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Published Version:

Alexopoulou, E., Zanetti, F., Scordia, D., Zegada-Lizarazu, W., Christou, M., Testa, G., et al. (2015). Long-Term Yields of Switchgrass, Giant Reed, and Miscanthus in the Mediterranean Basin. BIOENERGY RESEARCH, 8(4), 1492-1499 [10.1007/s12155-015-9687-x].

Availability:
This version is available at: https://hdl.handle.net/11585/545200 since: 2019-08-07

Published:

DOI: http://doi.org/10.1007/s12155-015-9687-x

Long-term yields of switchgrass, giant reed and miscanthus in the Mediterranean basin

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Abstract

Uncertainty in predictions of long-term yields of perennial grasses makes business plans untenable in the short run. Long-term data across varied environments, including marginal lands, will help in preventing uncertainty while providing farmers and entrepreneurs with sound information to estimate reliable and affordable strategies on what, where and how long to grow perennial grasses. In the present study, the long-term yields (11 to 22 years) of switchgrass (*Panicum virgatum* L.), miscanthus (*Miscanthus* × *giganteus* Greef et Deuter) and giant reed (*Arundo donax* L.) grown in northern and southern Mediterranean environments are reported. Switchgrass was grown in Greece and northern Italy, giant reed in southern and northern Italy, and miscanthus in southern Italy. Furthermore, lowland and upland switchgrass ecotypes were compared in Greece. Despite similar biomass productions (9.8 and 10.0 Mg DM ha^{-1} for uplands and lowlands, respectively), the upland ecotypes showed a significantly higher yield stability (CV of 24% and 32% for uplands and lowlands, respectively) over a 17-year period. Biomass yield varied considerably across years and locations; giant reed outperformed switchgrass under northern Italy environment (21.2 and 13.6 Mg DM ha^{-1} for giant reed and switchgrass respectively). Annual yield of switchgrass was 30% higher in the north than south Mediterranean; miscanthus showed intermediate production compared to giant reed and switchgrass (average of 22 years) and a CV similar to switchgrass. In summary these results evidence that multi-location, long-term trials are strongly needed to reduce uncertainties on crop yield variability and provide more accurate data from which optimized socio-economic and environmental predictions can be achieved.

Keywords: Marginal land, biomass crop, biofuel, bioeconomy, yield prediction models

Introduction

Switchgrass (*Panicum virgatum* L.), miscanthus (*Miscanthus* × *giganteus* Greef et Deuter) and giant reed (*Arundo donax* L.) are attractive feedstocks to produce advanced biofuels or bio-based products because of their high biomass yields and cellulose/hemicellulose composition. They are also recognized for providing substantial environmental benefits in term of greenhouse gas savings, soil erosion mitigation, soil fertility, and increased biodiversity [1–3]. Moreover, being perennial biomass grasses successfully grown on marginal or degraded lands, controversies over competing land-use for food would be allayed [4–7].

From the beginning of the 1990's, several European projects (Miscanthus productivity networks, Giant reed network, Switchgrass for Energy, Bioenergy Chains, 4FCROPS, EUROBIOREF, etc.) addressed miscanthus, switchgrass and giant reed for energy or biorefinery purposes. The current EU research project OPTIMA (www.optimafp7.eu) was inspired by the aforementioned projects with the aim to provide insights into perennial grasses grown on marginal lands in the Mediterranean area. In this regard, long-term trials established in previous EU research projects were used.

Marginality of Mediterranean lands mostly concerns water scarcity and salt and/or nutrient stresses. Water availability is the most significant constraint to spring-summer crop production. This is particularly true in semi-arid Mediterranean type climates (e.g. southern Europe), due to both low annual rainfall and/or its irregular distribution during the year and from year to year. Perennial grasses, like other common crops, their yields varied considerably in response to climatic conditions, crop management, experiment type and stand age [8–16]. Such variation is exacerbated when they are grown under rainfed conditions in Mediterranean areas [15, 16]. Nonetheless, little is known about long-term yield across different environments, including marginal lands. In a persuasive review on biomass crop models [17], the authors concluded that detailed information on biomass production is scarce, and considerable work remains regarding the parameterization and validation of process-based models for bioenergy crops. Therefore, high-quality and representative field data are imperative for reliable, high-resolution and efficient simulations of biomass production. On the other hand, long-term agricultural studies are difficult to find and very few studies on long term yields of perennial grasses have been published, mostly due to the limited duration of research projects (generally 3–4 years), while the putative lifetime of these crops is much longer. Furthermore, most of these studies refer to one location [12–14, 18] and very few compare different species in variable environments [10, 11, 19]. Moreover, as switchgrass, miscanthus and giant reed are not yet grown on a commercial scale, a solid database is far from exhaustive, while the majority of results derives from plot and various experiments whose results are difficult to compare [10,11], since adopted experimental protocols are different and not always reported in detail.

In the present study, we report the long-term productivity (11 to 22 years) of switchgrass, miscanthus and giant reed grown under low input in Mediterranean North and South [20], with the aim of providing insights into the bioenergy and biorefinery industry's planning and forecasting processes. This study will provide a clearer picture of the real potential of these crops in southern Europe under low input management (i.e., rainfed and unfertilized conditions).

Materials and Methods

Four long-term (11, 17, 18 and 22 years) field trials were carried out in central Greece (Aliartos), northern Italy (Bologna) and southern Italy (Catania) (Table 1). Soil characteristics of the three locations are reported in Table 2. Meteorological characterization was performed in the three locations between 2005 and 2014 (common years, not including the establishment year), according to Monti and Venturi [21], in order to compare yearly rainfall patterns of different locations (uneven rainfall distribution - U_R [21]) in the whole year or within the crop maximum development growing season (March-October). This approach was chosen in order to better evidence differences among locations, since the only rainfall amount would partially mask environmental effects on crop growth. Air temperature was also monitored in all locations.

Plantations

Mediterranean South (Greece)

In 1998, at the beginning of the EU project 'Switchgrass for Energy' (www.switchgrass.nl), five switchgrass ecotypes—Alamo, Pangburn, Kanlow (lowland ecotypes), Blackwell and Cave-in-Rock (upland ecotypes)—were manually seeded [1.04 g m^{-2} of pure live seeds (PLS), 0.13 m row spaced] in central Greece, in a low fertility sandy loam soil previously left for more than 20 years as fallow land (Table 2). Before sowing, 33 kg ha^{-1} of P and 83 kg ha^{-1} of K were applied. Switchgrass was irrigated about once a week in the establishment year, while from the second year onwards, about three watering were performed in the period May to July. Weed control was necessary only in the establishment year. Harvest was carried out in wintertime (January–February). Aboveground biomass was determined on a sampling area of 12 m^2 per plot; biomass sub-samples were collected and oven-dried at 105 °C until constant weight for dry matter determination.

Mediterranean South (southern Italy)

Miscanthus and giant reed were grown on a typical sandy-clay-loam soil (Table 2) at the experimental farm of the University of Catania (south Italy). Micro-propagated miscanthus plants, provided by Piccoplant (Oldenburg, Germany), were transplanted in summer 1993 (4 plants m^{-2}) and weekly irrigated (80 mm in total) to guarantee the desired plant density. Irrigation was also applied in summertime 1994 and 1995, about every 20 days (215.5 and 76.5 mm, respectively) to sustain crop growth. Subsequently, irrigation was not applied.

Giant reed plantlets were produced in summer 1996 from stem cuttings of the local ecotype "Fondachello", and transplanted manually in spring 1997 at a density of 2.5 plants m^{-2}. Irrigation was applied after transplant and only during the first summertime in order to guarantee a successful establishment. In both trials, autumn ploughing followed by spring disc-harrowing was performed before transplant. Mechanical weeding was also performed in the first year only. No fertilization was applied; neither at transplant nor in subsequent years in both species. The detailed methodology of the two trials is reported elsewhere [15, 16].

Harvest was carried out in wintertime (between January and February). Aboveground biomass yield was determined on a sampling area of 20 m^2 per plot; biomass sub-samples were oven-dried at 105 °C until constant weight for dry matter determinations.

Mediterranean North (northern Italy)

Switchgrass (variety Alamo) and giant reed were compared in an 11-year (2004–14) side-by-side trial located in northern Italy (Bologna) in the Po Valley. Climate is characterized by cold humid winters and hot summers. Soil was classified as silty loam (Table 2).

Seedbed preparation was disc-ploughing, harrowing and rotary cultivator. Phosphate (44 kg ha^{-1}) was applied before seeding/transplanting; fertilizers were not applied from the second year onward. Switchgrass was seeded in May 2004 at a density of ~0.4 g PLS m^{-2}, 0.48 m row-spaced. Irrigation was used only in the first year: three applications (25 mm each) were made during the establishment and three others (30 mm each) from June to July. Giant reed plantlets (provided by the University of Catania) were manually transplanted (1 plant m^{-2}) in July 2004. Irrigation was applied after transplant in order to ensure a successful stand. Chemical and/or mechanical weeding was necessary on both species only in the first year. Harvest was carried out in wintertime (January–February). The aboveground biomass was determined on a sampling area of 6 m^2 per plot; dry matter content was measured on biomass sub-samples of approx. 500 g oven-dried at 105 °C until constant weight.

Statistical analysis

One-way ANOVA was performed to compare biomass yields of switchgrass and giant reed in northern Italy (Bologna), and lowland and upland switchgrass ecotypes in Greece (Aliartos)~~.~~ Given the different establishment year of perennial grasses in and among locations, one-way analysis of covariance (ANCOVA) was used. Fisher's LSD test ($P \leq 0.05$) was used to separate means. The

Shapiro–Wilk test was developed to test residuals for normality. Coefficients were considered significant when *P*-value was ≤0.05. All analyses were run with XLSTAT's (AddinSoft SARL).

Results

Meteorological characterization of the three sites

Although the three sites are located in Mediterranean area, differences were evident between north and south Mediterranean in terms of mean temperature, mean rainfall and rainfall distribution (Table 3). Southern Italy (Catania) was the warmest site (17.7±0.4 and 20.4±0.7 °C, mean annual and growing season temperatures, respectively), while northern Italy (Bologna) the coldest (13.4±0.6 and 17.8±0.6 °C, respectively). Greece (Aliartos) had the lowest precipitation rate (485±108 and 218±42 mm annual and growing season means, respectively). Northern and southern Italy did not differ in the annual amount of rainfall (Table 3), but rainfall patterns varied considerably: within the growing season (March to October) the north (Bologna) had almost 30% more rain than the south (Catania), which showed the most uneven distribution among the three sites (significantly higher U_R), while Bologna presented the most regular pattern (lower U_R). Year to year rainfall variation was more pronounced in southern Italy than Greece and northern Italy.

Long term productivity of switchgrass, miscanthus and giant reed

Seventeen-year dry biomass yields of switchgrass ecotypes grown in Greece (Aliartos) are shown in Figure 1a. Lowlands and uplands performed similarly in terms of biomass yield, with the exception of the second year in which lowlands outperformed uplands ($P \leq 0.05$). Despite similar biomass yields of lowlands and uplands (10.0 and 9.8 Mg DM ha^{-1}), the coefficient of variation (CV), which accounts for yield stability, was clearly higher in the uplands (32% vs. 24% for lowland ecotypes).

Miscanthus and giant reed were compared in southern Italy (Catania, Fig. 1b). Miscanthus required a shorter period than giant reed to reach ceiling yields, however giant reed showed slightly higher potential yield in the long term. It is worth noting that, unlike giant reed, miscanthus was irrigated for three consecutive years, which explains the faster yield ceiling of miscanthus (3rd year) compared to giant reed (7th year). After yield ceiling, relatively stable yields were observed in giant reed for 16 years; miscanthus showed a significant decrease of biomass yield after 5 years, then fluctuating yields for 14 years before a visible decline of productivity. Mean annual biomass production of miscanthus and giant reed were 13.3 and 15.7 Mg DM ha^{-1}, respectively. Yield stability was slightly higher in giant reed than miscanthus (CV 28% and 31%, respectively).

Side-by-side comparison of switchgrass (ecotype Alamo) and giant reed in north Italy (Bologna) is shown in Figure 1c. Aside from the establishment year, in which productivity of switchgrass was clearly higher than giant reed (6.2 and 2.4 Mg DM ha^{-1}), two periods could be distinguished: i) year 2 to 7, in which switchgrass and giant reed produced similar amount of biomass; ii) year 8 to 11, in which giant reed clearly exceeded switchgrass (about 50% more biomass per year). Thus, in the long term, giant reed resulted in a clearly higher productivity than switchgrass (21.2 and 13.6 Mg DM ha^{-1}yr^{-1}, respectively), while yield stability of the two crops was quite similar (CV of 34% and 37% for giant reed and switchgrass, respectively).

Site effects on long-term productivity of switchgrass and giant reed

Since switchgrass (ecotype Alamo) and giant reed were grown either in Mediterranean South (switchgrass in Greece and giant reed in southern Italy) or in Mediterranean North (both species in northern Italy), local effects on biomass productivity and stand longevity can be discussed (Figs. 2 and 3).

Mean annual yield of switchgrass was significantly (P=0.039) higher in the north than in the south (13.6 vs. 10.6 Mg DM ha^{-1}) (Fig. 2). The yield stability was also higher (CV 37%) in north than south (48%), which might reflect the even rainfall distribution in the north during the growing season. The considerably higher biomass yields of switchgrass in Greece in the establishment year (14.0 and 6.2 Mg DM ha^{-1}, Greece vs. northern Italy, respectively) were likely due to a two-fold plant density adopted.

Giant reed was grown in northern (Bologna) and southern Italy (Catania) (Fig. 3). As with switchgrass, mean annual biomass yield of giant reed was significantly higher in north (21.2 Mg DM ha^{-1}) than south (15.6 Mg DM ha^{-1}) Mediterranean. In northern Italy, giant reed productivity increased from year 1 to 4; thereafter, biomass yield was consistently above 20 Mg DM ha^{-1}. In southern Italy, giant reed reached yield ceiling after seven years, after which biomass yield was similar in the two environments. Yield stability (CV) of giant reed was also very similar: 33% and 32% in north and south Mediterranean, respectively.

Discussion

Long-term yield studies, particularly in large fields, are challenging and difficult to maintain due to the limited duration of research projects (usually 3–4 years), discontinuity of funding, and changing research objectives. Therefore, limited information is available on long-term productivity of perennial grasses, and prediction models are generally used to estimate biomass yields [22–25]. These models, however, are often based on few short-term studies, variable assumptions, different species, genotypes and biomass end-uses [26]. Furthermore, to the best of our knowledge, no model has been specifically developed for giant reed due to its relatively limited history as a biomass crop. Thus prediction studies on this crop are performed through models developed for other perennial grasses [27]. Therefore, in most cases, predicted yields are not straightforward with other parameters included in the models [24, 25], thus the uncertainty/risk of exploitation and business plans could become sometimes unacceptable to farmers or entrepreneurs, since significant changes on stand lifespan could heavily condition final profitability of the plantation. It follows that comprehensive real yield data over a plant’s lifespan, not short time frames, would be necessary for providing more reliable information to farmers and entrepreneurs with consistent and affordable economic plans, such as adequate plantation size and tailor-designed processing plants.

Although all perennial grasses showed similar yield patterns—an upward trend in the first 2–4 years, then fluctuating yields during the maturity stage, and finally a gradual decrease associated with stand decline—our results clearly show that biomass production was very uneven, both spatially and temporally, and as such very difficult to predict (Figs. 1a-c). These results are also in agreement with long term studies carried out in northern Europe [7, 28].

Generally speaking, giant reed showed considerably higher yields than switchgrass (about 50% higher) under northern Mediterranean conditions. In south Mediterranean, giant reed also outperformed miscanthus and switchgrass, but differences among the three crops, especially between giant reed and miscanthus, were much less evident than in the north Mediterranean. Therefore, although a more comprehensive analysis including economic, logistic and environmental assessments would be needed, given the considerably higher plantation cost of giant reed (sterile seeds) compared with switchgrass, the actual yield potentiality of giant reed seems to remain more locally defined.

Moreover, the ability of miscanthus to maintain high photosynthetic rates at low temperatures [29, 30] can likely offset the lower biomass accumulation rate compared with giant reed during hot periods, which is characterized by inefficient PAR interception in late summer/early autumn [31]. Switchgrass also showed remarkably lower yield stability (i.e., a higher CV) than giant reed in south Mediterranean: switchgrass biomass yield fluctuated considerably between 5 and 18 Mg ha^{-1} yr^{-1} over a short period of 5 years in the maturity stage. Similar results were also reported by Wullshcleger et al. [26], who showed a much higher potential of switchgrass (24 Mg DM ha^{-1}) across the U.S. in comparison with our results. In the northern Mediterranean the CV of switchgrass and giant reed, even if still remarkable (38% and 33%, respectively), were not that different as they were in the south Mediterranean. It is worth noting that all these crops were grown using low input techniques (no fertilization supply except at the establishment); therefore, apart from the different environmental conditions of the sites, soil characteristics might have played a crucial role in determining the biomass production level. For example, in north Italy (Bologna), along with higher and evenly distributed (higher U_R, Tab. 3) precipitation during the summer, soils are characterized by higher water holding capacities (clay soils) compared to Greece (Aliartos) and south Italy (Catania) (sandy soils), that make drought stress less frequent in Bologna. Moreover, Greece and south Italy sites are characterized by lower soil fertility (organic matter content of 0.5% and 1.4%, respectively) than northern Italy (2.7%) (Table 2).

Although biomass yield of the lignocellulosic perennial grasses evaluated in the present study might resemble low values as compared to the broad range reported in literature [32], mainly for southern environments, it must be pointed out that yields were likely affected by rainfed condition and unfertilized management. According to Cosentino et al. [16], the yields of giant reed were significantly increased (40%) under high input management (well-watered conditions + 120 kg N ha^{-1} yr^{-1} fertilization) as compared to rainfed and no-nitrogen treatment in the same environment. In miscanthus, Cosentino et al. [15] found similar yield increases by raising nitrogen and irrigation water. Thus, higher yields can be obtained by using high-input management systems; however, the question remains on the sustainability of biomass crop cultivation. Nonetheless, the transition toward a modern bio-based economy implies challenges, such as the sustainability of biomass raw material, efficiency in biomass use and economy of scales in biomass mobilization, among others [33]. The need to raise biomass availability when land is limited (e.g., European Union) might lead to increased use of water, fertilizers and pesticides with additional problems linked to pollution and water scarcity [33].

Conclusions

The increased use of models needs to be accompanied by more detailed information on the parameterization, validation, and uncertainty quantification. Our knowledge is still insufficient to interpret and determine key productivity factors of perennial grasses toward the challenges facing the modern bio-based economy. The generation of high quality/resolution field data from an integrated framework will be useful to improve the quality of the models by reducing the uncertainty of yield predictions, an imperative aspect for industrial development planning models. Studies like this can greatly contribute to a more comprehensive view of the real potential of these crops in Europe.

Long-term yields of switchgrass, giant reed, and miscanthus grown in the Mediterranean basin under low-input management were highly variable across years and locations. Generally, giant reed and switchgrass were the highest and lowest yielding crops, respectively. Compared with switchgrass and miscanthus, giant reed also showed lower yield variability over time and across locations. Such variability may entail practical implications for planning and developing new value chains. We emphasized the need to investigate real long-term production, since projections based on short term studies of perennial grasses might easily lead to misinterpretation of the real potential of these species.

Acknowledgements

This research work was funded for the period 2011 through 2015 by the FP7 OPTIMA project “Optimization of Perennial Grasses for Biomass production (Grant Agreement 289642)” and for the period 1993 till 2005 by Miscanthus productivity Network, Giant reed Network, Bioenergy chains (www.cres.gr/bioenergy_chains) and Switchgrass for Energy (www.switchgrass.nl).

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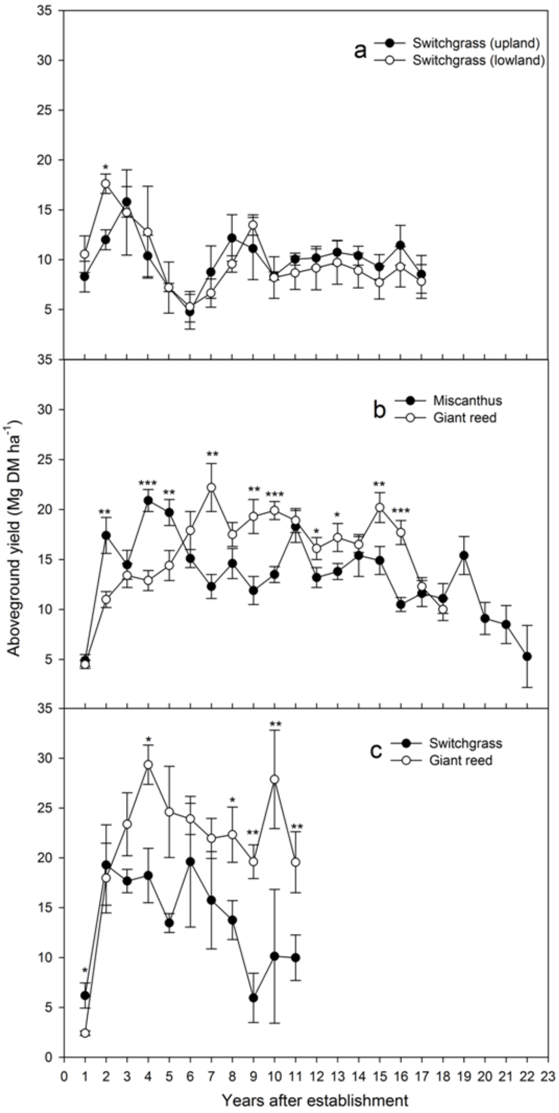

Figure 1. (a) Long-term aboveground biomass yield (Mg DM ha^{-1}) of different switchgrass ecotypes (upland: Blackwell, Cave-in-Rock, vs. lowland: Alamo, Kanlow, Pangburn) grown in Greece (Aliartos). (b) Long-term aboveground biomass yield (Mg DM ha^{-1}) of giant reed and miscanthus grown in southern Italy (Catania).

(c) Long-term aboveground biomass yield (Mg DM ha^{-1}) of giant reed and switchgrass grown in northern Italy (Bologna).

Mean values ± standard deviation of three replications. ANOVA (a and c) and ANCOVA (b) per $P \leq 0.05$. $P \leq 0.05$ (*); $P \leq 0.01$ (**); $P \leq 0.001$ (***).

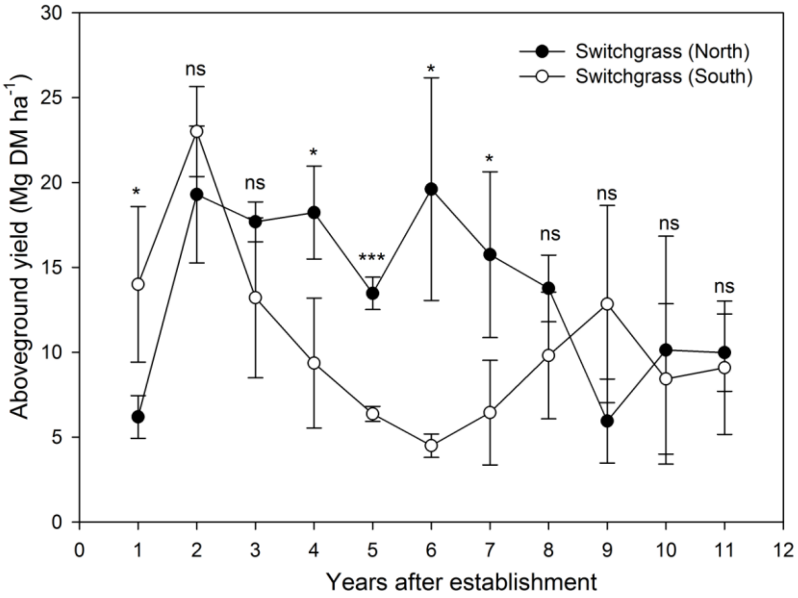

Figure 2. Aboveground biomass yield (Mg DM ha^{-1}) comparison between switchgrass ecotype Alamo grown in North (north Italy-Bologna) and South Mediterranean (Greece-Aliartos). Mean values ± standard deviation of three replications (ANCOVA per $P \leq 0.05$). $P \leq 0.05$ (*); $P \leq 0.01$ (**); $P \leq 0.001$ (***).

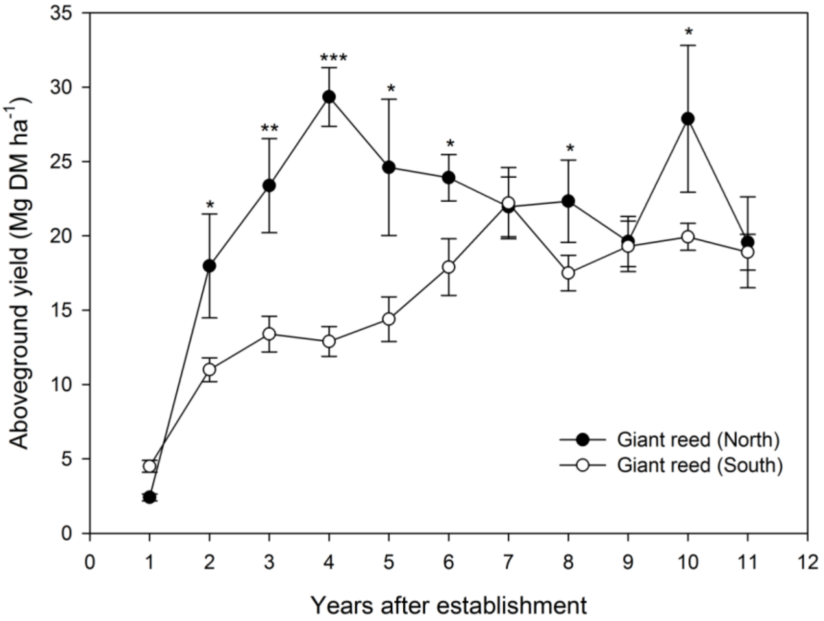

Figure 3. Aboveground biomass dry matter yield (Mg DM ha^{-1}) comparison between giant reed grown in North (north Italy-Bologna) and South Mediterranean (south Italy-Catania). Mean values ± standard deviation of three replications (ANCOVA per $P \leq 0.05$). $P \leq 0.05$ (*); $P \leq 0.01$ (**); $P \leq 0.001$ (***).

Table 1. Characterization of long-term field trials in Greece and Italy (Bologna and Catania in north and south Italy, respectively; Aliartos in central Greece)

Sites	Species	Establishment method	Experimental layout	Plot size (m^2)	Trial duration
Aliartos (GR); latitude 38°22’N, longitude 23°10’E, altitude 114 m a.s.l.	Switchgrass	Seed	Randomized blocks (n=3)	47.25	1998-2014
Catania (IT); latitude 37°24’N, longitude 15°03’E, altitude 10 m a.s.l.	Miscanthus	Micro-propagated plant	Randomized blocks (n=3)	134.4	1993-2014
	Giant reed	Plantlet			1997-2014
Bologna (IT); latitude 44°34'N, longitude 11°47'E, altitude 5 m a.s.l.	Switchgrass	Seed	Randomized blocks (n=3)	2250	2004-2014
	Giant reed	Plantlet			

Table 2. Soil characteristics at the three sites (Bologna and Catania, IT; Aliartos, GR) for the layer depth (0-0.5 m).

Soil characteristics	Greece (Aliartos)	Southern Italy (Catania)	Northern Italy (Bologna)
Loam (%)	25.4	22.4	51.0
Sand (%)	62.8	49.3	21.0
Clay (%)	11.7	28.3	28.0
Organic matter (%)	0.5	1.4	2.7
pH	8.0	8.6	7.5
N (ppm)	756	1000	1370
P_2O_5 (ppm)	NA	5.0	12.0
K_2O (ppm)	NA	244.8	315.0

NA: data not available

Table 3. Meteorological characterization of the three sites (Bologna and Catania, IT; Aliartos, GR) between 2004 and 2014 (common years for all localities, excluding establishment year).

Location	Year	Rainfall (mm)	U_R	Mean T° ± SD (°C)	Rainfall^{GS} (mm)	U_R^{GS}	Mean T°^{GS}± SD (°C)
Greece (Aliartos)	2005	544	2.78	NA	212	1.30	NA
	2006	555	3.98	16.0±9.5	227	3.55	19.7±8.3
	2007	442	3.67	16.8±9.3	217	2.33	20.1±8.9
	2008	285	4.01	16.8±9.3	198	3.46	20.5±8.2
	2009	460	2.41	16.4±8.9	212	1.74	19.6±8.5
	2010	332	1.06	17.4±9.0	239	2.21	20.2±8.6
	2011	544	5.71	15.8±9.3	205	1.87	19.3±8.9
	2012	599	4.48	NA	290	3.07	NA
	2013	482	2.94	16.9±9.3	127	0.57	20.6±8.7
	2014	606	5.31	17.3±9.0	251	2.54	20.4±8.8
mean±SD		485±108	3.63±1.39	16.7±0.2	218±42	2.26±0.94	20.1±0.2
Southern Italy (Catania)	2005	640	4.37	17.0±6.4	313	2.37	20.0±5.3
	2006	922	8.09	17.9±6.3	333	5.89	20.9±5.3
	2007	721	7.32	18.1±5.9	361	4.51	20.9±5.0
	2008	468	6.43	17.5±5.4	220	2.72	20.0±4.4
	2009	504	3.70	18.0±5.9	329	4.80	20.5±5.3
	2010	623	4.69	17.7±5.6	259	2.69	20.1±4.9
	2011	859	4.73	17.1±5.7	457	4.40	19.7±4.8
	2012	623	8.62	18.3±6.8	251	3.82	21.6±5.4
	2013	397	2.30	18.0±6.1	209	1.92	21.1±4.7
	2014	404	3.46	17.4±5.3	164	1.76	19.5±4.9
mean±SD		616±180	5.37±2.13	17.7±0.4	290±86	3.49±1.39	20.4±0.7
Northern Italy (Bologna)	2005	653	4.08	12.3±8.6	449	3.35	16.9±6.2
	2006	495	1.29	13.1±8.4	390	1.43	17.5±6.3
	2007	562	1.45	13.5±7.7	434	2.59	17.8±5.5
	2008	614	2.28	13.6±8.0	376	2.22	17.7±6.1
	2009	561	1.96	13.5±8.5	324	2.48	18.1±6.1
	2010	846	0.98	12.7±8.5	537	1.26	17.1±6.2
	2011	390	1.71	13.6±8.7	270	1.61	18.2±6.3
	2012	457	3.81	13.6±9.6	321	2.77	18.9±6.5
	2013	769	3.23	13.4±8.2	498	2.29	17.7±6.0
	2014	780	1.98	14.4±6.7	486	1.77	17.9±5.0
mean±SD		613±150	2.28±1.07	13.4±0.6	409±87	2.18±0.66	17.8±0.6

[1] U_R, is uneven rainfall distribution (the sum of square of the distances of the actual cumulated rainfall points from the respective evenness lines), for more details on unevenness calculations see [21]; [2]GS, growing season from March 01 until October 31; NA data not available.