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Evaluation of European developed fibre hemp genotypes (*Cannabis sativa* L.) in semi-arid Mediterranean environment

Salvatore L. Cosentino[a,*], Ezio Riggi[b], Giorgio Testa[a], Danilo Scordia[a], Venera Copani[a]

[a] Dipartimento di Scienze delle Produzioni Agrarie e Alimentari – DISPA, University of Catania, Via Valdisavoia 5, 95123 Catania, Italy
[b] CNR-ISAFOM – National Research Council ITALY – Institute for Agricultural and Forest System in the Mediterranean, Str.le V. Lancia, Blocco Palma I, Zona Industriale, 95121 Catania, Italy

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ABSTRACT

In the present study two experiments, namely, (i) the adaptation and productivity of different hemp genotypes, both monoecious and dioecious, developed in Central-Northern and Southern Europe, and (ii) the water consumption, water use efficiency (WUE), radiation use efficiency (RUE), leaf transpiration and net photosynthesis of Futura 75 hemp cultivar were studied. Experiments were carried out in Southern Italy in two subsequent year periods. Sowing occurred in May in both years.

Results show that fibre hemp, both monoecious and dioecious, performed well giving high productivity; however, fibre hemp needs almost 250 mm of water for monoecious early genotypes and 450 mm for dioecious late genotypes. Higher biomass and stem dry yields were achieved with genotypes developed for Central-Southern environments, such as the dioecious Dioica 88 and Fibranova.

In order to estimate the water consumption and WUE of Futura 75, four water regimes (I_3, I_2, I_1 and I_0 corresponding respectively to 100%, 50%, 25% ETm restoration and irrigation until crop establishment) were tested.

Futura 75 was strongly affected by water shortage and the WUE ranged between 2.73 g l^{-1} in good water conditions and 3.45 g l^{-1} in water stress conditions. The highest light extinction coefficient (k) was observed in water stressed (0.58) than in good watered conditions (0.40). The water stress reduced RUE, LAI and therefore aboveground biomass yield.

Air temperature strongly influenced net photosynthesis with an optimum at 24 °C; higher and lower values of air temperature led to a decrease of net photosynthesis.

1. Introduction

There are big concerns for farming systems in the Mediterranean area where climate is indeed characterized by hot and dry summers and water shortage is the main constraint limiting yield of major crops (Araus et al., 2002; Cosentino et al., 2012a). In addition, several million hectares of arable land are continuously ploughed to grow cereals or annual forage crops. This causes the soil to be very exposed to water and wind erosion, and results in a decline of organic matter and fertility as well as weed, pest and diseases accumulation. Introductions of different crops in the common rotation schemes and/or alternative crops with high tolerance to hot temperatures and limited water demands have to be urgently identified and adapted.

In this respect, as annual crop, fibre hemp (*Cannabis sativa* L.) may fit well into crop rotations, where it may serve to control weeds, diseases, and pests (Venendaal et al., 1997; Robson et al., 2002; Ranalli and Venturi, 2004). It has been reported that crops following hemp in the rotation (e.g. cereals autumn–winter) will significantly benefit both for the action of secondary roots that facilitate the structuring of the soil and for the important mass of organic residues left on the ground (Venturi and Amaducci, 1999).

Fibre hemp is well-known for its industrial and textile applications and can be grown in a wide range of environmental conditions, from Northern to Southern Europe (Zegada-Lizarazu et al., 2010). While fibre hemp has been extensively reported as raw material for industrial applications (Bledzki et al., 2006), its use as an energy crop, however, is relatively new. In view of second-generation feedstock for ethanol production, fibre hemp could take a leading role because of its high cellulose content (~60% w/w) and low lignin content (7–8% w/w) (Struik et al., 2000) compared with dedicated lignocellulosic bioenergy crops, such as giant reed (Scordia et al., 2011, 2012, 2013) and *Saccharum spontaneum* (Scordia et al., 2010).

The appropriate site-specific selection of genotypes, however, plays an important role in stabilizing and optimizing yields. Late

* Corresponding author. Tel.: +39 95 234411; fax: +39 95 234449.
E-mail addresses: cosentin@unict.it, cosentin@hotmail.com (S.L. Cosentino).

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Table 1
Soil characteristics of the field site in the top layer (0–50 cm).

Soil characteristics	Unit	Value	Method
Sand	%	49.3	Gattorta; Lotti and Galoppini, 1980
Loam	%	22.4	Gattorta; Lotti and Galoppini, 1980
Clay	%	28.3	Gattorta; Lotti and Galoppini, 1980
pH (in water solution)		8.6	
Total calcareous	%	15.2	Gas-volumetric; AOAC, 1990
Organic matter	%	1.4	Walkley and Black; AOAC, 1990
Total *N*	‰	1.0	Kjeldahl; AOAC, 1990
P_2O_5 availability	ppm	5	Ferrari; AOAC, 1990
K_2O availability	ppm	244.8	Dirks and Sheffer; AOAC, 1990
Bulk density	$g\,cm^{-3}$	1.1	
Field capacity at −0.03 MPa	%	27	
Wilting point at −1.5 MPa	%	11	

flowering cultivars and the proportion of male plants are also important determinants for increased hemp productivity (van der Werf et al., 1996; Struik et al., 2000). This is particularly true for the Northern environments of Europe, where water is not a limiting factor and the extended growth period by either early sowing or delayed harvest are beneficial for maximizing biomass yields (van der Werf et al., 1995, 1996); however, to the best of our knowledge, the behaviour of genotypes developed in North, Central and Southern Europe has not been studied in the semi-arid Mediterranean environment so far. In this environment water shortage is the main factor limiting yields of several crops. Water use efficiency (WUE) might be an useful tool to describe the relationship between the crop growth development and the amount of water used. It is assumed that a variety having a higher WUE than another has the potential of using less water when achieving the same yield.

In the present work and in the framework of the UE project QLK5.CT-2002-01363 "HEMP-SYS", a research was carried out in order to study the constraints conveyed by the hot dry Mediterranean climate to fibre hemp production (*Cannabis sativa* L.). Experimental trials were performed with the aim to evaluate (i) the adaptation and productivity of different hemp genotypes, both monoecious and dioecious, developed in Central-Northern and Southern Europe, and (ii) the water consumption, water use efficiency, leaf transpiration, net photosynthesis and radiation use efficiency of hemp.

2. Materials and methods

2.1. Experimental site

Experiments were carried out in southern Italy at the Experimental Farms of Catania University, (Catania plane, 10 m asl, 37°25′ N Lat., 15°30′ E Long) on a typical Vertic Xerofluvents soil (USDA, 1999) and in two subsequent year periods, 2003 and 2004. The soil characteristics of the field site are reported in Table 1. The following meteorological variables were collected daily throughout the crop growing season: maximum and minimum air temperature, global radiation, rainfall, class-A pan evaporation, by means of a data logger (CR10, Campbell Scientific, USA) located approximately 50 m apart from the experimental field.

2.2. Adaptation and productivity of different hemp genotypes

Twelve genotypes in the first year (2003) and seven genotypes in the second year (2004) were used (Table 2). Sowing occurred on May 19th in 2003 and May 10th in 2004. According to Cosentino et al. (2012b) sowings before middle April or later than the end of May determine a shortening of the "emergence–flowering", short stems and consequently lower yields due to the short daylength. For this reason we performed the sowings at about middle May, when the daylength does not affect hemp vegetative growth.

A randomized block experimental design with three replications was applied, with a single plot measuring 29.25 m^2 (4.5 × 6.5 m). Plant distance between rows was 20 cm and the programmed plant density was 240 plants m^{-2}. Before sowing 100 kg ha^{-1} P_2O_5 and 100 kg ha^{-1} N, respectively as mineral phosphate and ammonium sulphate, were applied.

The water was distributed by means of a drip irrigation system. The irrigation was determined on the basis of the maximum available soil water content in the first 0.6 m of soil, where most of the root is expected to grow, according to Doorenbos and Pruitt (1979) formula:

$$V = 0.66(\mathrm{FC} - \mathrm{WP}) \times \Phi \times D \times 10^3$$

where *V* = water amount (69.7 mm); 0.66 = readily available water not limiting for evapotranspiration; FC = soil water at field capacity, equal to 27% of dry soil weight; WP = soil water at wilting point, equal to 11% of dry soil weight; Φ = bulk density (1.1 g cm^{-3}); *D* = rooting depth where the bulk of roots is expected to develop (0.6 m).

Table 2
European country of origin, sexual type, growing area and maturity group of monoecious and dioecious fibre hemp genotypes used in the two-year periods.

Genotype	2003	2004	Origin	Sexual type	Growing area	Maturity group
Beniko	◊		PL	Monoecious	North EU	Early
Epsylon 68	◊		FR	Monoecious	Central-North EU	Medium
Felina 34	◊	◊	FR	Monoecious	Central-North EU	Early
Ferimon	◊		DE	Monoecious	Central-North EU	Early
Fedora 17	◊	◊	FR	Monoecious	Central-North EU	Early
Futura 75	◊	◊	FR	Monoecious	Central-North EU	Medium
Bialobrzeskie	◊		PL	Monoecious	Central-North EU	Early-medium
Dioica 88	◊	◊	FR	Dioecious	Central-South EU	Late
Fibranova	◊	◊	IT	Dioecious	Central-South EU	Late
Tiborszallasi	◊	◊	HU	Dioecious	Central EU	Medium-late
Lovrin 110	◊		RO	Dioecious	Central EU	Medium-late
Carmagnola	◊		IT	Dioecious	Central-South EU	Late
Chamaeleon		◊	NL	Dioecious	Central-North EU	Early