEDS				
Methyl bromide	2,118.00	3,616.00	1,498.00	91,7
Dazomet	2,117.00	2,801.00	684.00	84,5
Metam sodium	2,119.00	3,532.00	1,413.00	88,2
Solarization	2,114.00	3,493.00	1,379.00	87,6
Biofumigation	2,114.00	3,653.00	1,539.00	92,5
LOW TUNNEL				
Floating	2,224.00	3,151.00	927.00	86,4
HIGH TUNNEL				
Floating	2,314.00	3,088.00	774.00	87,8
Suspended tray	2,312.00	3,262.00	950.00	90,0

Table 27. Production cost, gross income, profit and qualitative rate of one hectare of Virginia tobacco plants, developed from seedlings produced in different systems at Santa Catarina, Brazil, 1999-2000 (in US$)

Systems	Production cost		Gross income	Profit	Qualitative rate
	Seedlings	Total			
SEEDBEDS					
Methyl bromide	115,06	1,894.51	3,731.00	1,836.49	62,4
Solarization	98,55	1,878.00	3,427.00	1,549.00	64,4
LOW TUNNEL					
Floating	147,65	1,927.10	3,022.00	1,094.90	72,5
Bed of substrate	408,40	2,187.85	1,951.00	-236.85	65,9
HIGH TUNNEL					
Floating	179,24	1,958.69	3,925.00	1,966.31	73,2
Bed of substrate	505,11	2,284.56	2,506.00	221.44	52,9

Table 28. Production cost, gross income, profit, and qualitative rate of one hectare of burley tobacco plants, developed from seedlings produced in different systems at Santa Catarina, Brazil, 1999-2000 (in US$)

Systems	**Production cost**		**Gross income**	**Profit**	**Qualitative rate**
	Seedlings	**Total**			
SEEDBEDS					
Methyl bromide	115,06	1,473.13	3,322.00	1,848.87	90
Solarization	98,55	1,456.61	3,322.00	1,865.39	90
LOW TUNNEL					
Floating	147,65	1,505.71	3,322.00	1,816.29	90
Bed of substrate	408,40	1,766.46	2,907.00	1,140.54	90
HIGH TUNNEL					
Floating	179,24	1,537.30	3,410.00	1,872.70	100
Bed of substrate	505,11	1,863.17	3,645.00	1,781.83	100

V - FINAL CONSIDERATIONS

Several conclusions may be drawn from the results obtained in the demonstration project "Alternatives to the use of methyl bromide":

Seedbed solarization proved to be a technically feasible and cost-effective non-chemical alternative to methyl bromide. The high temperature reached during the process, controlled both weeds and pathogens in the upper layers of soil of the treated seedbeds. Since tobacco seedlings present a shallow root system, this technique can be used with satisfactory results. This system has advantages compared to the chemical fumigation, because it is safer, less expensive and has lower effect on the biological soil equilibrium. However, special care must be taken in connection to climate conditions. Solarization is effective only in sites with high temperature and radiation during the summer months.

Metam sodium is safer and easier to use than methyl bromide, serving as a potential alternative to this chemical, since it bears similar costs. Metam sodium showed a good weed control, and contrary to Dazomet, had no effect on seed germination.

Bio-fumigation presented different results related to weed control. Despite its low cost, this alternative is limited to the high volume of fresh manure necessary to implement the system efficiently.

Generally, seedling production on seedbed, particularly the soil solarization, were the alternatives with the lowest cost, compared to the other alternatives tested.

The system suspended trays in high tunnel produced good quality seedlings, but offered some difficulties in irrigation management. Moreover high cost is involved.

The results obtained with seedling production in bed of substrate using drip irrigation showed that this alternative is technically viable, with low input of chemicals.

However, it is limited economically by the large amount of substrate used in the system, which substantially increases the seedling production cost. By reducing the price of substrate, this soilless system could be a good alternative for tobacco seedling production.

Soilless cultivation using the float-tray system proved to be a reliable technology. The seedlings produced in this system presented great homogeneity and almost 100% of the seedlings are useful for transplanting. This soilless system has the advantage of low input of chemicals, and adequate water supply without the need for frequent irrigation. Benefits of the floating system could be summarized as having a greater uniformity of seedlings with less labor requirements.

In both states, Rio Grande do Sul and Santa Catarina, the floating system, in low or high tunnel demonstrated to be an adequate method for producing tobacco seedlings. However, seedling production in high tunnels is not recommended for most of the growers, since this requires a very high investment. This alternative may be viable for commercial groups of seedling growers.

Considering all aspects involved, namely management, cost, and plant performance in the field, the floating in low tunnel system is recommended for tobacco seedling production. For growers using seedbeds, the solarization can be used and is a safe alternative.

Annex 1. Labor cost per open field hectare of tobacco seedlings produced in seedbed with methyl bromide

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Plowing - animal traction	w/h	3	1	0.6857	2,06
Manure and fertilize application	w/h	4	1	0.6857	2,74
Harrowing - animal traction	w/h	3	1	0.6857	2,06
Seedbed preparation	w/h	10	1	0.6857	6,86
Methyl Bromide application	w/h	4	1	0.6857	2,74
Soil revolving	w/h	0.6	1	0.6857	0,41
Sowing	w/h	0.5	1	0.6857	0,34
Covering the seedbed with straw	w/h	1.5	1	0.6857	1,03
Irrigation	w/h	20	1	0.6857	13,71
Covering seeds with plastic	w/h	1.5	1	0.6857	1,03
Application of pesticides	w/h	8	1	0.6857	5,49
Seedling pruning	w/h	7.5	1	0.6857	5,14
Nitrogen fertilization	w/h	2	1	0.6857	1,37
Daily plastic management	w/h	10	1	0.6857	6,86
Total		**75.6**			**51,84**

Annex 2. Labor cost per open field hectare of tobacco seedlings produced in seedbed without treatment (control)

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Plowing - animal traction	w/h	3	1	0.6857	2,06
Manure and fertilize application	w/h	4	1	0.6857	2,74
Harrowing - animal traction	w/h	3	1	0.6857	2,06
Seedbed preparation	w/h	10	1	0.6857	6,86
Soil revolving	w/h	0.6	1	0.6857	0,41
Sowing	w/h	0.5	1	0.6857	0,34
Covering the seedbed with straw	w/h	1.5	1	0.6857	1,03
Irrigation	w/h	20	1	0.6857	13,71
Covering seeds with plastic	w/h	1.5	1	0.6857	1,03
Application of pesticides	w/h	8	1	0.6857	5,49
Seedling pruning	w/h	7.5	1	0.6857	5,14
Nitrogen Fertilization	w/h	2	1	0.6857	1,37
Daily plastic management	w/h	10	1	0.6857	6,86
Manual control of weeds	w/h	56	1	0.6857	38,40
Total		**127.6**			**87,50**

Annex 3. Labor cost per open field hectare of tobacco seedlings produced in seedbed using Dazomet

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Plowing - animal traction	w/h	3	1	0.6857	2,06
Manure and fertilize application	w/h	4	1	0.6857	2,74
Harrowing - animal traction	w/h	3	1	0.6857	2,06
Seedbed preparation	w/h	10	1	0.6857	6,86
Dazomet application	w/h	5	1	0.6857	3,43
Soil revolving	w/h	0.6	1	0.6857	0,41
Sowing	w/h	0.5	1	0.6857	0,34
Covering the seedbed with straw	w/h	1.5	1	0.6857	1,03
Irrigation	w/h	20	1	0.6857	13,71
Covering seeds with plastic	w/h	1.5	1	0.6857	1,03
Application of pesticides	w/h	8	1	0.6857	5,49
Seedling pruning	w/h	7.5	1	0.6857	5,14
Nitrogen Fertilization	w/h	2	1	0.6857	1,37
Daily plastic management	w/h	10	1	0.6857	6,85
Total		**76.6**			**52,52**

Annex 4. Labor cost per open field hectare of tobacco seedlings produced in seedbed using Metam sodium

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Plowing - animal traction	w/h	3	1	0.6857	2,06
Manure and fertilize application	w/h	4	1	0.6857	2,74
Harrowing - animal traction	w/h	3	1	0.6857	2,06
Seedbed preparation	w/h	10	1	0.6857	6,86
Metam sodium application	w/h	5	1	0.6857	3,43
Soil revolving	w/h	0.6	1	0.6857	0,41
Sowing	w/h	0.5	1	0.6857	0,34
Covering the seedbed with straw	w/h	1.5	1	0.6857	1,03
Irrigation manually	w/h	20	1	0.6857	13,71
Covering with plastic	w/h	1.5	1	0.6857	1,03
Application of pesticides	w/h	8	1	0.6857	5,49
Seedling pruning	w/h	7.5	1	0.6857	5,14
Nitrogen fertilization	w/h	2	1	0.6857	1,37
Daily plastic management	w/h	10	1	0.6857	6,85
Total		**76.6**			**52,52**

Annex 5. Labor cost per open field hectare of tobacco seedlings produced in solarized seedbed

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Plowing - animal traction	w/h	3	1	0.6857	2,06
Manure and fertilize application	w/h	4	1	0.6857	2,74
Harrowing - animal traction	w/h	3	1	0.6857	2,06
Seedbed preparation	w/h	10	1	0.6857	6,86
Solarization application	w/h	2.5	1	0.6857	1,71
Soil revolving with rake	w/h	0.6	1	0.6857	0,41
Sowing	w/h	0.4	1	0.6857	0,27
Covering the seedbed with straw	w/h	1.5	1	0.6857	1,03
Irrigation	w/h	20	1	0.6857	13,71
Covering seeds with plastic	w/h	1.5	1	0.6857	1,03
Application of pesticides	w/h	8	1	0.6857	5,49
Seedling pruning	w/h	7.5	1	0.6857	5,14
Fertilizing	w/h	2	1	0.6857	1,37
Daily plastic management	w/h	10	1	0.6857	6,86
Total		**74**			**50,74**

Annex 6. Labor cost per open field hectare of tobacco seedlings produced in bio-fumigated seedbed

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Plowing - animal traction	w/h	3	1	0.6857	2,06
Fertilizer application	w/h	4	1	0.6857	2,74
Harrowing - animal traction	w/h	3	1	0.6857	2,06
Seedbed preparation	w/h	10	1	0.6857	6,86
Manure application/incorporation	w/h	6.5	1	0.6857	4,46
Soil revolving	w/h	0.6	1	0.6857	0,41
Sowing	w/h	0.5	1	0.6857	0,34
Covering the seedbed with straw	w/h	1.5	1	0.6857	1,03
Irrigation manually	w/h	20	1	0.6857	13,71
Covering seeds with plastic	w/h	1.5	1	0.6857	1,03
Application of pesticides	w/h	8	1	0.6857	5,49
Seedling pruning	w/h	7.5	1	0.6857	5,14
Nitrogen fertilization	w/h	2	1	0.6857	1,37
Daily plastic management	w/h	10	1	0.6857	6,86
Total		**78.1**			**53,55**

Annex 7. Labor cost per open field hectare of tobacco seedlings produced in the floating system in micro tunnel

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Land preparation (leveling)	w/h	4	3	0.6857	0,91
Wood boxes mounting	w/h	4	3	0.6857	0,91
Wood boxes leveling	w/h	4	3	0.6857	0,91
Black plastic fixing	w/h	2	2	0.6857	0,69
Addition of water and copper	w/h	0.5	1	0.6857	0,34
Fixing of arcs, plastic and belts	w/h	3	1	0.6857	2,06
Filling of substrate in trays	w/h	2	1	0.6857	1,37
Sowing	w/h	2	1	0.6857	1,37
Transportation/positioning trays	w/h	1	1	0.6857	0,69
Replanting of seedlings in trays	w/h	16	1	0.6857	10,97
Spraying pesticides	w/h	4	1	0.6857	2,74
Pruning of seedlings on trays	w/h	2	1	0.6857	1,37
Fertilizing	w/h	0.5	1	0.6857	0,34
Water reposition level	w/h	0.5	1	0.6857	0,34
Daily plastic management	w/h	2.5	1	0.6857	1,71
Washing and sterilization of trays	w/h	8	1	0.6857	5,49
Plastic and arcs removing	w/h	1	1	0.6857	0,69
Total		**48**			**32,91**

Annex 8. Labor cost per open field hectare of tobacco seedlings produced in floating system in high PVC tunnel

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Land preparation	w/h	4	5	0.6857	0,54
Tunnel mounting	w/h	12	5	0.6857	1,64
Wood boxes mounting	w/h	4	3	0.6857	0,91
Wood boxes leveling	w/h	4	3	0.6857	0,91
Black plastic fixing	w/h	2	1	0.6857	1,37
Addition of water and copper	w/h	0.5	1	0.6857	0,34
Filling of substrate in trays	w/h	2	1	0.6857	1,37
Sowing	w/h	2	1	0.6857	1,37
Transportation/positioning trays	w/h	1	1	0.6857	0,68
Replanting of seedlings in trays	w/h	16	1	0.6857	10,97
Spraying pesticides	w/h	4	1	0.6857	2,74
Pruning of seedlings on trays	w/h	2	1	0.6857	1,37
Fertilizing	w/h	0.5	1	0.6857	0,34
Water reposition level	w/h	0.5	1	0.6857	0,34
Daily plastic management	w/h	2.5	1	0.6857	1,71
Washing and sterilization of trays	w/h	8	1	0.6857	5,48
Total		**46.9**			**32,14**

Annex 9. Labor cost per open field hectare of tobacco seedlings produced in bed of substrate in micro tunnel

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Land preparation	w/h	10	3	0.6857	2,29
Wood boxes mounting	w/h	12	3	0.6857	2,74
Black plastic fixing	w/h	6	3	0.6857	1,37
Substrate filling	w/h	18	3	0.6857	4,11
Fixing of arcs, plastic and belts	w/h	13	3	0.6857	2,97
Fertilizing	w/h	2	1	0.6857	1,37
Sowing	w/h	0.5	1	0.6857	0,34
Spraying pesticides	w/h	8	1	0.6857	5,49
Pruning seedlings	w/h	7.5	1	0.6857	5,14
Daily plastic management	w/h	9	1	0.6857	6,17
Removing of plastic and arcs	w/h	3	1	0.6857	2,06
Total		**49.7**			**34,06**

Annex 10. Labor cost per open field hectare of tobacco seedlings produced in bed of substrate in PVC high tunnel

Unit Operation	Unit	Quantity	Duration	Unit cost	Total
Land preparation	w/h	10	5	0.6857	1,37
Tunnel assembling	w/h	18	5	0.6857	2,47
Wood boxes mounting	w/h	12	3	0.6857	2,74
Black plastic fixing	w/h	6	3	0.6857	1,37
Substrate filling	w/h	16	1	0.6857	10,97
Sowing	w/h	0.5	1	0.6857	0,34
Spraying pesticides	w/h	4	1	0.6857	2,74
Pruning seedlings	w/h	7.5	1	0.6857	5,14
Fertilizing	w/h	1	1	0.6857	0,69
Daily plastic management	w/h	8	1	0.6857	5,49
Total		**48.6**			**33,33**

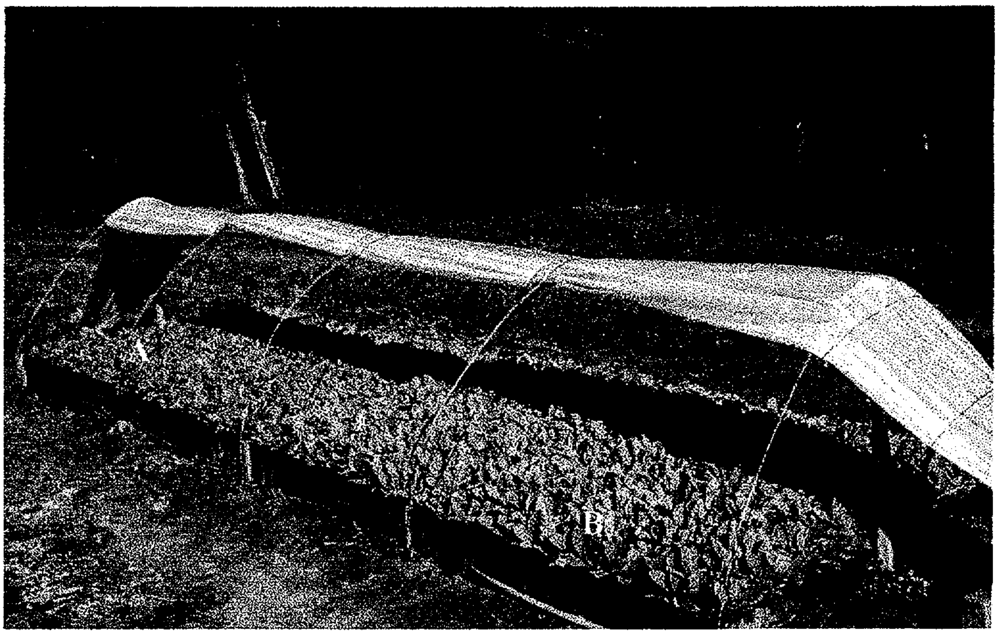

Figure 1. Bed of substrate (A) and float tray system (B) in micro tunnel, Vera Cruz , Rio Grande do Sul

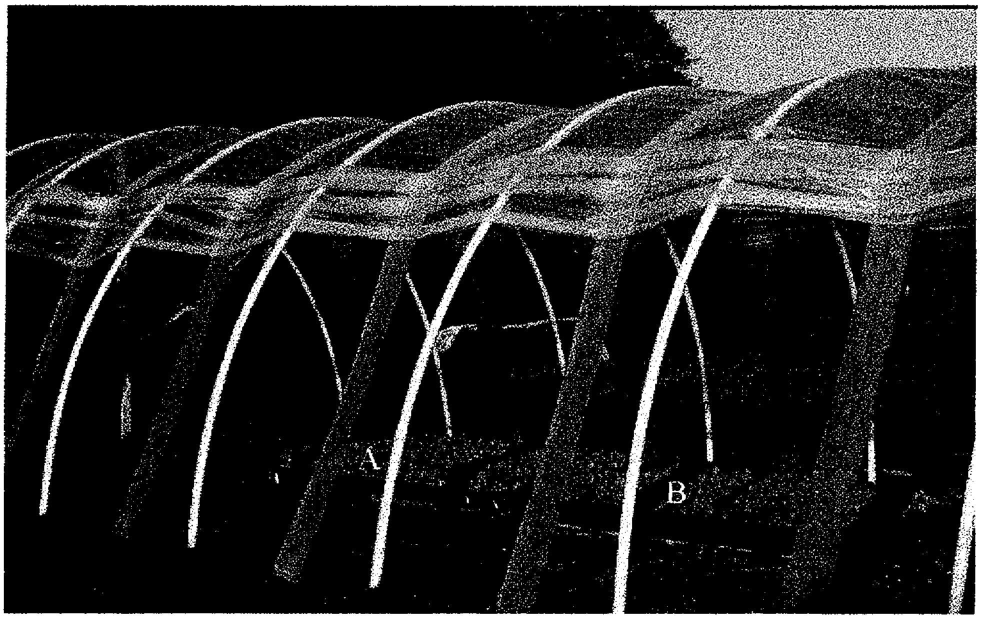

Figure 2. High PVC tunnel used in the float tray system (A) and bed of substrate (B), Vera Cruz, Rio Grande do Sul

Figure 3. Solarized seedbed, Vera Cruz, Rio Grande do Sul

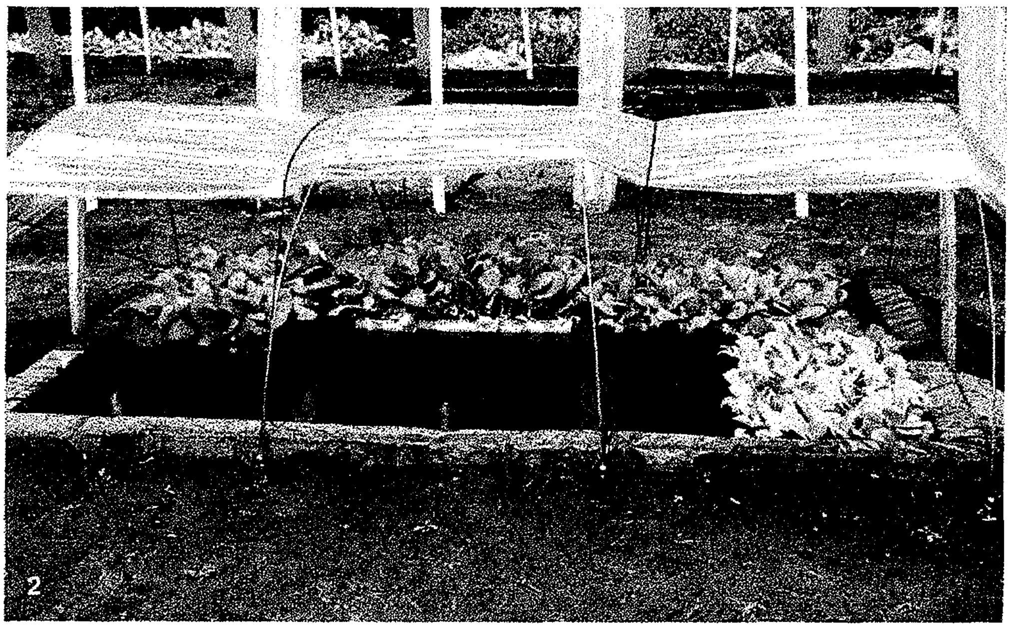

Figure 4. Float tray system in micro tunnel, Ituporanga, Santa Catarina

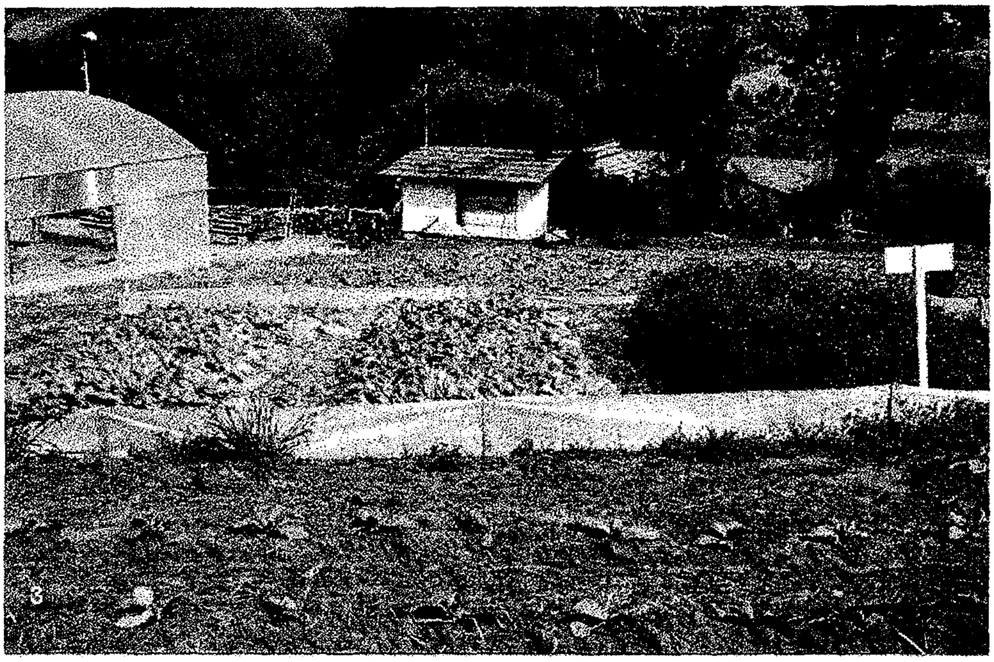

Figure 5. Seedbeds (left to right): solarized, with methyl bromide and without treatment, Aurora, Santa Catarina

Figure 6. High metallic tunnel, Ituporanga, Santa Catarina

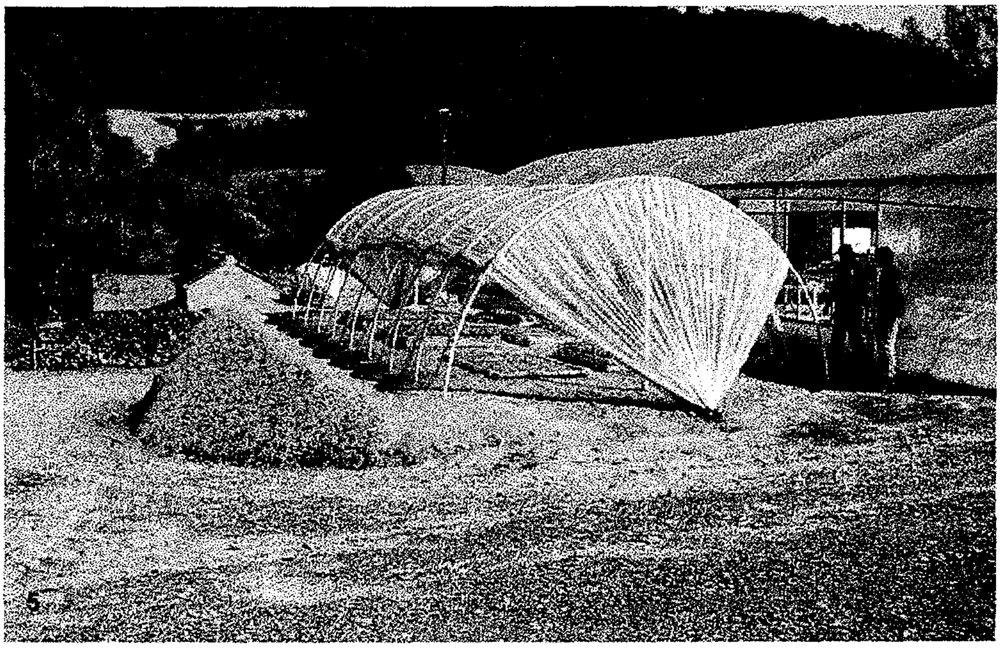

Figure 7. High PVC tunnel, Aurora, Santa Catarina

Figure 8. Tobacco plants, 81 days after transplanting, Ituporanga, Santa Catarina