EVALUATION OF TOBACCOS GROWN UNDER ORGANIC CULTURAL PRACTICES.

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Abstract

Organic plant cultivation appeals to cultural practices concerned with the respect of natural balances. It limits the use of inputs and excludes the use of chemical fertilizers, GMO and synthetic pesticides with, as a consequence, no PPP residues in the raw matter thus produced.

European consumers are asking for more and more organic agricultural products, creating new opportunities and markets. A niche market for organic tobacco appears to exist and may grow.

Prior experiments allowed us to select some efficient organic products against the main tobacco diseases.

In 2007, greenhouse trials were carried out to establish an organic float bed transplant production. An organic compost was used and among five fertilizers which were evaluated, two help to produce transplants comparable to traditional ones.

Field trials were also set up with two varieties of burley and two varieties of filler flue-cured. Organic cultivation was compared to traditional cultivation.

Castor-oil plant cake, feather meal and natural potassium sulfate were evaluated as fertilizers and a seaweed elicitor to control blue mold. After topping, rapeseed oil was used to inhibit sucker development.

The organic practices for burley tobacco are to be improved in 2008 so as to obtain better quality of cured raw matter and yields. Mean yields of organic tobaccos were lower: from 700 to 1 600 kg/ha less according to the variety.

On the other hand, the flue-cured organic cultivation practices used were well-adapted. Yields were greater than 4 000 kg/ha and quality not significantly different from that of the same varieties cultivated according to a classic farming.

Finally, other results concerning physical and chemical measurements on the raw tobaccos will also be discussed as well as smoke evaluation and cigarette sensory analysis.

Key-words: Organic cultivation, Tobacco, Float bed transplant, Castor-oil plant cake, Feather meal, Seaweed elicitor, Rapeseed oil.

I Introduction

Organic plant cultivation appeals to cultural practices concerned with the respect of natural balances. It limits the use of inputs and excludes the use of chemical fertilizers, GMO and synthetic pesticides with, as a consequence, no Plant Protection Product (PPP) residues in the raw matter thus produced. Some other principles that characterize organic production include biodiversity in the field to disrupt habitat for pest organisms, sustainability, soil conservation and fertility, and ecological production, involving a total rethinking of crop production methods. The popularity and demand of organically grown products is increasing rapidly in Europe, creating new opportunities and markets. A niche market for organic tobacco appears to exist and may grow.

Few studies dedicated to organic tobacco cultivation have been published. Some published works are available from USA (1, 2, 3) but pedo-climatic and phytosanitary conditions are different from France. No published work is yet available from France. This paper presents the results of investigations carried out on burley and flue-cured (FC) tobaccos to determine the factors for growing organic tobacco under French conditions and the best way to manage the crop. All trials were conducted at the Tobacco Institute of Bergerac (ITB).

II Materials and methods

II-1 Prior experiments

Sérénade® Biofungicide (Nufarm, active ingredient (a.i.): *Bacillus subtilis* strain QST 713) was first evaluated in 2002 in order to test its efficiency towards grey mold (*Botrytis cinerea*) after inoculation (10 Kg of commercial product /ha). It was compared to the chemical product Rovral® Aqua Flo as a reference (BASF, a.i.: iprodione) (1 L of commercial product /ha). The two products were sprayed at 1 000 L/ha. They are both registered for use on tobacco. A control without treatment was also set up.

The evaluation was performed using the burley variety TN86 which is quite susceptible to grey mold. Twenty four plantlets cultivated on a float tray system were treated with each product. Two treatments were applied, 25 and 37 days after plantlet transplantation into the float trays. The inoculation with *Botrytis cinerea* spores was done 10 days later.

The evaluation of symptoms was carried out, at first about one month after inoculation and then 10 days later, on each plantlet, according to the size of the necrotic spot observed on the stem. A 0 to 11 scale was used with 0 meaning no spot and 11 meaning a spot bigger than 1 cm. Results are expressed as the mean of the evaluation of the 24 plantlets per term.

Tilco Biotonic (Tilco, based on dark seaweeds' extract, recommended as an elicitor and as a fertilizer) was previously evaluated in the fields in 2004 and 2005 in order to test its efficiency towards blue mold (*Peronospora tabacina*) after natural contamination (6 L of commercial product /ha, with Agral® 90 (Syngenta, a.i.: polyethoxylated nonylphenol) as an adjuvant with a dose of 0.5 L/ha). It was compared with Bion MX® as a reference (Syngenta, a.i.: acibenzolar-S-methyl + metalaxyl-M) and Acrobat® M DG (BASF, a.i.: dimethomorph + mancozeb) which are both registered for use on tobacco. For Bion MX®, 0.3 to 0.4 Kg/ha of commercial product was used according to plant development and for Acrobat® M DG, 2.5 Kg/ha for all treatments. Treatments were applied every 14 days (except for Acrobat® M DG in 2005, every 10 days) from the beginning of August or the end of July until mid-September. All the products were sprayed at 400 L/ha. A control without treatment was also set up.

A 3 replicate randomized split-plot design was used. Each subplot consisted of 30 plants (2 rows of 15 plants) of ITB 3304 FC variety, which is susceptible to blue mold, and was bordered with rows of non treated plants not included in the trial. The transplantation to the field was done at the end of July in 2004 and at mid-July in 2005 so that the plants be more receptive to the disease during the period the most favorable to blue mold development.

The evaluation of symptoms was carried out twice in September, on each plant from each subplot, according to the number of necrotic spots observed on the leaves and to the spoiled foliar surface. A 0 to 9 scale was used. Results are expressed for each subplot as the mean of the evaluation of the 30 plants per term.

II-2 Transplant production

First trials for transplant production (ITB 501 burley variety) were conducted in a float tray system in June 2007, in a glass greenhouse. Five commercial organic fertilizers (based on seaweed, sugar beet or nettle extracts alone or in association), which are ideal for float beds because they dissolve easily in water, were evaluated on 2 replicates of 96 plants. An organic compost was used: Klasmann KKS Bio Tray Substrate (fertilized at 1 Kg/m^3 with 50 % horn meal and 50 % horn shaving; 400 mg/L N including 80-120 mineralized N, 200-350 mg/L P_2O_5, 300-500 mg/L K_2O). Previous experiments had shown that it could not be used without fertilization, probably because of a lack of mineralization in asphyxiating conditions. A control was also set up using Klasmann Tray Substrate and the fertilizer Hydrokani H2 (Hydroplus™, Yara) as usually done at ITB for transplant production. Nitrogen availability was 7 mg per plant for all fertilizers.

II-3 Field trials

II-3-1 Plant cultivation

The trials comprised 4 multi-resistant varieties grown in France: 2 burley, ITB 574 and ITB 501, and 2 filler FC, ITB 683 and ITB 623 (Table 1).

***Table 1**: Resistances of varieties selected for organic cultivation trials*

Variety	Blue mold	Powdery mildew	Black root rot	Potato Virus Y	Tobacco Mosaic Virus
ITB 574	T	R	R	R	R
ITB 501	S	S	R	R	S
ITB 623	S	S	R	R	S
ITB 683	S	R	R	R	S

R: resistant, S: susceptible, T: tolerant

Sowing was done on March 30, 2007. The seedlings were then grown conventionally in a float tray system, in a plastic greenhouse, from the beginning of April. Fertilization was managed to bring at first 7 mg N per plant for burley and 5.6 mg for FC and then 2.8 mg per week after the first clipping for burley and 1.4 mg for FC. Preventive treatments against blue mold and grey mold were applied with Bion MX® and Rovral® Aqua Flo respectively.

The seedlings were transplanted on May 24 in sandy-loam soils with 1.6 % organic matter and a pH of 6.5 to 6.9. The field was previously under conventional tobacco and wheat cultivation in 2005 and 2006 respectively. Land was mechanically prepared in April, using a cover crop. Tillage was done just before seedling transplantation.

A 3 replicate split-plot design was used. Each subplot consisted of 80 plants (2 rows of 40 plants) and was bordered with rows of non treated plants which were not included in the trials. Organic farming was compared with standard cultivation: 2 tobacco types * 2 varieties * 2 agricultural practices (conventional and organic) * 3 replicates.

Tobacco seedlings were transplanted at a spacing of 0.9 m x 0.44 m for burley (25 250 plants /ha) and 0.9 m x 0.35 m for FC (31 750 plants /ha). Overhead irrigation was managed according to Potential EvapoTranspiration. All plants were cultivated according to common agricultural practices implemented in ITB with the exception of fertilization, weed and disease management (Table 2) and sucker control for the organic production practices. Granulated castor-oil plant cake (Sopropêche), granulated feather meal (Sopropêche) and natural potassium sulfate (Kali) were used for organic cultivation (Tables 2 and 3).

Table 2*: Fertilization applied for conventional and organic burley and FC cultivation*

Tobacco type	**Agricultural practices**	**Fertilizer**	**Amount (Kg/ha)**	**Date of application**	**N-P-K availability (Kg/ha) ***
Burley	**Conventional**	Potassium sulfate	500	07/05/24	275 - 46 - 385
		Ammonium nitrate	500		
		Ammonium phosphate	100	07/05/31	
		Potassium nitrate	400	07/06/25	
		Lime nitrate	245	07/07/06	
	Organic	Castor-oil plant cake	2 000	07/05/24	253 - 44 - 320
		Feather meal	1 100		
		Natural potassium sulfate	500		
FC	**Conventional**	Potassium sulfate	500	07/05/24	18 - 46 – 250
		Ammonium phosphate	100	07/05/31	
	Organic	Castor-oil plant cake	500	07/05/24	28 - 11 – 249
		Natural potassium sulfate	500		

*** needed according to soil analysis: Burley 260 - 45 - 350, FC 30 - 45 - 250**

Table 3*: Organic fertilizers' analyses provided by suppliers (%)*

	N	**P**	**K**	**Others**
Castor-oil plant cake	5.5	2.2	1.75	
Feather meal	13	0.2	0	
Natural potassium sulfate	0	0	50	45 SO_3 - 1 Cl max

The fertilizer application rate was on a 100 % availability of the organic sources during the growing season. The nitrogen release from feather meal and castor-oil plant cake is progressive and takes place from 14 to 90 days after application. Organic fertilizers were surface applied just before planting, which is essential especially for castor-oil plant cake, also known to be efficient against wireworms (4). They were then plough with a rotary harrow at a depth of 10-15 cm.

For organic weed control, mechanical cultivation was required between tobacco rows, and hand cultivation between plants. Table 4 summarizes the different treatments applied to tobaccos in order to control weeds, pests and diseases, according to agricultural practices.

***Table 4**: Weed, pest and disease control management of conventional and organic burley and FC tobaccos*

Agricultural practices	Weed, Pest and disease	Product	Active ingredient	Firm	Amount for each application	Date of application
Conventional	**Wireworms**	ONCOL® S	Benfuracarb	Dupont	7 Kg/ha in row	07/05/24
	Slugs	LIMATAK® B	Metaldehyde	Cheminova	7 Kg/ha	07/05/25 07/06/07
	Weeds	CENTIUM® 36 CS	Clomazon	Belchim Crop Protection	1 L/ha	07/05/25
	Blue mold	BION MX®	Acibenzolar-S-methyl + Metalaxyl-M)	Syngenta	0.3 Kg/ha	07/06/07
					0.35 Kg/ha	07/07/02
					0.4 Kg/ha	07/07/12
		ACROBAT® M DG	Dimethomorph + Mancozeb	BASF	2.5 Kg/ha	07/06/22
	Aphids	SUPREME®	Acetamiprid	Certis	0.25 Kg/ha	07/07/02
Organic	**Wireworms**	Castor-oil plant cake				07/05/24
	Slugs	FERRAMOL®	Ferric phosphate	Biobest	20 Kg/ha	07/05/25 07/06/07
	Blue mold	TILCO BIOTONIC	Seaweeds' extract	Tilco	4 L/ha	6 applications, every 10 days from 07/06/07 to 07/07/31 (topping)

Products against blue mold and aphids were diluted in order to be applied at 300 L/ha. No treatment against aphids was necessary for organically grown tobaccos. Otherwise Roténobiol (Samabiol, a.i.: rotenone) could have been used.

Other organic products, registered for use on tobacco, could have been used if necessary, for example: Delfin® against defoliator noctua (Certis, a.i.: *Bacillus thuringiensis* serotype 3a 3b), Contans® WG against *Sclerotinia* rot (*Sclerotinia sclerotiorum*) (Belchim Crop Protection, a.i.: *Coniothyrium minitans*) and Preferal® WG against white flies (Biobest, a.i.: *Paecilomyces fumosoroseus*).

Tilco Biotonic was applied with Héliosol® (Samabiol, a.i.: terpenic alcohols from pine) (2 L/ha) as an organic adjuvant. Tilco Biotonic is also said to have an effect against powdery mildew.

Topping was done after 16 leaves for burley (68 or 75 days after transplantation according to plant development) and 20 for FC (71 days after transplantation). The application of the sucker control product was done just after topping. For the conventionally grown tobaccos, Tamex® AG (Bayer CropScience, a.i.: butralin) was used; 15 mL of a 4.5 % solution were applied per plant using a backpack sprayer. For the organically grown tobaccos, we experimented with rapeseed oil; 7 mL were applied per plant in 3 spots (wound, first and second leaf axils below the wound), with an oilcan.

II-3-2 Raw matter evaluation and smoke analysis

Ripe leaves of FC tobaccos were harvested from July 24 to September 11 (6 harvests: 61, 67, 81, 95, 102 and 110 days after transplantation) and bulked in a bulk-curing barn traditionally used for FC tobacco with a direct flame gas burner.

The burley tobacco was stalk-cut on August 27 (95 days after transplantation) and cured as whole plants in a traditional plastic shed with green plastic roof, sides that may be completely raised for higher ventilation, and one tier of plants. An air heater may be used. When the curing was completed, leaves were stripped from the stalk-cut plants.

Yields were then evaluated. Also, certain quality factors such as color and elasticity were appreciated by ITB experts. After classification of the cured tobacco leaves into quality classes, the net quality index (QI) was calculated, after removal of rejected raw matter, from quality coefficients and weights of each class. The commercial value was estimated on the basis of 3.65 €/Kg for 2007 (price for France, tobacco subsidy included), with 100 % of the price for raw matters classified in the A group; B: 80 %; C: 65 %; D: 25 %; E: 5 %; Rejected: 0 %.

Representative leaf samples (1 Kg) of leaf (B) and tip (T) leaves for burley and of the 4^{th} and 5^{th} harvests for FC were taken, for each replicate, and threshed together in a Cardwell thresher to separate strips and stems. The stem percent of each replicate was calculated from those samples. The strip samples were ground for chemical analyses. Individual alkaloids (nicotine, nornicotine, anatabine and anabasine) were determined using an internal HPLC method already described by de Roton *et al.* (5). Nitrogen, chlorine and, for burley, NH_3 and NO_3 contents were also determined using the method of Dumas for nitrogen and continuous flow analyzer methods for the others.

The remaining cured leaves of leaf (B) and tip (T) leaves for burley and of the 4^{th} and 5^{th} harvests for FC from the same subplot in each replicate were combined into a single sample for cigarette manufacture. The lamina were stemmed and made into 70 mm non-filtered cigarettes for smoke evaluation (0.8 mm cut width). The cigarettes were manufactured to a constant diameter and selected for constant pressure drop. They were smoked under ISO 4387 conditions on a rotary smoking machine, with 2 replicates of 20 cigarettes. The puff count was determined and the smoke was analyzed for tar, nicotine, total particulate matter (TPM) and CO. Tobacco weight (12 % moisture) per cigarette was also measured on 50 cigarettes. The organoleptic properties of cigarettes with organic tobaccos were compared to those of cigarettes with conventional tobaccos (4 cigarette tasters, 15 descriptors). For that purpose 21 mm filters were added to cigarettes (84 mm cigarettes).

Filling power determination was done on the cut-rag tobacco used for cigarette making. Results obtained with a Borgwaldt DD60A densimeter are the mean of 8 measurements, each one using 20 g of tobacco.

Burning capacity measurements were done on 25 burley cutters in each replicate, with 2 measurements per leaf in the middle of each half lamina. The burning index, which is the median value of the 50 measured burning times, was also calculated.

For statistical analyses, means were compared using the analysis of variance (Anova) and the criterion of Newman-Keuls ($p = 0.05$). Significantly differing means or homogeneous groups of means were quoted with different letters (a, ab, b …).

III Results

III-1 Prior experiments

III-1-1 Sérénade® Biofungicide evaluation

Despite favorable conditions, the disease development was quite slow. The disease spread between the two evaluations on the control. Rovral® Aqua Flo and Sérénade® Biofungicide both proved to be efficient (Table 5).

***Table 5**: Evaluation of grey mold symptoms using a 0 to 11 scale after artificial inoculation of tobacco plantlets treated with different products*

	First evaluation of symptoms (1 month after inoculation)	**Second evaluation of symptoms (10 days later)**
No treatment (control)	0.96	2.78
Rovral® Aqua Flo (reference)	0.92	0.50
Sérénade® Biofungicide	0.18	0.23

III-1-2 Tilco Biotonic evaluation

Climatic conditions were very favorable to blue mold development as observed for the control (Tables 6 and 7). The first spots were observed at the end of August. No phytotoxicity was observed.

In 2004 (Table 6), the reference Bion MX® proved to be very efficient. Tilco Biotonic was less efficient but statistically different from the control and more efficient than Acrobat® M DG (significant only for the first evaluation).

***Table 6**: Evaluation of blue mold symptoms using a 0 to 9 scale after natural contamination of tobacco plants in the field: effect of different products; 2004 results*

	First evaluation of symptoms (mid-September)				**Second evaluation of symptoms (end of September)**			
	Replicate 1	**Replicate 2**	**Replicate 3**	**Mean**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Mean**
No treatment (control)	6.1	7.2	5.6	6.3 **d**	9.0	8.6	8.6	8.7 **c**
Bion MX® (reference)	0.0	0.0	0.0	0.0 **a**	0.1	0.1	0.0	0.1 **a**
Acrobat® M DG	3.2	4.7	4.0	4.0 **c**	7.3	7.0	5.9	6.7 **bc**
Tilco Biotonic	3.6	1.9	2.0	2.5 **b**	7.6	4.7	3.4	5.2 **b**

In 2005 (Table 7), the behavior of the tobacco plants treated with the reference Bion MX® was not consistent with previous results. Tilco Biotonic was significantly less efficient than Acrobat® M DG at the beginning of September but not significantly different from the reference and from the control. No significant differences were observed at mid-September.

***Table 7**: Evaluation of blue mold symptoms using a 0 to 9 scale after natural contamination of tobacco plants in the field: effect of different products; 2005 results*

	First evaluation of symptoms (beginning of September)				Second evaluation of symptoms (mid-September)			
	Replicate 1	**Replicate 2**	**Replicate 3**	**Mean**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Mean**
No treatment (control)	6.9	5.2	4.3	5.5 **c**	8.7	6.5	7.5	7.6 **a**
Bion MX® (reference)	2.4	3.3	1.3	2.3 **ab**	8.0	4.3	4.3	5.5 **a**
Acrobat® M DG	0.4	0.2	0.0	0.2 **a**	6.3	5.5	3.3	5.1 **a**
Tilco Biotonic	6.7	2.3	2.5	3.8 **bc**	7.8	4.0	4.9	5.6 **a**

III-2 Transplant production

Under float tray system conditions and using the organic compost KKS Bio Tray Substrate, 2 of the 5 evaluated organic fertilizers proved to be equal to Hydrokani H2 for transplant production: BioSevia™ Grow (GHE, complete fertilizer) and Tilco Biotonic. It is noteworthy that Tilco Biotonic is not yet approved for organic cultivation contrary to BioSevia™ Grow.

Using the same methodology as described in II-2 we were able to produce field-ready organic transplants in 2008, using these 2 fertilizers. The cultivation took place from end of March to May in a plastic greenhouse as usually done for transplant production. FC (ITB 683 and ITB 623) and burley (ITB 574 and ITB 501) varieties were experimented and organic transplant production was once again compared with standard ITB transplant production, with no notable differences. The fertilization was managed to bring at first 7 mg N per plant for burley and 6 mg for FC and then 3.5 mg after the first clipping (end of April) for burley and 1.4 mg for FC. A second clipping was done on FC seedlings at mid-May followed by a 2.8 mg N fertilization.

Preventive treatments with Sérénade® Biofungicide and Tilco Biotonic were applied every 2 weeks from the 4 leaf development stage and every 10 days respectively with a dose of 5 Kg/ha for Sérénade® Biofungicide and 4 L/ha for Tilco Biotonic at 500 L/ha. A treatment against aphids was applied with Roténobiol just before transplantation. It is noteworthy that the use of rotenone will be forbidden in France at the end of 2008. The organic adjuvant Héliosol® was associated with Tilco Biotonic and Roténobiol with a dose of 2 L/ha. No *Pythium* attack was observed; Tilco Biotonic is also said to be efficient against *Pythium* root rot.

III-3 Field trials

III-3-1 Plant cultivation

From June 8, organically grown burley tobaccos showed a small delay in their development in comparison with conventionally grown tobaccos and they flowered 6 days later. From July 23, they were also found slightly more yellow than conventionally grown tobaccos. This coloration becomes more pronounced later on, because of a lack of nitrogen availability.

Six tobacco plants from each replicate were randomly selected and measured each week from June 20 to July 19 (data not shown). Organically grown burley tobacco plants, especially ITB 574 variety, were found smaller than conventionally grown ones and also produced less leaves (almost 37 cm less and 3 leaves less). Visual observations until harvest also showed that their leaves were smaller, less spread and the plants were more erect. On the contrary, no delay and no coloration difference were observed for organically grown FC plants. They were roughly as high as conventionally grown tobaccos and produced the same number of leaves (data not shown).

2007 climatic conditions were very favorable to blue mold development which was first observed on organically grown FC varieties, from July 23. The disease then spread to the whole field trial and even to conventionally grown tobaccos. Though no systemic symptoms were observed, the blue mold attack was more important on organically grown tobaccos.

As far as suckering is concerned, the amount of oil must be controlled. Too much oil girdle the plant base and some leaf drop can occur after application and before harvest for burley. No burn on the stem was observed. For FC, removal of developing buds was later necessary on some plants. Though showing some efficiency, rapeseed oil is less efficient than Tamex® AG. Other trials (data not shown, FC variety, 2 replicates of 10 plants) showed that the mean number of developing buds per plant (5.6 vs 0.2 for Tamex® AG) and their mean weight (40.9 g vs 0.2 g for Tamex® AG) were greater with rapeseed oil.

II-3-2 Raw matter evaluation

Four percent of the ITB 574 organic field crop was rejected (2.87 %, 4.65 % and 5.19 % respectively for replicates 1, 2 and 3). The QI of organically grown burley tobaccos are lower (Table 8). The gap between conventional and organic QI is almost the same for both burley varieties. The two burley varieties also exhibit very inferior yields and commercial values when organically grown. Gaps are more important for ITB 574.

For a same FC tobacco variety, there is no difference for QI between standard and organic cultural practices. Net yields and commercial values are inferior for organically grown FC varieties (significant only for ITB 623). However, it is noteworthy that the yields are very acceptable since they are all greater than 4 000 Kg/ha. No FC raw matter was classified as rejected.

***Table 8**: Yields, quality index and commercial values of conventional and organic burley and FC tobaccos*

Variety and cultural practices	Net yield (Kg/ha)				Net quality index				Estimated commercial value (€/ha)			
	R 1	R 2	R 3	Mean	R 1	R 2	R3	Mean	R 1	R 2	R 3	Mean
ITB 501 Conventional	3334	3413	2887	3211 b	94	95	97	95 c	11459	11822	10214	11165 b
ITB 574 Conventional	3187	4377	3965	3843 b	81	91	89	87 c	9415	14492	12903	12270 b
ITB 501 Organic	2351	2530	2557	2479 a	52	62	64	59 b	4479	5704	5964	5382 a
ITB 574 Organic	2283	2180	2175	2213 a	41	46	54	47 a	3387	3639	4317	3781 a
ITB 683 Conventional	4312	4236	4315	4288 ab	77	75	69	74 a	12739	12152	11292	12061 a
ITB 623 Conventional	4249	4498	4500	4416 b	85	87	82	85 b	13822	14999	13989	14270 b
ITB 683 Organic	4073	4010	4117	4067 a	79	73	69	73 a	12259	11119	10809	11396 a
ITB 623 Organic	4041	4325	4025	4130 a	76	83	76	79 ab	11799	13765	11674	12413 a

Stem percent of organic or conventional grown FC tobaccos are not significantly different (Table 9). On the contrary, organically grown burley varieties exhibit significantly higher stem percents (4-5 % more) than the same varieties conducted under conventional cultural practices.

***Table 9**: Stem percent of conventional and organic burley and FC tobaccos*

Variety and cultural practices	Stem %			
	Replicate 1	Replicate 2	Replicate 3	Mean
ITB 683 Conventional	21.06	20.94	21.94	21.31 **a**
ITB 623 Conventional	23.73	19.33	23.77	22.28 **a**
ITB 683 Organic	22.95	19.05	23.17	21.72 **a**
ITB 623 Organic	23.43	21.55	20.68	21.89 **a**
ITB 501 Conventional	30.00	27.60	27.00	28.20 **a**
ITB 574 Conventional	28.77	27.19	27.30	27.75 **a**
ITB 501 Organic	33.21	33.46	33.02	33.23 **b**
ITB 574 Organic	30.78	31.96	32.44	31.73 **b**

Representative leaf samples (1 Kg) of leaf (B) and tip (T) leaves for burley and of the 4th and 5th harvests for FC

For a same FC variety, the content of each alkaloid as well as the sum of alkaloids do not differ significantly between the two cultural practices (Table 10). On the other hand, significant differences exist between conventional and organic burley. The alkaloid content is lower for organic burley especially for nicotine (53 % of the standard content for ITB 501 and 47 % for ITB 574), nornicotine (53 and 35 %) and the sum of alkaloids (52 and 47 %).

__Table 10__: Alkaloid content of conventional and organic burley and FC tobaccos

Variety and cultural practices	Anabasine (% DM)				Anatabine (% DM)				Nicotine (% DM)				Nornicotine (% DM)				Sum of alkaloids (% DM)			
	R 1	R 2	R 3	Mean	R 1	R 2	R 3	Mean	R 1	R 2	R 3	Mean	R 1	R 2	R 3	Mean	R 1	R 2	R 3	Mean
ITB 683 Conventional	0.01	0.02	0.02	0.02 a	0.10	0.15	0.15	0.13 b	0.98	1.38	1.56	1.31 ab	0.03	0.05	0.05	0.04 a	1.12	1.60	1.78	1.50 ab
ITB 623 Conventional	0.01	0.02	0.02	0.02 a	0.07	0.10	0.09	0.09 a	1.47	1.42	1.67	1.52 b	0.04	0.03	0.05	0.04 a	1.59	1.57	1.83	1.66 b
ITB 683 Organic	0.02	0.02	0.02	0.02 a	0.11	0.12	0.11	0.11 ab	1.06	0.94	1.04	1.01 a	0.04	0.03	0.04	0.04 a	1.23	1.11	1.21	1.18 a
ITB 623 Organic	0.01	0.02	0.02	0.02 a	0.06	0.09	0.11	0.09 a	1.03	1.25	1.60	1.29 ab	0.03	0.04	0.04	0.04 a	1.13	1.40	1.77	1.43 ab
ITB 501 Conventional	0.04	0.04	0.07	0.05 c	0.25	0.25	0.37	0.29 c	4.55	4.55	6.01	5.04 b	0.57	0.36	0.43	0.45 c	5.41	5.20	6.88	5.83 b
ITB 574 Conventional	0.03	0.04	0.04	0.04 bc	0.19	0.21	0.21	0.20 b	4.42	4.80	4.96	4.73 b	0.11	0.14	0.26	0.17 ab	4.75	5.19	5.47	5.14 b
ITB 501 Organic	0.02	0.02	0.02	0.02 ab	0.11	0.15	0.15	0.14 ab	2.27	2.88	2.81	2.65 a	0.19	0.27	0.25	0.24 b	2.59	3.32	3.23	3.05 a
ITB 574 Organic	0.02	0.01	0.01	0.01 a	0.10	0.07	0.08	0.08 a	2.57	2.06	2.09	2.24 a	0.06	0.05	0.08	0.06 a	2.75	2.19	2.26	2.40 a

Representative lamina samples of leaf (B) and tip (T) leaves for burley and of the 4th and 5th harvests for FC

The chlorine and nitrogen contents do not differ significantly among the two cultural practices for FC varieties (Table 11). On the other hand, significant differences exist for these two components, for NH_3 content and also for ITB 501 nitrate content between conventional and organic burley tobaccos with lower levels for organic burley (chlorine: 76 % of the standard content for ITB 501 and 82 % for ITB 574, nitrogen: 65 and 68 %, nitrates: 12 and 21 %, NH_3: 57 and 67 %).

Table 11*: Chlorine, nitrogen, nitrate and NH_3 contents of conventional and organic burley and FC tobaccos*

Variety and cultural practices	Chlorine (% DM)				Nitrogen (% DM)				NO_3 (% DM)				NH_3 (% DM)			
	R 1	**R 2**	**R 3**	**Mean**	**R 1**	**R 2**	**R 3**	**Mean**	**R 1**	**R 2**	**R 3**	**Mean**	**R 1**	**R 2**	**R 3**	**Mean**
ITB 683 Conventional	0.50	0.36	0.48	0.45 **a**	1.74	1.95	2.21	1.97 **a**								
ITB 623 Conventional	0.52	0.38	0.63	0.51 **a**	1.96	1.71	2.05	1.91 **a**								
ITB 683 Organic	0.42	0.30	0.40	0.37 **a**	1.82	1.62	1.82	1.75 **a**								
ITB 623 Organic	0.29	0.43	0.45	0.39 **a**	1.53	1.69	1.92	1.71 **a**								
ITB 501 Conventional	0.78	0.74	0.77	0.76 **b**	4.77	4.42	5.36	4.85 **b**	0.33	0.37	1.07	0.59 **b**	0.59	0.57	0.59	0.58 **b**
ITB 574 Conventional	0.65	0.77	0.62	0.68 **b**	4.30	4.96	4.78	4.68 **b**	0.28	0.56	0.71	0.52 **ab**	0.52	0.61	0.53	0.55 **b**
ITB 501 Organic	0.54	0.60	0.61	0.58 **a**	2.86	3.50	3.02	3.13 **a**	0.03	0.16	0.03	0.07 **a**	0.32	0.37	0.31	0.33 **a**
ITB 574 Organic	0.58	0.56	0.53	0.56 **a**	3.45	2.79	3.37	3.20 **a**	0.10	0.06	0.16	0.11 **a**	0.43	0.32	0.37	0.37 **a**

Representative lamina samples of leaf (B) and tip (T) leaves for burley and of the 4th and 5th harvests for FC

The burning capacity and index of the organically grown burley cutters are more important than that of the same varieties grown under conventional agricultural practices (on average, + 6 seconds for the burning capacity and burning index 2 times more important for both varieties), which has to be related with the thinness of the leaves (Table 12). All differences are significant excepted for ITB 501 burning index.

Table 12*: Burning capacity and index of cutters from conventional and organic burley tobaccos*

Variety and cultural practices	Burning capacity (seconds)				Burning index (seconds)			
	Replicate 1	Replicate 2	Replicate 3	Mean	Replicate 1	Replicate 2	Replicate 3	Mean
ITB 501 Conventional	4.74	5.22	3.54	4.5 **a**	4.4	4.8	3.3	4.2 **a**
ITB 574 Conventional	12.09	6.42	6.92	8.5 **b**	9.5	5.5	5.8	6.9 **a**
ITB 501 Organic	10.78	10.06	10.78	10.5 **c**	9.3	7.4	8.5	8.4 **a**
ITB 574 Organic	13.14	16.88	14.02	14.7 **d**	11.8	18.0	12.5	14.1 **b**

Though statistically different, filling powers of organic and conventional FC tobaccos can be considered as equal (Table 13). On the contrary, organic burley exhibits higher filling powers than the conventional one. This also has to be related with the thinness of the leaves.

Table 13*: Filling power of conventional and organic burley and FC tobaccos*

Variety and cultural practices	Filling Power (cm^3/g)
ITB 683 Conventional	3.87 **a**
ITB 623 Conventional	3.93 **b**
ITB 683 Organic	3.98 **c**
ITB 623 Organic	4.20 **d**

ITB 501 Conventional	5.48 **a**
ITB 574 Conventional	5.69 **b**
ITB 501 Organic	6.57 **c**
ITB 574 Organic	6.74 **d**

Cut-rag tobacco from lamina samples of leaf (B) and tip (T) leaves for burley and of the 4th and 5th harvests for FC

III-3-3 Smoke analysis

Puff numbers are not significantly different between organic and conventional FC cigarettes. Significant differences are observed for ITB 623 concerning CO, TPM and tar levels which are more important for the organic raw matter. Higher TPM and tar levels can be related to higher sugar levels (+ 15 %) measured by near infrared reflectance spectrometry (data not shown). Organic ITB 683 yields significantly less nicotine as observed in the raw matter.

Puff numbers are significantly lower for organic burley cigarettes. This has to be related to the more important burning capacity. Significantly lower levels are also observed for TPM, nicotine (to be related to raw matter's nicotine content) and tar (ITB 501). Tobacco weight per cigarette appears to be lower for organic burley raw matter which has to be related to higher filling powers.

***Table 14**: Smoke analysis and physical measurements of cigarettes from conventional and organic raw matter*

Variety and cultural practices	Tobacco weight (mg/cig)	Puff Nb		CO (mg/cig)		TPM (mg/cig)		Nicotine (mg/cig)		Tar (mg/cig)	
ITB 683 Conventional	938	7.9		12.8		26.45		1.43		20.83	
		8.2	8.1 **de**	13.0	12.90 **c**	26.73	26.59 **d**	1.49	1.46 **b**	20.90	20.86 **c**
ITB 623 Conventional	918	7.5		13.7		26.01		1.61		20.23	
		7.8	7.7 **d**	14.2	13.95 **d**	26.92	26.47 **d**	1.64	1.62 **d**	20.82	20.53 **c**
ITB 683 Organic	967	8.1		13.0		26.10		1.10		21.05	
		8.5	8.3 **e**	12.8	12.90 **c**	26.15	26.13 **d**	1.13	1.11 **a**	20.91	20.98 **c**
ITB 623 Organic	915	7.8		14.9		28.36		1.58		21.83	
		8.0	7.9 **de**	14.9	14.90 **e**	28.42	28.39 **e**	1.53	1.55 **bcd**	21.93	21.88 **d**
ITB 501 Conventional	635	5.1		11.9		20.44		3.59		13.25	
		5.3	5.2 **c**	11.9	11.9 **ab**	21.00	20.72 **c**	3.68	3.63 **f**	13.34	13.29 **b**
ITB 574 Conventional	592	4.8		12.0		21.20		3.37		13.60	
		4.8	4.8 **b**	12.3	12.15 **b**	20.87	21.04 **c**	3.33	3.35 **e**	13.70	13.65 **b**
ITB 501 Organic	568	4.2		11.4		17.33		1.59		12.68	
		4.3	4.3 **a**	11.4	11.4 **a**	17.60	17.47 **a**	1.58	1.59 **cd**	12.66	12.67 **a**
ITB 574 Organic	510	4.0		12.6		18.86		1.52		13.63	
		4.0	4.0 **a**	12.0	12.3 **bc**	18.43	18.65 **b**	1.45	1.49 **bc**	13.40	13.52 **b**

Cut-rag tobacco from lamina of leaf (B) and tip (T) leaves for burley and of the 4th and 5th harvests for FC

Sensory evaluation showed no significant difference between organic and conventional FC cigarettes, whatever the variety and whatever the descriptor. On the contrary, significant differences were observed between organic and conventional burley cigarettes with less piquant nose for the two organic burley tobaccos, less aroma intensity and an easier inhalation for organic ITB 501, less taste intensity and a taste line less typical of burley for organic ITB 574.

IV Conclusion and prospects

For organic tobacco cultivation, production methods have to be altered to take into account the lack of some pesticides and fertilizer materials allowable in traditional tobacco production. The phase of transplant production may be the most difficult. Alternative materials that may work in the field are not necessarily suitable for the float system. Cool weather also limits nutrient availability in plastic greenhouse by slowing decomposition of fertilizer materials. However, successful results were obtained for transplant production in float tray system.

Successful results were also obtained for organic FC tobacco field cultivation. Yields were greater than 4 000 Kg/ha. The organic raw matter produced did not differ from conventional raw matter for quality, stem percent, filling power, chemical content (alkaloids, chlorine and nitrogen) and sensory analysis. Some significant differences were observed for smoke analysis but they are different according to the FC variety considered. The same trials were set up in 2008 to confirm these results: plant behavior in the field seems to be identical to 2007 (other results pending).

Organic burley fertilization was not sufficient. The organic burley raw matter produced differed from conventional raw matter by lower quality, yield and commercial value and higher stem percent, filling power and burning capacity. Lower alkaloid, chlorine, nitrogen, nitrate and NH_3 contents were also observed. Significant differences were also observed between organic and conventional burley tobaccos for sensory analysis.

Although some plant nutrients may be immediately available, using fertilizer materials that are organically based requires mineralization by microbial activity so that most of the nutrients become soluble in the soil and eventually available for plant uptake. Mineralization requires oxygen and water to proceed and depends on weather, warm and moist conditions being more favorable than cold and dry ones. Moreover, organic materials do decompose slowly. So, it was difficult to forecast how quickly the organic products release nitrogen and what amounts were readily available to plants and to decide how much fertilizer to apply before planting and how much may be added later as side dressing.

New trials for burley fertilization improvement (more important amounts of organic fertilizers and plant density decreasing) were initiated in 2008. Encouraging results were obtained as far as plant behavior in the field is concerned (other results pending). We intended to apply feather meal some weeks before planting so the material would have time to break down and release nitrogen but, unfortunately, it was not possible due to 2008 rainy climatic conditions.

Improvements are also needed for blue mold and sucker control.

As Tilco Biotonic proved to be not sufficiently efficient for blue mold control, 9 other organic products (especially products from seaweeds or cupric products, all known for their efficiency on other plants) were evaluated under artificial contamination of young plants cultured under artificial conditions on float trays. Six of them will be evaluated in the field in 2009.

New trials for the control of sucker development were also conducted during summer 2008, including dilutions of rapeseed oil with water and different ways of application (oilcan or backpack sprayer). Promising results have to be validated next year.

Of course other organic practices could also be integrated into the organic tobacco cultivation such as crop rotations, cover crops and the use of manures. Finally, organic tobacco cultivation should be evaluated at the farm level on organic land.

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