Research and Development Protocol for the Participatory Plant Breeding of Durum Wheat for Mediterranean Agroforestry Group

Project name	AGFORWARD (613520)
Work-package	4: Agroforestry for arable farmers
Specific group	Mediterranean silvoarable systems in France Participatory plant breeding of durum wheat
Milestone	Milestone MS16 (4.3) Part of experimental protocol for WP4
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AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to the second objective. It contributes to the initial research and development protocol, Milestone 16 (4.3) for the participative research and development network focused on the use of agroforestry in arable crops systems.

2 Background

Cultivated varieties of all major arable crops have been selected under conditions of full light. There might be room for improvement for shade tolerance and/or other traits that would make varieties more adapted to cultivation in agroforestry systems. The stakeholders' group in French Mediterranean arable agroforestry systems identified breeding for varieties specifically adapted to agroforestry as an innovation worth developing (Gosme 2014). One of the farmers present in the first stakeholders' meeting agreed to host part of the trial on his farm, as well as INRA experimental station DIASCOPE and INRA research unit SYSTEM (on Restinclières estate).

3 Objective of trial

The objective of this experiment is to determine if there is genetic variability in durum wheat regarding the suitability for cultivation in agroforestry systems and to perform a first screening of accessions from INRA collections in order to use them in a selection program of varieties adapted to agroforestry. During the first year of experimentation, 30 accessions are compared by growing them in different shading conditions (obtained by using deciduous or evergreen trees, different tree densities, tree height or tree pruning strategy). The measurements concern 1) the growth and development of durum wheat: germination, winter survival, phenology, growth in height and ground cover, and 2) the yield components that determine yield. The decrease in light intensity under the trees is also measured. The comparison of these variables between the different shading conditions will be used to classify the varieties regarding their shade tolerance.

4 System description

The trial is set up under 7 conditions, in 3 sites:

1. at a farmer's farm, near Nîmes, in a plot with almond trees.
    a. 1 alley between 2 rows of almond trees (Figure 1)
    b. 1 alley with no trees on the South side (=> full sunlight)
2. at Restinclières estate, north of Montpellier, in plot B17 (deep silty clay limestone):
    a. 1 alley between mature poplar trees (distance between trees: 6 m along tree row, 13 m across). Poplars are 15 years old and measure approximately 30 m in height (Figure 2a)
    b. 1 alley between stunted sorb (*Sorbus domestica*) trees (distance between trees: variable along tree row because of missing trees, 13 m across). Sorb trees are 20 years old but grew poorly and measure approx. 2 m in height, providing virtually no shade (Figure 2b).
3. at INRA experimental station, South-East of Montpellier:
    a. in plot 13B: high density olive trees (distance between trees: 1.5 m along tree row, 5 m across), unpruned trees. (Figure 3),
    b. in plot 15A: organic olive grove (distance between trees: 5 m along tree row, 6 m across), trees pruned regularly (Figure 4),
    c. in an agricultural plot (Figure 5).

Figure 1. Cultivated area between almond trees (19 January 2015)

Figure 2. Cultivated area between b) poplars (19 February 2015), and c) the sorb trees (19 February 2015)

Figure 3. Cultivated area between high density olive trees (10 February 2015)

Figure 4. Cultivated area between olive trees (10 February 2015)

Figure 5. Cultivated agricultural field (10 February 2015).

Table 3. Description of the site, with soil, tree, understorey, and climate characteristics.

	Site characteristics		
	Farmer's field	Restinclières estate	INRA station
Area (ha):	0.07 ha	0.3 ha (whole plot), 756 m^2 (experiment)	0.45 ha (trial 1), 0.1 ha (trial 2)
Co-ordinates (googlemaps):	43.885609, 4.523502	43.715298, 3.853324	43.609786, 3.980403
Site contact:	François Caizergues	Lydie Dufour	Brigitte Montegano
Site contact email address	brigitte.montegano@supagro.inra.fr	lydie.dufour@supagro.inra.fr	brigitte.montegano@supagro.inra.fr
Soil characteristics			
Soil type (WRB classification)			Fluvisol FL
Soil depth			deep
Soil texture		Deep silty clay limestone	loam (23% clay, 30 to 40% sand)
Aspect		Flat	flat
Tree characteristics			
Tree species	Almond tree	Poplar (*Populus nigra*)/Sorb (*Sorbus domestica*)	Olive tree
Variety/rootstock	Ferraduel and Ferragnés		Clones Picholine and hybrids Verdale x Picholine (trial 1) - Hybrid Olivière x Arbequine (trial 2)
Tree density (spacing)	4 m x 6 m	6 m x 13 m	5 m x 6 m (trial 1) and 2 m x 6 m (trial 2)
Tree protection	None	None	None
Additional details	planted in 1980	Poplars planted in 2000, sorbs in 1995	Planted in 2002-2003 (trial 1) and 2005 (trial 2)
Understorey characteristics			
Species	durum wheat (*Triticum durum)*	durum wheat (*Triticum durum)*	durum wheat (*Triticum durum)*
Coverage	cultivated alley: 4m; uncultivated strip at the foot of the trees: 2.3 m (full light) and 2.5 m (shaded conditions).	cultivated alley =9.3m ; uncultivated strip at the foot of the trees = 3.7m	cultivated alley =10 m ; uncultivated strip at the foot of the trees = 1.4 m
Additional details		Uncultivated strip managed by shredding the natural vegetation when necessary	Uncultivated strip managed by shredding the natural vegetation when necessary

Table 3 (continued). Description of the site, with soil, tree, understorey, and climate characteristics.

Livestock characteristics			
Species	None	None	None

	Climate data		
	Farmer's field	Restinclières estate	INRA station
Mean monthly temperature		14.2°C (2011-2013)	15.5°C (2012-2014)
Mean annual precipitation		851 mm (2011-2013)	598 mm (2012-2014)
Details of weather station (and data)		Campbell weather station. weather in agreement with the Ensemble data: clipick*	

*Climate_yieldsafe_A1B_hadcm3q0_monthly_from_01-01-2011_to_31-12-2013_near_Aiguelongue, Montpellier, France) gives 15.72°C and 977mm for the same period

5 Experimental design

5.1 Conceptual design

The design involves three sites, with two or three shading treatments and a different number of varieties in each site (Table 2), and the measurements are described in Section 5.

5.2 Description of design

The layout of the farmer's field is illustrated in Figure 7. The layout at Restinclières is shown in Figure 8. The layout at the INRA Experimental Station is presented in figures 9, 10 and 11.

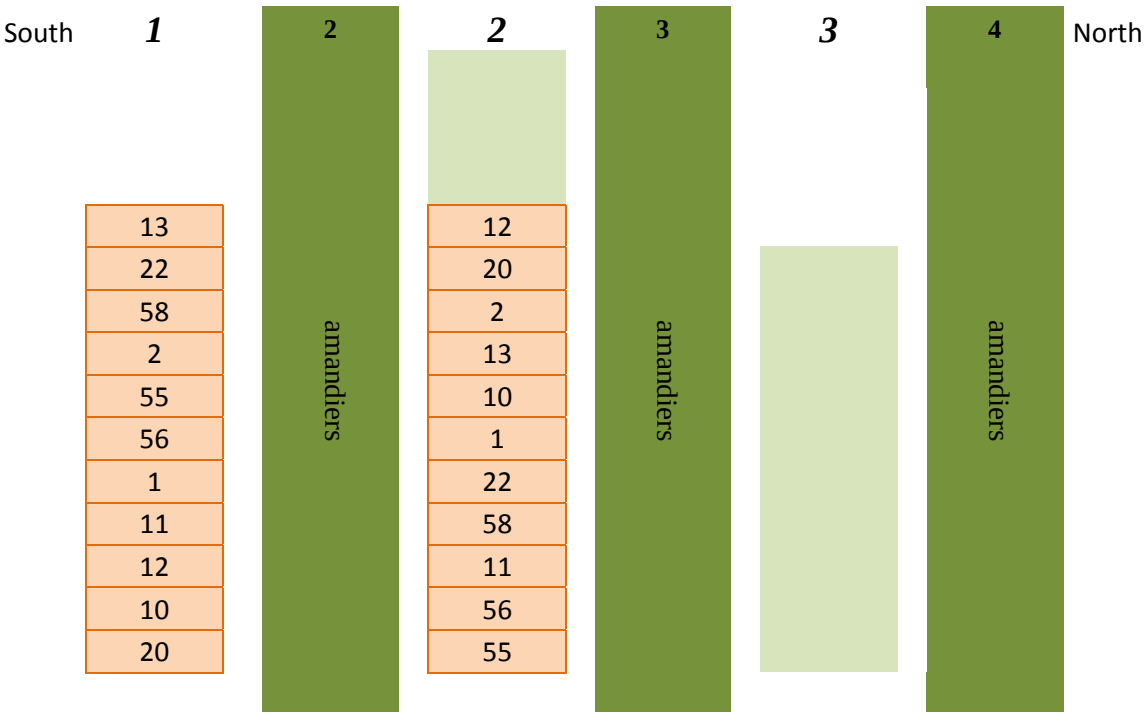

Figure 6. Schematic layout of the farmer's field

Table 1. Number of repetitions for each variety/shade condition in each site

Variety code	Farmer's field		Restinclières estate		INRA experimental station			Total
	Full light	Almond Shade	Sorb Full light	Poplar Shade	13B Dense shade	15A Shade	15B Full light	
1	1	1	3	3	2	2	2	14
2	1	1	3	3	2	2	2	14
3						2	2	4
4						2	2	4
5						2	2	4
6						2	2	4
7						2	2	4
8			3	3		2	2	10
9						2	2	4
10	1	1	3	3	2		2	12
11	1	1	3	3	2	2	2	14
12	1	1			2	2	2	8
13	1	1	3	3	2	2	2	14
14			3	3				6
20	1	1			2		2	6
22	1	1						2
23			3	3				6
38			3	3		2	2	10
40						2	2	4
43						2	2	4
47						2	2	4
50						2	2	4
52						2	2	4
53			3	3		2	2	10
54			3	3	2	2	2	12
55	1	1			2	2	2	8
56	1	1			2	2	2	8
57						2	2	4
58	1	1				2	2	6
88			3	3				6
Total	**11**	**11**	**36**	**36**	**20**	**48**	**52**	**214**

Restinclières:

field (North-East)	entrance	seeder pass A	seeder pass B	seeder pass C	seeder pass D	seeder pass E	seeder pass F	1 tree=6m
tree row #4		1.55m	1.55m	1.55m	1.55m	1.55m	1.55m	tree row #5
tree 1		1	2	11	fill-up	fill-up	fill-up	missing
missing		fill-up	fill-up	fill-up	fill-up	fill-up	fill-up	missing
tree 3		23	88	8	10	38	53	tree 3
tree 4		fill-up	fill-up	fill-up	13	54	14	tree 4
missing		8	10	38	53	1	2	tree 5
tree 6		11	13	54	14	23	88	tree 6
tree 7		38	53	1	2	11	13	tree 7
tree 8		54	14	23	88	8	10	tree 8
small tree 9								missing
small tree 10								small tree 10
				30 m fill-up				missing
								tree 12
zone 1 (6m)		1	2	11	13	54	14	zone 1
zone 2		23	88	8	10	38	53	zone 2
zone 3		8	10	38	53	1	2	zone 3
zone 4		11	13	54	14	23	88	zone 4
zone 5		38	53	1	2	11	13	zone 5
zone 6		54	14	23	88	8	10	zone 6
				175 m fill-up				

Figure 7. Schematic layout of the farmer's field

INRA Experimental Station Field 13B

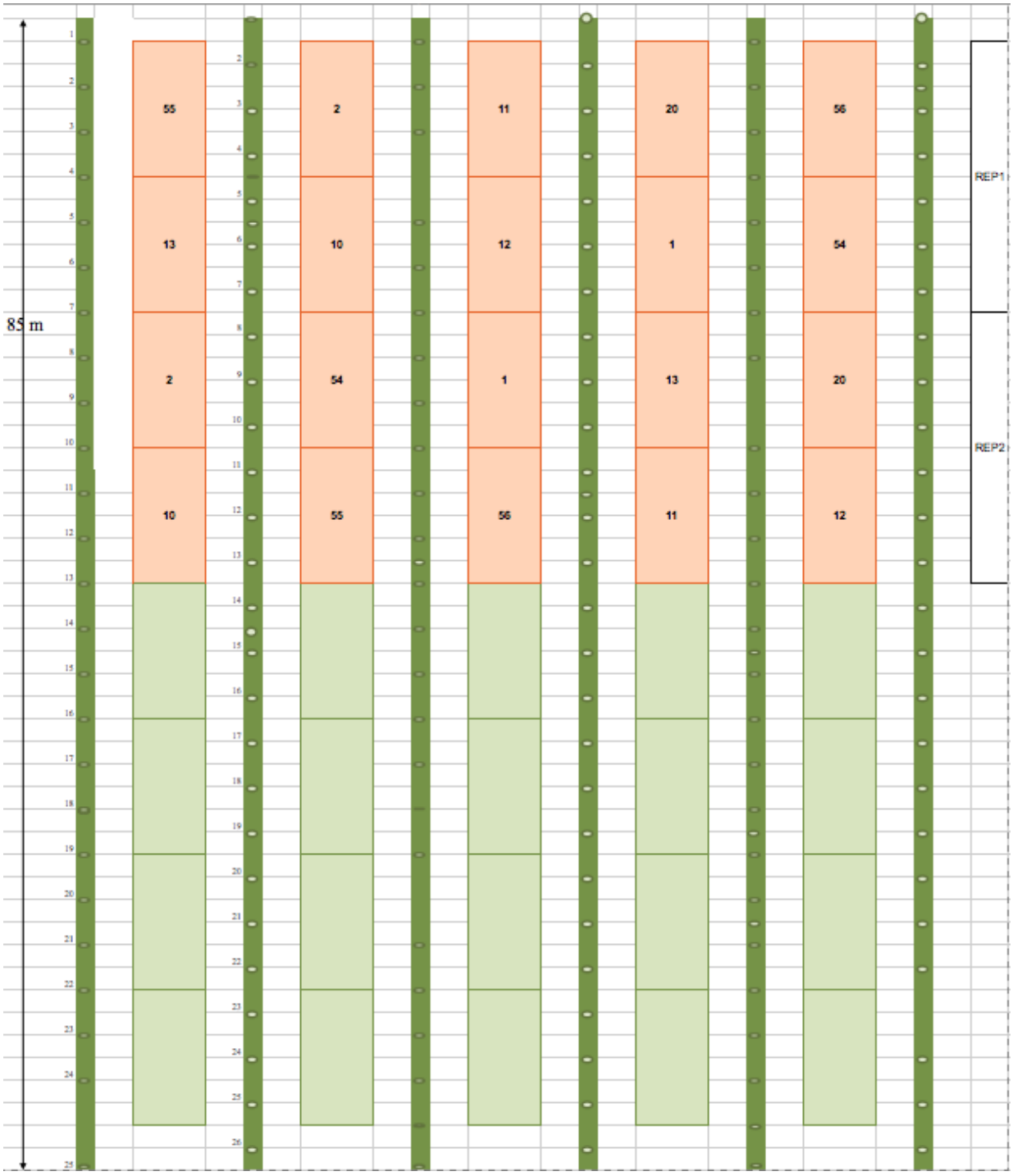

Figure 8. Schematic layout of Field 13B at the INRA Experimental Station Field 13B

INRA Experimental station Field 15A

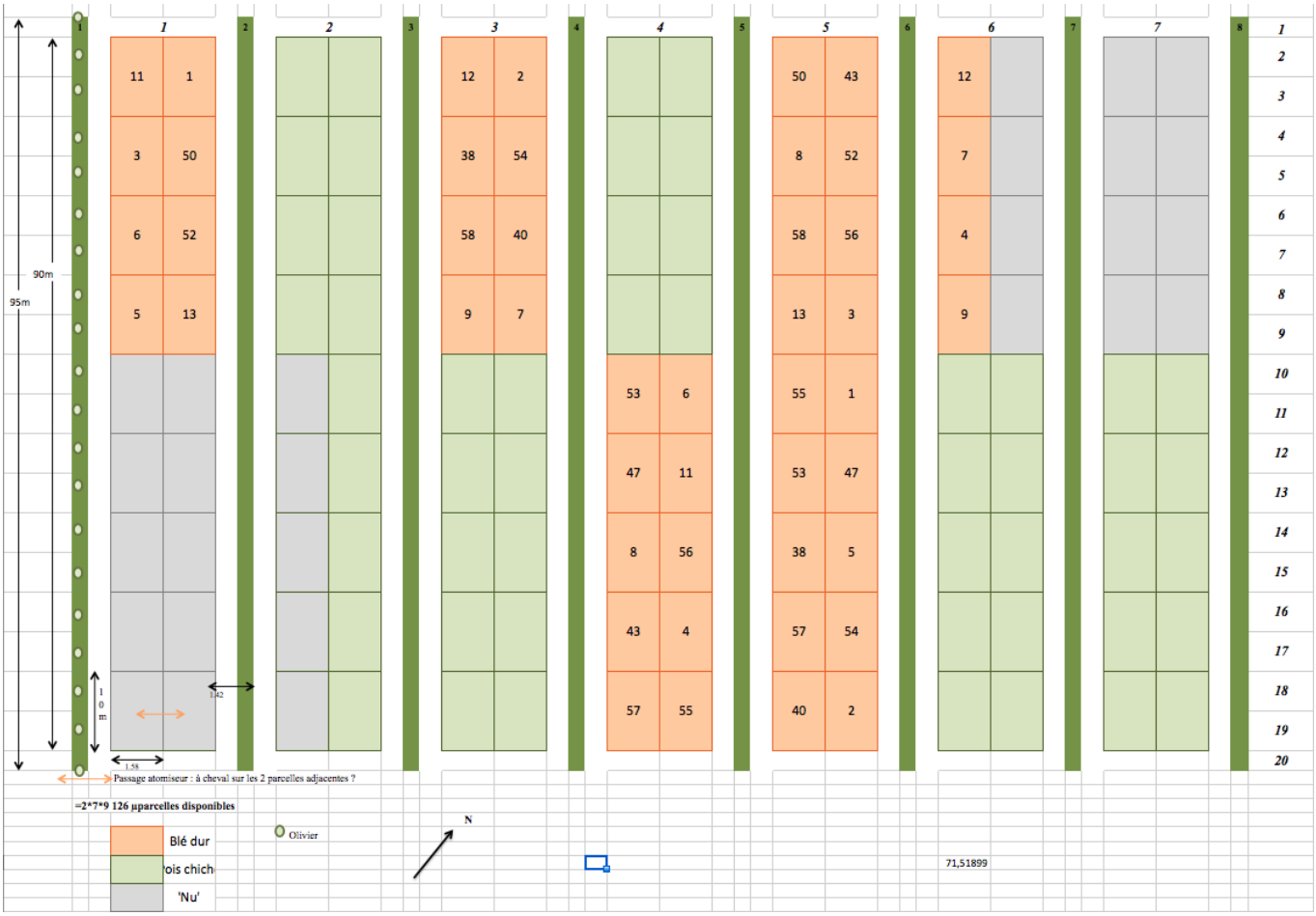

Figure 9. Schematic layout of Field 13B at the INRA Experimental Station Field 15A

INRA Experimental station Field 15B

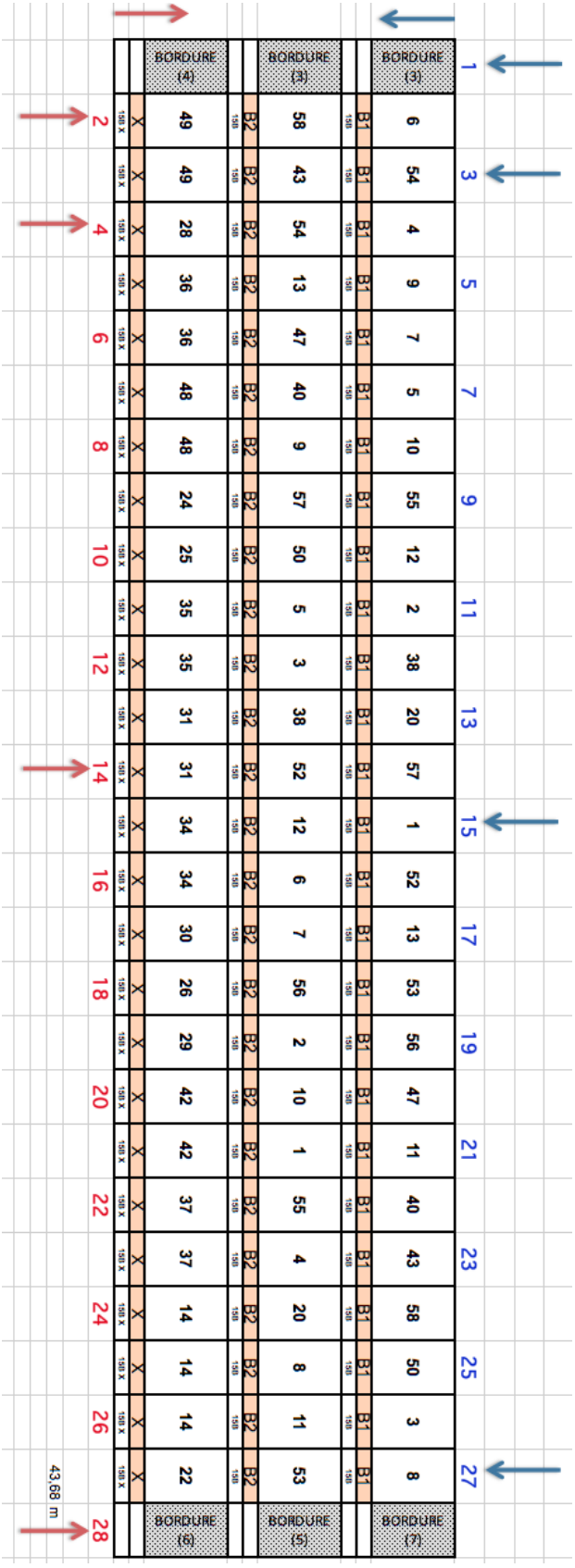

Figure 10. Schematic layout of Field 13B at the INRA Experimental Station Field 15A

6 Measurements

The measurements to be taken are described in Table 3.

Table 3. Description of the measurements to be taken.

Component	Description of measurements
Plants	• seedling emergence nb / m2 • nb plants / m2 at the end of winter • growth in height of plants every week until flowering • monitoring of phenological stages • number of tillers per plant • estimation of chlorophyll content • number of ears per plant • number of grains per spike • 1000 kernel weight • machine and / or quadrat (1m2) yield • harvest index?
Trees	• bud break dates of poplars, Sorb and almond trees
Climate	• hemispherical photographs to be done in the center of each microplot once before and once after budbreak of trees or pruning of olive trees • temperature and radiation measured continuously along a transect in each shadine condition • radiation measurements at the center of each microplot to be done at growth stage Z30 of the reference variety in full light, at Z55 and then each week until harvest.

7 Acknowledgements

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8 References

Gosme M (2014). Initial Stakeholder Meeting Report: Mediterranean Silvoarable Systems in France. 8 October 2014. 12 pp. Available online: http://www.agforward.eu/index.php/en/mediterranean-silvoarable-systems-in-france.html