BIOMASS PRODUCTION IN MIXED PLANTATIONS WITH SRC AND NOBLE HARDWOODS

Gianni Facciotto*, Sara Bergante*, Chiara Gugino*, Claudia Piagnani**, Cesare Lioia*
* Consiglio per la Ricerca e la sperimentazione in Agricoltura – Unità di Ricerca per le Produzioni Legnose Fuori Foresta (CRA-PLF). St. Frassineto Po 35 – I-15033 Casale Monferrato (AL) - Italy
Tel: +39 0142 330900, E-mail: facciotto@populus.it
** Università degli studi di Milano, DI.PRO.VE, Sezione di Coltivazioni arboree, via G. Celoria 2, I-20133 Milano - Italy.
Tel: +39 0250316564, E-mail: claudia.piagnani@unimi.it

ABSTRACT: A new model of cultivation that combines reforestation with noble hardwood species (Maple, Cherry, Service and Wild Service Trees, etc) and Short Rotation Coppices (SRC) with poplar, willow and black locust was studied in Italy. This paper refers the results obtained during the first 2-4 years of growth. If correctly grown, the clones of poplar and willow selected for biomass can assure good productions up to 8-9 Odt·ha^{-1}·year^{-1}. The poplar and willow clones had shown a different behavior depending on the pedological and climatic characteristics of the sites, therefore it will be necessary to carefully choose the clones to insert in the stand. On a Piedmont sites, characterized by marginal soil for the agriculture, also the Black Locust has given good results of growth and production: 4 Odt·ha^{-1}·year^{-1}. The interaction among the intercalary SRC and the noble hardwood plants still have not been put in evidence from the statistical analysis.
Keywords: Poplar, willow, biomass production.

1 INTRODUCTION

Today in Italy short rotation coppices (SRC) are grown to obtain raw material for heat and power generation. Considering the European Union target of a 20% share of renevable energy by 2020 it can be expected that SRC becomes more important; particularly when new technologies for second generation biofuels production from ligno-cellulosic material will be introduced in the market. The competition between food/feed and energy crops could be exclude the establishment of SRC on productive agricultural land. A solution could be the cultivation of multipurpose plantations producing biomass and logs for industry. They are mixed plantation of hardwood species, sometimes noble hardwood species, and SRC of poplars, willows and black locust. Currently in Italy plantations outside forest cover a surface around 125.000 hectares, the most part established in the period 1994-2006 with fund of EU [1]. Further incentives for new plantations in the next years have been approved from the Italian regions in their Rural development plan.

The advantages of this cultural model could be that:

- the farmers can receive payments for biomass every 2-5 years for 10 or more years when noble hardwood species are in the juvenile phase,
- the noble hardwood species can be planted at definitive spacing, so plantation thinning could be avoided and so it is possible to reduce production cost.
- the SRC with a rapids coverage of the soil have a positive environmental impact reducing soil erosion and increasing biodiversity (soil fauna, birds and little mammals) [2].
- The SRC can protect the noble hardwood trees from wind and storm
- a certain competition of SRC with noble hardwood trees causes the correct growth of the their stem and the formation of a smaller number of thin branches, in comparison to traditional outside forest plantation, with reduction of pruning intensity [3].

This new cultural model has been tested in Piedmont and Lombardy with two research projects coordinated by CRA-PLF: Ri.Selv.Italia (financed by the MiP.A.F.F) and Mo.pro.Legno (financed by the Lombardy Region).

This paper refers only the result obtained during the first 2-4 years of growth: biomass production of SRC and survival and growth of the noble hardwood trees.

Figure 1: Chivasso (TO) Src and noble hardwood after planting.

2 MATERIALS AND METHODS

2.1 Trials

In table I, sites, farms and establishment year of the experimental plantation are reported. The involved farms are partly public and partly private; the last ones had shown a certain interest toward this new model of cultivation because they had change the heating system

of the farm buildings, from oil or natural gas to wood chips.

Table I: Experimental plantation: site, farm and establishment year

Sites	Farm	Year
Chivasso (TO)	Cerello	2005
Brusnengo (BI)	Bebba	2005
Bigarello (MN)	Carpaneta	2006
Casale Monferrato (AL)	Mezzi	2007

In Cerello farm at Chivasso (TO), mixed plots of noble harwood trees with 2 or 3 rows of black-locust SRC were compared. Spacing is 12×6.75 m between a couple of noble hardwood trees (fig. 1). The distance between noble hardwood trees and two SRC rows is 4 m while between noble hardwood trees and three SRC rows is 3 m. The distance among the black locust seedling on the rows is 0.9 m. SRC densities are reported in table VII.

Figure 2: Brusnengo (BI).SRC planting machine.

In Cascina Bebba farm near Brusnengo (BI)), mixed plots of noble harwood trees with 2 rows of poplar and willows clones SRC were compared (fig. 2). The *Salicaceae* clones utilized are reported in table II. Spacing is 12×6 m between noble hardwood trees,. 4 m between noble hardwood trees and SRC rows, and 2.7 m between the two SRC rows and 0.7 m on the rows. SRC density is 2380 trees per hectare.

Figure 3: Bigarello (MN) Src and noble hardwood during 1st vegetative season.

In the Carpaneta farm, (ERSAF- Lombardy Region) situated at Bigarello (MN), pure plots of Sorbus spp., and Pyrus spp were compared with mixed plots of hardwood with one or two rows of SRC of poplar and willow clones (fig. 3). The *Salicaceae* clones utilized are reported in table II. .Spacing is 8×8 m between noble hardwood trees, 3 or 4 m between noble hardwood trees and respectively two or one SRC rows, 2.1 m between the two SRC rows and 0.73 m on the rows corresponding to a density of 1712 plants per hectare with 1 row and 3425 p/ha with 2 rows..

In Mezzi farm, (C.R.A.- PLF) at Casale Monferrato (AL), pure plots of Sorbus spp., and Pyrus spp were compared with mixed plantations: Sorbus and Pyrus with poplar SRC. In this trial three *Sorbus domestica* clones and a *Pyrus* spp. clone (PVC 74-15-53) are planted. Poplar clone are reported in table II. Spacing is 8×8 m between noble hardwood trees, 3 m between noble hardwood trees and SRC rows, and 2 m between SRF rows. The distance among SRC plants is random because there were utilized poplar cuttings, 1.2 m length, horizontally planted 5 cm deep in the soil, one after the other. The effective SRC densities, at the end of second year are reported in table IX.

Figure 4. Casale Monferrato (AL) noble hardwood establishment.

The plantation designs were randomized complete blocks or split-plots with 3-4 replication.

2.2 Clones and planting material

Poplar and willow clones utilized are reported in table II; fifteen of them were selected and supplied by C.R.A–PLF and two (Pegaso and AF2) by Franco Alasia nursery. These clones were selected for:

- rapid increase,
- disease resistance,
- good re-sprouting ability after coppicing.

Black locust seedlings (Hungarian provenance) and hardwood species (Acer, Carpinus, Prunus, Pyrus, Quercus, Tilia) utilized in the Cerello and Cascina Bebba Farm were acquired by Franco Alasia nursery.

Sorbus and *Pyrus* trees utilized at Carpaneta farm were selected and supplied by ERSAF-Lombardy Region. While a *Pyrus* spp clone 'PVC 74-15-53' and three *Sorbus* spp clones 'TOSCA 3', 'TOSCA 10/5' and 'TOSCA 10/16', propagated in vitro culture and grown one year in box, were selected and supplied by Department of Crop Science - Woody Plant section of the University of Milan (DIPROVE).

2.3 Establishment and cultivation techniques

The fields were ploughed to 30-40 cm depth and

harrowed before planting.

Poplar and willow unrooted cuttings (20 or 120 cm long) were prepared in February and preserved in refrigerator until march/april. This material was hydrated for 48 hours before planting.

Table II: Species (Pd=*Populus deltoides*, Pc=*P.* x *canadensis*, Pgn=*P.* ×*generosa* × *P. nigra*, Sa=*Salix alba*, Sba=*S. babilonyca* × *S. alba*, Smi=ibrids of *S. matsudana*) and clones of poplar and willow utilized in the trials at Brusnengo (Bru) Bigarello (Big) and Casale (Cas).

Clones	Species	Bru	Big	Cas
84-078	Pd	-	x	-
85-037	Pd	-	x	-
Baldo	Pd	x	x	-
Lux	Pd	-	-	x
Oglio	Pd	-	-	x
83.039.018	Pc	x	-	-
AF2	Pc	-	x	-
Imola	Pc	-	x	-
Orion	Pc	x	x	-
Triplo	Pc	-	-	x
Pegaso	Pgn	x	-	-
131-25	Sba	-	x	-
Drago	Smi	x	x	-
Levante	Smi	x	x	-
S76-008	Smi	x	x	-
S78-003	Smi	-	x	-
SI64-017	Sa	x	x	-

Noble hardwood seedling were planted manually and endowed with shelter.

Poplar and willow unrooted cuttings and black locust seedling are mechanically planted utilizing different transplanting machine.

After establishment and after every coppicing, chemical herbicide was sprayed on the SRC rows At Casale Monferrato *Lolium perenne* was utilized as cover-crop instead of chemical control and organica mulch was utilized on Sorbus and Pyrus trees as weed protection.

Figure 5: Chivasso (TO). Hardwood and SRC (3 rows) at the end of the third years after establishment.

During the summer of the first year, three or four harrowings were carried out between the rows. During the second and following years cultural practices were reduced: weed control by disc harrowing was done only once in late spring. The plots were irrigated by sprinkler once or twice per year at Casale and Bigarello only.

The SRC plots of Casale were harvested at the end of the second year, the ones of Bigarello partly at the second and partly at the third year. Chivasso trials were harvested at the end of the third year while the plots of Brusnengo are in stand yet.

2.4 Measurements

At the end of each vegetative season, in all the trials, survival %, diameter at breast height (mm), and total height (cm) were recorded. The total green weights of stem and branches of poplar, willow and black locust were measured on a sample of 10-30 trees per clone on each site at the end of each rotation. To obtain dry weight, stem and branch samples were dried to constant weight in an oven at 105°C. Biomass production values were estimated by a potential regression.

Analysis of variance (ANOVA) of the data recorded in each trial were performed.

3 RESULTS AND DISCUSSION

3.1 Hardwood species

In the second year, at Chivasso (table III), there were significant differences among species in diameter and height. Maple and Hornbeam trees grew more than oak trees. There were no significant differences between the hardwood plots mixed with two or three rows of SRC (fig.5).

Table III: Chivasso (TO). Hardwood species. Means (see note 1) and ANOVA (see note 2) of DBH in mm (D130) and total height in cm (H3) at the end of the 3rd year in plot 1 (mixed stand with 3 SRC rows) and 2 (mixed stand with 2 SRC rows).

Plot	1		2	
Species	D130	H3	D130	H3
Maple	18	350 A	15 B	273 A
Oak	16	284 B	13 B	220 B
Hornbeam	18	340 A	22 A	391 A
General mean	17	325	16	261
F value	0.5	542**	187**	669**

Table IV: Brusnengo (BI). Hardwood species in mixed stand with SRC. Means (see note 1) and ANOVA (see note 2) of total height in cm (H) at the end of the 1st (1), 2nd (2), 3rd (3) and 4th (4) year and DBH at the end of the 4th year in mm (D130).

Species	H1	H2	H3	H4	D130	
Pear	66	88	121	189	8.6	BC
Hornbeam	58	87	160	258	18.8	B
Oak	70	92	123	141	11.5	C
Cherry	101	182	294	384	42.3	A
Maple	88	132	192	242	20.4	B
Lime	50	51	110	140	5.6	C
General mean	70	116	170	220	20.1	
F value	4.3*	11**	14**	14**	12**	

At Brusnengo (table IV), growth of Cherry were excellent throughout the four years of study period. At fourth year the average of diameter at breast height was 42.3 mm and average of height 384 cm. The diameters and heights of Maple and Hormbeam trees were superior than those of oak and lime trees; growth performances of pear trees were intermediate

Table V Casale Monferrato (AL). Sorbus and Pyrus clones. Means (see note 1) and ANOVA (see note 2 and 3) of survival percent (S) and total height in cm (H) at the end of the 1st (1) and 2nd (2) year, and diameter in mm at 10 cm (D10).

Clones	S1	S2	H1	H2	D10
PVC75/15/53	70	59	47 B	112	9.6 b
TOSCA 3	92	73	97 A	153	13.9 a
TOSCA 10/5	86	73	69 B	132	15.6 a
TOSCA 10/16	84	53	64 B	120	13.1 a
General mean	83	64	69	129	13.0
F value	1.8	0.9	18**	2.5	5.7*

In the second year, at Casale Monferrato (AL) (table V) there were significant difference only in diameter among the three Sorbus clones and the Pyrus clone. No significant difference were found between pure and mix plots. There were no competition between hardwood and SRC.

Table VI: Bigarello (MN). Noble hardwood species. Means (see note 1) and ANOVA (see note 2and 3) of survival percent (S) and DBH in mm (D130) at the end of the 2nd year, total height in cm at the end of the 1st (H1) and 2nd year (H2) in pure stand or in mixed plots with 1 or 2 SRC rows.

Plot model	Species	S	H1	H2
1 (Pure stand)	Wild Service	100	40	45
	Service	93	122	263
	Pear	100	86	207
2 (1 row SRC)	Wild Service	97	45	84
	Service	100	103	274
	Pear	100	126	257
3 (2 rows SRC)	Wild Service	89	41	75
	Service	99	67	193
	Pear	100	110	251
Mean SRC	Pure stand	97	83	185
	1 row SRC	99	91	205
	2 rows SRC	96	73	173
Mean Species	Wild Service	92	42 b	81 B
	Service	98	97 a	243 A
	Pear	100	107 a	238 A
General mean		97	82	188
F value	Plot model (Pm)	0.7	1.4	1.3
	Species (Sp)	0.2	77*	723**
	Pm × Sp	0.8	4.5	2.6

Minimal differences, not statistically significant (table VI), in survival and height among plot model treatments were found at the end of the second year, near Bigarello (MN). While both service and pear trees were significantly greater in height than Wild Service trees.

Analyses show that SRC, grown in 1, 2 o 3 rows among hardwood species trees, have had no influence during first cutting cycle of 2 years (fig. 6).

Table VII: Chivasso (TO). Black locust SRC with 2 or 3 rows. Planting density (Pden) in plants per hectare, means and ANOVA of survival percent (S), Dbh (D130) and oven dry biomass at the end of the 3rd (Bs3) year in t per hectare per year.

Plot	**Pden**	**S**	**D130**	**BS**
1 (3 rows)	3456	87	43.8	4.37
2 (2 rows)	2304	63	42.3	2.23
General mean	-	75	43.1	3.25
F value		0.5	0.3	-

3.2 Mixed plantation. Black locust SRC.

At Chivasso (TO) growth and survival of Black locust trees (table VII) were not influenced by planting density during first rotation. While the level of this factor influenced total aboveground biomass production.

At age of three years the Black locust grew at high density (3456 plants per hectare) produced 4.37 oven dry (Od) $t \cdot ha^{-1} \cdot year^{-1}$ of biomass, while grown at low density (2304 $p \cdot ha^{-1}$) produced 2.23 $ODt \cdot ha^{-1} \cdot year^{-1}$, moreless 50%.

3.3 Mixed plantation. Poplar and willow SRC

At Brusnengo (BI) there were no statistically significant differences among the treatments (table VIII). Although in this site, willow clones survived and produced better than poplar clones.

Table VIII: Brusnengo (BI). Poplar and Willow SRC. Planting density: 2380 plants per hectare. Means (see note 1) and ANOVA (see note 2) of survival percent (S4) and oven dry biomass at the end of the 1st (Bs1), 2nd (Bs2), 3rd (Bs3), and 4th year (Bs4) in t per hectare per year. .

	Clone	**S4**	**Bs1**	**Bs2**	**Bs3**	**Bs4**
Poplar	Orion	77	0.04	0.23	1.27	1.98
	83.039.018	70	0.03	0.09	0.66	1.74
	Baldo	46	0.02	0.08	0.49	1.40
	Pegaso	33	0.01	0.04	0.25	0.57
Willow	SI64-017	65	0.04	0.15	0.59	1.42
	Drago	63	0.01	0.07	0.91	2.42
	Levante	64	0.04	0.11	0.58	1.89
	S76-008	67	0.02	0.08	0.73	2.13
Means	Poplar	57	0.03	0.11	0.67	1.42
Species	Willow	65	0.03	0.10	0.70	1.97
General mean		61	0.03	0.11	0.68	1.70
F value	Species .	1.9	0.1	0.2	0.1	2.3
	Clones	2.6	2.5	2.2	2.0	1.5

. Mean annual increment of total aboveground biomass are still increasing at the end of the fourth growing season in all poplar and willow clones.

Table IX: Casale Monferrato (AL). Poplar SRC. Means (see note 1) and ANOVA (see note 2 and 3) of real density in plants per hectare, Dbh in mm (D130) and oven dry biomass at the end of the 2nd (Bs2) in t per hectare per year. .

Clone	**Density**	**D130**	**Bs2**
Triplo	3122	28.9 B	2.29 B
Oglio	3554	37.7 A	4.52 A
Lux	1287	23.4 C	0.54 C
General mean	2654	30.3	2.45
F value		128**	45.2**

At Casale Monferrato (AL), long cutting (120 cm), 5 cm under soil surface horizontally planted and partially overlapped, produced different quantities of shoots per linear meter of line. So the density is different per each clone (table IX). The difference among the three poplar clones were highly statistically significant.

Diameter growth and aboveground biomass production of Oglio clone were greater than ones of other two clones. In particular Oglio produced two-fold of

Triplo and nine time of Lux.

Figure 6: Bigarello (MN). Hardwood and SRC (2 rows) at the end of the second years after establishment.

At Bigarello (MN) the aboveground biomass productions of two poplar (Imola and 84-078) and two willow clones (131-25 and SI64-017) were significantly larger than those in the other clones.

Table X: Bigarello (MN). Poplar and Willow SRC. Planting density: corresponding Means (see note 1) and ANOVA (see note 2and 3) of survival % (S2) and dry biomass at the end of the 2nd (Bs2) year in ODt per hectare per year.

	Clone	D130	BS	
Poplar	Baldo	83	4.80	CD
	84-078	84	7.88	ABC
	85-037	46	2.23	D
	Orion	90	4.31	D
	Imola	91	9.43	A
	AF2	84	4.54	CD
Willow	S78-003	96	5.31	CD
	Drago	93	5.34	CD
	Levante	71	4.35	D
	S76-008	86	5.56	BCD
	131-25	94	8.01	ABC
	SI64-017	91	8.64	ABC
Mean	1 Rows	75	2.83	B
	2 Rows	85	5.84	A
Means	Poplar	78	4.56	B
Species	Willow	86	5.49	A
General mean		82	4.99	
F value	Rows n.	6.7*	46.2 **	
	Species	9.1*	9.1 **	
	Clone	8.0*	5.8 **	

Willow produced more than poplar and SRC with two row doubled the production of SRC with one row.

The production in this site is greater than those of all other three ones.

4 CONCLUSIONS

The first results show that noble hardwood species and SRC in mixed plantation grow without problems: survival is good for poplar, willow, and noble hardwood trees. The interaction between them still have not been put in evidence from the statistical analysis.

If correctly grown, the clones of poplar and willow selected for biomass can assure good productions, near 7-8 Odt·ha^{-1}·year^{-1}.

Poplar and willow clones had shown a different behavior depending on the pedological and climatic characteristics of the sites; therefore it will be necessary to carefully choose the clones to insert in a mix stand.

On a Piedmont sites, characterized by marginal soil for agricultural crops, also Black Locust has given good results of growth and production; 4 Odt·ha-1·year-1.

Considering the productions in terms of biomass produced for linear meter, instead that for surface, this new cultural model generally produce more than normal SRC.

5 NOTES

(1) Duncan's multiple range test means with at least one minuscule letter in common are not significantly different at p=0.05, while with a capital letter are not significantly different at p=0.01.
(2) * = significant p≤0.05 ** highly significant p≤0.01
(3) Survival % is elaborated previous data transformation in arcsen√%.

6 REFERENCES

[1] CFS, Global Forest Resources Assessment update 2005. Italy. Country Report. Corpo Forestale dello Stato, Ministero delle Politiche Agricole e Forestali, Roma (2005).
[2] JRC/EEA, Proceeding of the Expert Consultation on Short Rotation Forestry, Short Rotation Coppice and perennial grasses in the European Union: Agro-environmental aspects, present use and perspectives. Editors J.F. Dallemand, J.E. Petersen, A. Karp. Harpenden, United Kingdom17 and 18 October 2007. Available at: http//re.jrc.ec.europa.eu/biof/ (2008), pag 123
[3] E. Buresti Lattes, P. Mori, Produzione aggiuntiva e produzione principale di biomassa. Accorgimenti progettuali e colturali. Sherwood Foreste e Alberi Oggi n. 126 (2006), pag. 22-24.