System Report: Durum Wheat Production in Agroforestry Systems in France

Project name	AGFORWARD (613520)
Work-package	4: Agroforestry for arable farmers
Specific group	Mediterranean silvoarable systems, France
Deliverable	Contribution to Deliverable 4.10 (4.1): Detailed system description of a case study system
Date of report	18 January 2016
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Contents

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 Objective 2, Deliverable 4.10: "Detailed system description of case study agroforestry systems". The detailed system description includes the key inputs, flows, and outputs of the key ecosystem services of the studied system. It covers the agroecology of the site (climate, soil), the components (tree species, crop system, management system) and key ecosystem services (provisioning, regulating and cultural) and the associated economic values. The data included in this report will also inform the modelling activities which help to address Objective 3.

2 Background

In Mediterranean climate, a strong constraint for agriculture is the temporal heterogeneity of rainfall, with periods of water shortage in the spring and summer, and high rainfall in autumn. Under certain conditions, silvoarable agroforestry (tree lines within the field) could alleviate this problem by improving water infiltration, and limiting soil evaporation and crop water use under the shade of trees.

Ideal soil requirements for agroforestry include i) deep soils that will do not constrain the deep rooting of trees, ii) high soil water holding capacity to limit water competition between trees and crops, and iii) no soil salinity, which would otherwise reduce the choice of tree and crop species. Given these requirements, the potential for agroforestry in the Languedoc-Roussillon region has been estimated at 280 000 ha, including 132 000 ha in arable systems (Figure 1) (Cardinael, 2011).

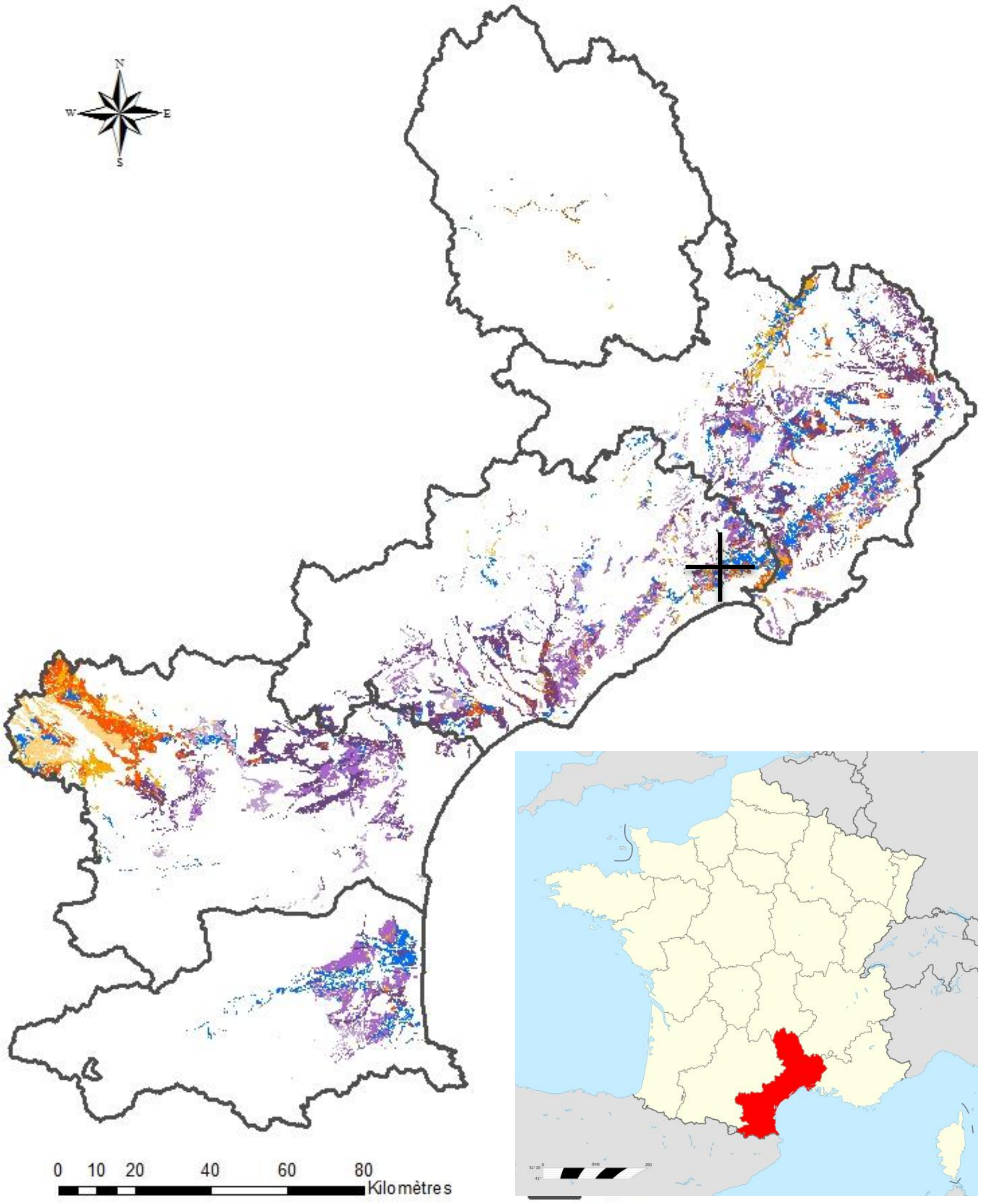

Figure 1. Map of potential areas suitable for agroforestry systems in the Languedoc-Rousillon administrative region, based on both soil characteristics (salinity, depth, water holding capacity), and current land use (meadows, arable land, vineyards). Green: meadows, orange: arable land, purple: vineyard, blue: mixed systems. Source: Cardinael (2011). The cross indicates the location of the experimental site.

3 Update on field measurements

The initial screening of durum wheat varieties was completed in 2014-2015 (Gosme and Desclaux, 2015) under poplars or under the minimal shading conditions of the Sorb tree plots. (Although the sorb trees had been planted, the amount of shading was restricted to a single tree (less than 3 m in height) as most trees failed due to poor adaptation of the species to the soil. The experiment was repeated in 2015-2016 in a neighbouring plot under ash trees or under the minimal shading conditions of the Sorb tree plots. Different varieties were chosen during the two years, although a few common varieties were included to allow data comparison between years.

4 System description

Table 1 provides a general description of the silvoarable agroforestry system. A description of a specific case study system is provided in Table 2.

Table 1. General description of the silvoarable agroforestry system

General description of system	
Name of group	Screening of durum wheat varieties in agroforestry in Southern France
Contact	Marie Gosme
Work-package	4: Agroforestry for arable farmers
Associated WP	None
Geographical extent	Currently, agroforestry is almost absent from the Languedoc-Roussillon region (the fact that this region did not adopt the agroforestry measure of the CAP 2007-2013 is probably related to this low uptake rate). However Cardinael (2011) reported that 47% of the arable land in the region had deep soils with a good water holding capacity which could be suitable for agroforestry. Although the current area under agroforestry is very low, the capacity for expansion on arable land is estimated to be up to 132 000 ha.
Estimated area	The area under agroforestry in the experimental site is 35 ha.
Typical soil types	The arable land on the Restinclières Estate comprises silty deep alluvial fluvisols containing 25% clay and 60% silt
Description	Timber trees aligned in rows within arable fields. The distance between rows must be adapted to the width of the machinery to allow normal agricultural operations.
Tree species	Poplar (*Populus spp*), walnut (*Juglans nigra x regia*), sorb (*Prunus domestica*), ash (*Fraxinus excelsior*), maple (*Acer spp),* hackberry (*Celtis australis*) and wild pear tree (*Pyrus pyraster*)
Tree products	Timber wood
Crop species	Cereals, alfalfa, common beans
Crop products	Grains, fodder, pulses
Animal species	none
Animal products	none
Other provisioning services	Possibility for intercrops with aromatic plants
Regulating services	Trees provide a microclimate which buffers daily temperature variations and protects from extreme values of temperature, which may increase the quantity of harvest by protecting crops against drought, but may also improve the quality of harvest production by protecting crops against thermal stresses. Trees can promote nutrient cycling, increase carbon storage, and reduce nitrogen leaching in autumn-winter.
Habitat services and biodiversity	Many animal species can use the trees and the herbaceaous vegetation on the tree lines for habitat resulting in increased biodiversity. as well as the herbaceous diversity on the tree lines.
Cultural services	Herbaceous vegetation on tree lines can host patrimonial vegetation. Trees contribute to landscape amenities.
Key references	(Andrianarisoa et al., 2016; Cardinael et al., 2015)

Table 2. Description of the specific case study system (two different plots in the harvest year 2015 and harvest year 2016)

Specific description of site	
Area	2 (shade vs sun) x 3 reps x 12 varieties x (1.55mx6m in 2015 or 1.55m x 7m in 2016)
Co-ordinates	43°42'54.4"N 3°51'12.9"E (B17 plot) 43°42'43.0"N 3°51'28.3"E (A6 plot)
Site contact	Lydie Dufour
Site contact	dufourl@supagro.inra.fr
Example photograph	 Figure 2. Plot B17: Wheat under poplars in the foreground with wheat in full sun in the background (17 June 2015)  Figure 3. Plot A6: soil preparation before sowing, the tractor is below the ash trees, where the agroforestry plots will be located, the two trees in the foreground (right-hand side) are wild cherry trees, and the "full sun" plots will be located in the gap between the last wild cherry and the first ash tree (23 October 2015)

Map of system	 Figure 4. Aerial photograph of the B17 plot, the black squares indicate the location of the experimental plots (under poplars/in full sun).  Figure 5. Aerial photograph of the A6 plot, the black squares indicate the location of the experimental plots (under ash trees/full sun).

Climate characteristics	
Mean monthly temperature	14.2 °C
Mean annual precipitation	851 mm
Details of weather station	Data from 2011-2013 (Campbell station on site)
Soil type	
Soil type	Silty deep alluvial fluvisol
Soil depth	Deep
Soil texture	Silty clay limestone
Additional soil characteristics	Carbonated soil
Aspect	Flat
Tree characteristics	
Species and variety	The screening of durum wheat varieties was performed in two different plots (B17 in 2015, A6 in 2016). In each of these two plots, part of the plot is planted with trees (poplars in B17, ash trees in A6). In the arable location at Restinclières the establishment of sorb trees has been poor; after 20 years, the trees are still less than 3 m high.
Date of planting	1995
Intra-row spacing	6 m
Inter-row spacing	13 m
Tree protection	None
Crop understory characteristics	
Species	Durum wheat (*Triticum turgidum* L. subsp. durum (Desf.) Husn.)
Management	Conventional arable crop management with ploughing
Typical crop yield	Farmer's yield: 4.5 t/ha. The yield with the selected durum varieties was generally lower because of the use of old varieties.
Fertiliser, pesticide, machinery and labour management	
Fertiliser	No fertiliser in 2015, ammonium nitrate + sulphur in 2016
Pesticides	No pesticide in 2015 harvest year, herbicide (Athlet, 3.6 L/ha) on 13 November 2015 for the 2016 harvest year
Machinery	Need for tractor access in crop alleys to allow soil preparation, sowing , phytosanitary treatments and harvesting
Manure handling	None
Labour	Normal practices
Fencing	None

5 Description of tree component

In plot B17, the poplars were planted in 1999 (to replace *Paulownia tomentosa*, which had died because of the cold), both the Sorb and ash trees were planted in 1995 . Tree rows are 13 m apart and trees spacing within the row is 6 m.

6 Description of crop component

Twelve durum wheat varieties (old varieties taken out of the genebank maintained by INRA + 1 or 2 "control varieties") were tested each year. In 2015, the control variety was LA1823, a variety recently created for organic farming; in 2016, the control varieties were LA1823 and Claudio (the variety usually used by the farmer). Sowing density was 350 seeds m^{-2}. Sowing was completed on 12 January 2015 (because of floods that prevented sowing in autumn) and 2 November 2015. Harvest was completed on 30 June 2015. The next harvest is scheduled for June 2016. No fertilizers nor pesticides were applied in 2015. The growing season was shorter than normal, because the sowing was later compared with other wheat plots of the farmer. For the 2016 growing season, herbicide Athlet (bifénox + chlortoluron; 3.6 l ha^{-1}) was applied manually on 13 November 2015. Fertilizer (ammonium nitrate 60 kg ha^{-1}) was applied on 12 January 2016.

7 Results

Measurements of crop growth (growth stage, height, LAI, green leaf area) were taken during the season and at harvest (number of tillers per square meter, number of spikes per tiller, number of grains per spike, grain weight). Microclimate variables were also monitored (air temperature, radiation, air humidity and, in 2016, soil temperature and soil humidity).

In 2015, severe weed infestation drastically reduced yield. The mean grain yield (15% moisture content) was 42.3 g m^{-2} in the unshaded treatment and 54.5 g m^{-2} under the poplars i.e. 29% higher under the poplars than in the sun. Poplars had a strong effect on microclimate the temperature was warmer during the night and cooler during the day under the poplars (Figure 6).

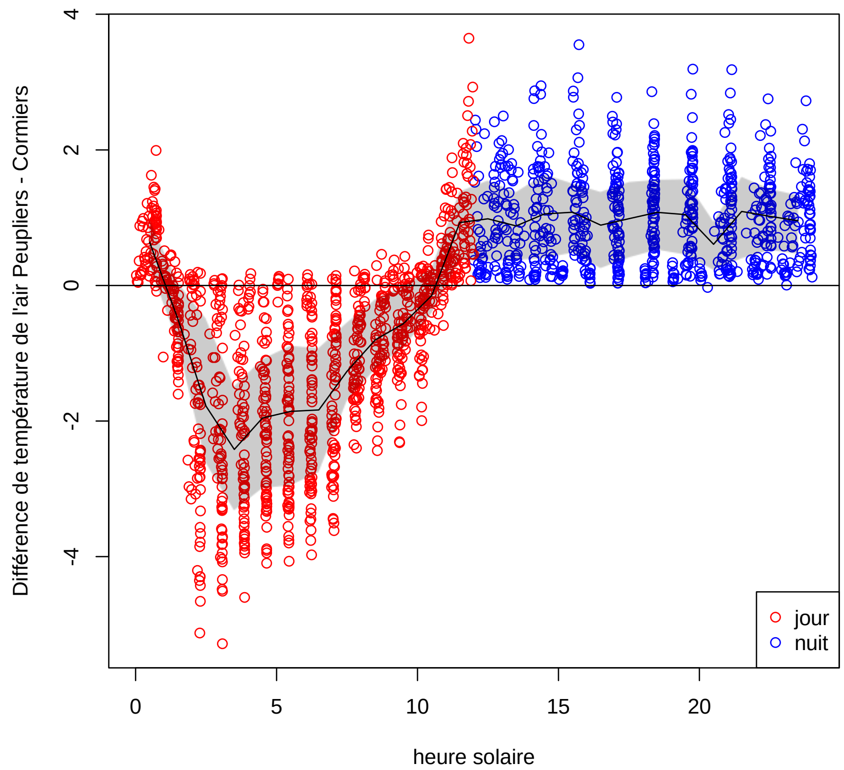

Figure 6. Difference in air temperature (°C) between the poplars and the full sun as a function of "solar hour" (0=sunrise, 12=sunset). Blue points: observations during the night, red points: observations during the day. The black line indicates the median, the grey zone indicates the 25 and 75% percentiles.

Because of the contrasting effect of the trees on night-time and day-time temperature, the effect of the trees on the mean daily temperature was very limited (Figure 7).

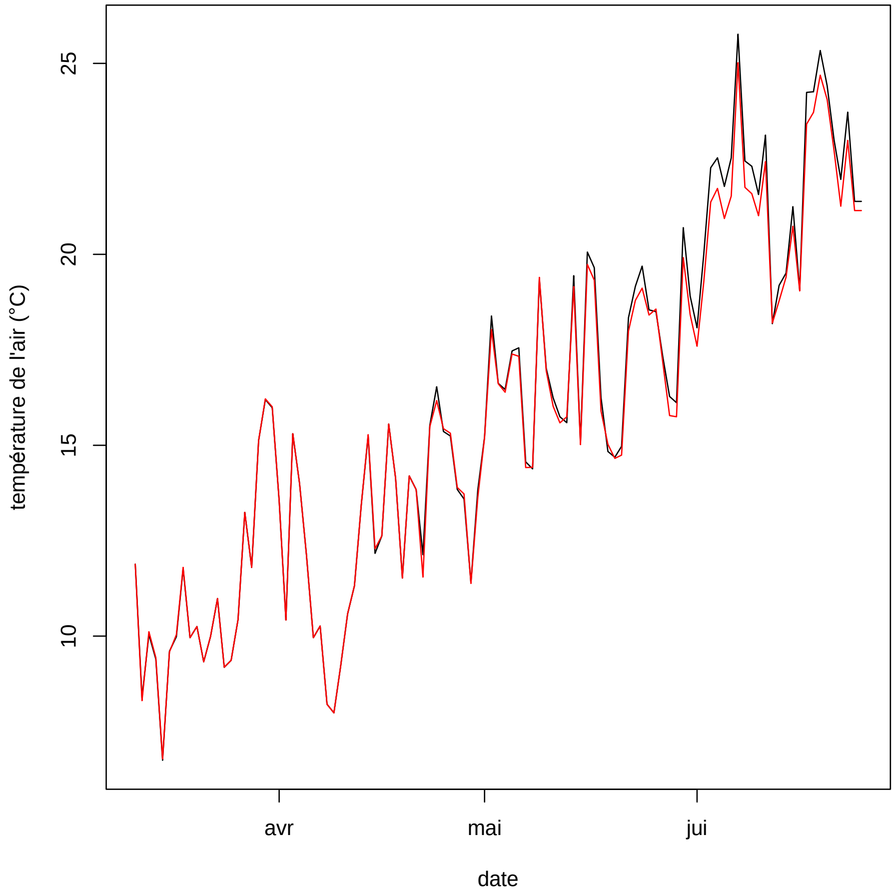

Figure 7. Daily mean air temperature (°C) as a function of time (avr= April, mai=May, jui=June) under the poplars (red) and in the sun (black)

The effect of the trees on light availability was more apparent (Figure 8). During the period when the sensors were in the field from 30 March 2015 to 25 June 2015, the light availability under the poplars was 40% of that in the sun (Figure 8).

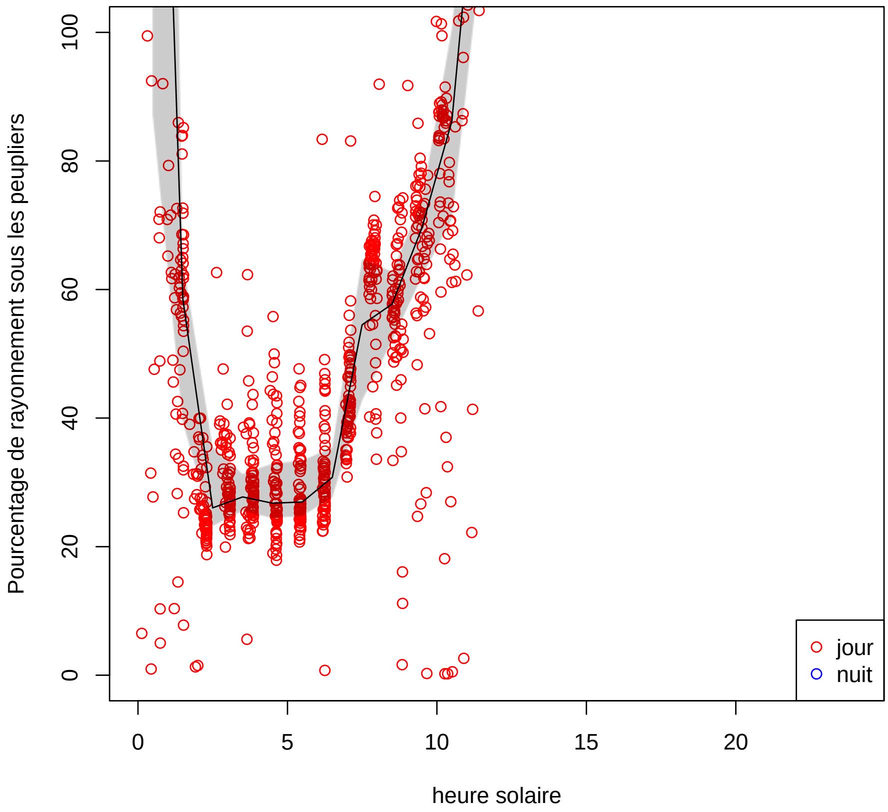

Figure 8. Proportion of light received under the poplars. The black line indicates the median, the gray zone indicates the 25 and 75% percentiles.

The wheat under the poplar reached Zadok's GS30 (1 cm head) quicker than the wheat in the full sun. However after 28 May 2015, the development of wheat under full sun was more advanced, and maturity was reached 2 weeks earlier in the sun than under the poplars (Figure 9). Plants were taller under the poplars than in the sun. The Leaf area index and green leaf area measurements require careful interpretation as the measures did not differentiate between the wheat and weeds.

In general the yield components did not vary between the wheat below the poplars and those in full sun, however some varieties performed better under the poplars than in the sun (Table 3).

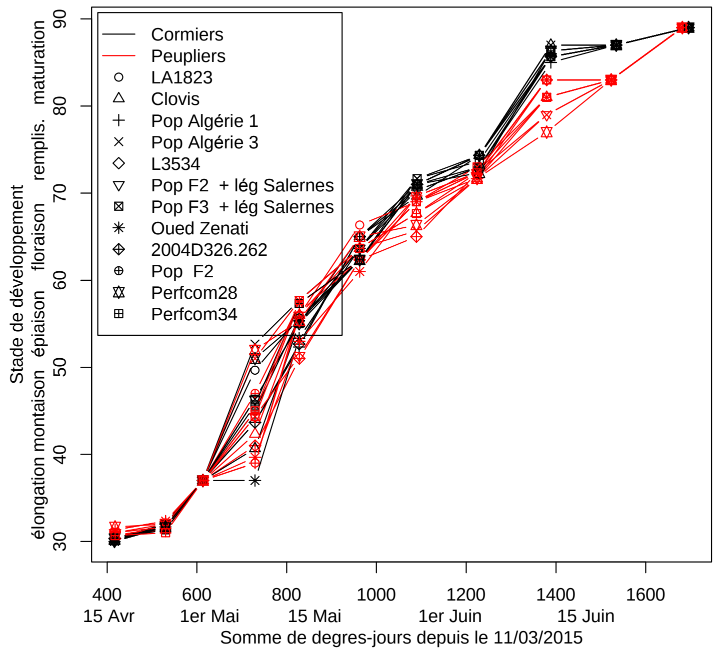

Figure 9. The seasonal change in the growth stage (Zadok's scale) as a function of growing degree days (superposed with calendar date) for the 12 varieties of wheat grown under the poplars (red) and in the sun (black).

Table 3. Significant differences measured for selected genotypes grown under poplars vs full sun

Component	Genotype	pvalue	Mean under poplars	sign	Mean in full sun
Harvest index	Pop Algérie 1	0.045	0.227	>	0.151
	Pop F2	0.031	0.341	>	0.243
	Perfcom28	0.018	0.365	>	0.243
Plants m^{-2} at end of winter	Perfcom34	0.043	174	>	142
Tillers m^{-2} at flowering	Perfcom28	0.006	196	>	117
Heads m^{-2} at flowering	Clovis	0.048	138	>	79
	Pop F2 + lég Salernes	0.038	119	>	67
	Perfcom28	0.018	153	>	69
Heads m^{-2} at harvest	Pop Algérie 1	0.042	149	>	44
	Perfcom28	0.035	117	>	51
	Perfcom34	0.023	157	>	69
Grains m^{-2}	Pop Algérie 1	0.010	1362	>	412
Weight (g) of 1000 grains	Perfcom28	0.004	38	>	30
Grains per ear	Oued Zenati	0.039	6.8	<	17.0
Grain yield (g m^{-2})	Pop Algérie 1	0.009	54.7	>	13.6
Grain yield (g m^{-2})	Perfcom28	0.026	52.6	>	21.7

The effects of treatment on heads per tiller and tillers per plant were not significant.

8 Acknowledgements

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9 References

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