Industrial Crops and Products 41 (2013) 46–52

Contents lists available at SciVerse ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

# Effects of sowing times on seed yield, protein and galactomannans content of four varieties of guar (*Cyamopsis tetragonoloba L.*) in a Mediterranean environment

Fabio Gresta[a,*], Orazio Sortino[b], Carmelo Santonoceto[a], Luca Issi[c], Cristina Formantici[c], Yves M. Galante[c]

[a] *Dipartimento di Biotecnologie per il Monitoraggio Agroalimentare ed Ambientale, Università Mediterranea di Reggio Calabria, Loc. Feo di Vito, 89122 Reggio Calabria, Italy*
[b] *Dipartimento di Scienze delle Produzioni Agrarie e Alimentari, Università di Catania Via Valdisavoia, 5; 95123 Catania, Italy*
[c] *Laboratory of Biotechnology Lamberti spa, Via Piave 18, 21041 Albizzate (VA), Italy*

ARTICLE INFO

*Article history:*
Received 10 February 2012
Received in revised form 30 March 2012
Accepted 5 April 2012

*Keywords:*
Guar
Seed yield
Protein
Galactomannans, Mediterranean environment

ABSTRACT

Guar (*Cyamopsis tetragonoloba* L.) is a summer, annual, legume crop primarily grown as an industrial crop for the galactomannans content of its seeds. Guar is grown in India, Pakistan and USA, but no cultivation has of yet been established in a Mediterranean environment. In the last few years, world demand for guar gum has considerably grown and its price has increased. In order to explore the possibility of extending guar cultivation into a Mediterranean environment, a 2-year experiment was carried out in Southern Italy with the aim of evaluating the seed yield, protein and galactomannan content as affected by two sowing times (early and late) and four different varieties. Guar seed was produced with an average of 2.650 $m^3$ $ha^{-1}$ of water, which is a volume compatible with many semiarid areas. Lewis and Santa Cruz cultivars proved to be the most productive varieties (2.5 t $ha^{-1}$) and the early sowing time resulted in higher yields compared to the later one (2.3 t $ha^{-1}$ vs. 2.1 t $ha^{-1}$). Protein content was variable among varieties and galactomannan content was higher in the second sowing time, the highest protein and gum yield was obtained in the early sowing due to higher seed yield by Lewis and Santa Cruz. Galactomannans yield was mainly related to pods per plant and seed yield, thus management techniques and genetic improvement of guar for gum production should be addressed to maximize the number of pods per plant. In general, guar seed and gum yield support the hypothesis that the Southern European Mediterranean environment is a potentially valuable area for guar cultivation.



## 1. Introduction

Guar (*Cyamopsis tetragonoloba* L.) is a summer, annual, legume crop that exhibits excellent drought resistance and is mainly cultivated in a few sub-tropical regions of the world, such as North-Western India, Pakistan, Sudan and the southern USA (Texas and Oklahoma) (Whistler and Hymowitz, 1979). In the past, guar was also cultivated in Sicily (Italy) (Whyte et al., 1953).

Guar is primarily grown as an industrial crop, but it is also used as forage for cattle, thanks to its high protein content (Whistler and Hymowitz, 1979). Together with carob (*Ceratonia siliqua*), it is the main source of galactomannans for industrial use (Jackson and Doughton, 1982; Whistler and Hymowitz, 1979). Galactomannans is a polysaccharide with a linear backbone of mannose residues linked by β,1–4 glycosidic bonds, with side chains of D-galactose monomers linked to mannose units by an α,1–6 glycosidic bond. Galactomannans functionally belong to the category of reserve polysaccharides of seed cells (Reid, 1985). Thanks to their good solubility in cold water, high chemical reactivity and flexibility, and peculiar rheological properties (Wang and Zhang, 2009), guar galactomannans are used in several industrial applications as thickening, gelling and suspending agent, viscosifier and emulsion stabilizer, and are used in a variety of fields such as textile, paper, paint, oil operation, drilling, civil engineering, agrochemistry, food, cosmetics and pharmaceuticals (Zambrano et al., 2004; Mudgil et al., 2011; Vaughna et al., 2011; Lubbe and Verpoorte, 2011). The importance of guar has increased considerably in recent years due to the general ecological trend of utilizing polysaccharides of renewable plant origin in different industrial applications. Recently, galactomannans have also been used in the production of water proof biocide films (Das et al., 2011).

Particularly last year, world demand for guar gum has skyrocketed and the price of guar has increased by approximately 230% and even more, mainly because of increased oilfield shale gas demand. As a consequence, there has been a 75% jump in exports from India, the largest guar producing country.

The guar plant is characterized by a short spring-summer cycle that fits well into a crop rotation (Tucker and Foraker, 1975). It

* Corresponding author. Tel.: +39 0965 801235; fax: +39 0965 311092.
*E-mail address:* fgresta@unirc.it (F. Gresta).

0926-6690/$ – see front matter 
http://dx.doi.org/10.1016/j.indcrop.2012.04.007

**Table 1**
Soil characteristics.

| Characteristic | Unit | Value |
|---|---|---|
| Stone | % | – |
| Sand | % | 39 |
| Silt | % | 24 |
| Clay | % | 37 |
| Total limestone (De Astis) | % | 18.6 |
| Total nitrogen (Kjeldahl) | ‰ | 1.7 |
| Phosphorus (Olsen) | ppm | 49.2 |
| Potassium (ammonium acetate) | ppm | 355.2 |
| Bulk density | g/cm$^3$ | 1.24 |
| Field capacity | % in weight | 27.5 |
| Wilting point | % in weight | 16.4 |

**Table 2**
Water supply, number and turn of irrigations.

| Sowing time | Water (m$^3$ ha$^{-1}$) | Number of irrigations | Turn of irrigations (days) |
|---|---|---|---|
| 2003 | | | |
| I Sowing time | 3290 | 10 | 9.2 |
| II Sowing time | 1960 | 8 | 6.8 |
| Average | 2625 | 9 | 8 |
| 2004 | | | |
| I Sowing time | 3110 | 12 | 8.6 |
| II Sowing time | 2360 | 10 | 7.1 |
| Average | 2735 | 11 | 7.85 |

grows well in hot climates, can tolerate extended periods of drought and high salinity (Ashraf et al., 2005; Francois et al., 1990). Being a legume plant, guar also has a good capacity for fixing atmospheric nitrogen (Elsheikh and Ibrahim, 1999). For all of these reasons, guar is considered a highly viable crop for semiarid zones (Ashraf et al., 2005) and an alternative crop for Mediterranean areas (Losavio et al., 1995; Sortino and Gresta, 2007), where limited water availability does not allow the cultivation of many summer crops. However, very little is known about agricultural management techniques and their effects on yield and qualitative aspects of guar in such an environment. Sowing date varies from May to August, but most of the information available applies to an Indian environment and there is little available data for a Mediterranean environment (Losavio et al., 2002). Moreover, to the best our knowledge, no previous publication has explored the galactomannans content of guar seeds produced in a Mediterranean climate.

Therefore, in order to explore a potential alternative legume crop for Mediterranean environments, a 2-year experimental trial was carried out to evaluate the effect of different sowing dates on the seed yield, protein and galactomannan content of four varieties of guar.

## 2. Materials and methods

### 2.1. Field experiment

The trial was carried out in 2003 and 2004 in an experimental field located in Southern Sicily, Italy (Cava d'Ispica, 325 m a.s.l., lat 36°50′, long 14°52′) using four different cultivars: Lewis, Esser, Kinman and Santa Cruz. Seeds were obtained from the Texas Cooperative Extension, USA. In both years, two sowing times (7 May and 26 June 2003, 18 May and 30 June 2004) were adopted, using a split plot randomized block design with plots of 20 m$^2$ (5 m × 4 m) with three replications. Sowing time was randomized in the main plot and variety in the sub-plot. Sowing was performed on clay-loam soil, the main physical, chemical and idrological traits of which are reported in Table 1. Seeds were arranged with a density of 25 plants/m$^2$ (50 cm between rows, 8 cm between plants). Weed control was managed by hand. Before sowing, 40 kg ha$^{-1}$ of $P_2O_5$ and 30 kg ha$^{-1}$ of $K_2O$ were distributed. Water was supplied with a drip system, restoring 100% of the $ET_m$ (maximum evapotranspiration), estimated by class A pan evaporation, corrected through the use of a pan coefficient (Kp) of 0.75 and the lowest crop coefficients (Kc) suggested by Doorenbos and Kassam (1979) related to each phenological phase of soybean: initial stage, 0.3; development stage, 0.7; mid-season stage, 1.0; late-season stage, 0.7; harvest, 0.4.

Information on the quantity of water supplied and the number and turn of irrigations are reported in Table 2. At the end of the trial, plant height, branch number, root length, pod length, 1000 seed weight, seed per pod and seed yield were recorded only for an area of 12 m$^2$ (4 m × 3 m) in the center of the plot to avoid the border effect. Temperature and rainfall were monitored throughout the experiment by a meteorological station (Data logger CR10 Campbell) located next to the field (Fig. 1). In 2003, during the trial period (May–October), the average temperature was 23.5 °C with a minimum temperature of 12.9 °C in May and a maximum of 34.1 °C in August. Rainfall was 295 mm, 70% of which occurred in September. In 2004, the temperature was a little cooler, but the weather was much drier compared to 2003: the average temperature was 21.6 °C, with a minimum temperature of 10.8 °C in May and a maximum temperature of 31.3 °C in July. Rainfall of 86.2 mm was recorded during the trial period. The temperature trend of the 2-year trial was quite similar to the 30-year data, in which the average temperature of the period is 22.5 °C. Thirty-year average rainfall is 155 mm, much less of the first year, but higher than the second one.

### 2.2. Chemical analysis

Grains were analyzed for their total nitrogen (Kjeldahl method). The samples for the analysis were weighed and 10 were grounded in an analytical mill to pass through a 1 mm screen.

Before proceeding with the enzymatic galactomannans determination, a visual examination of the seeds was performed and their color was recorded. In order to evaluate their galactomannans

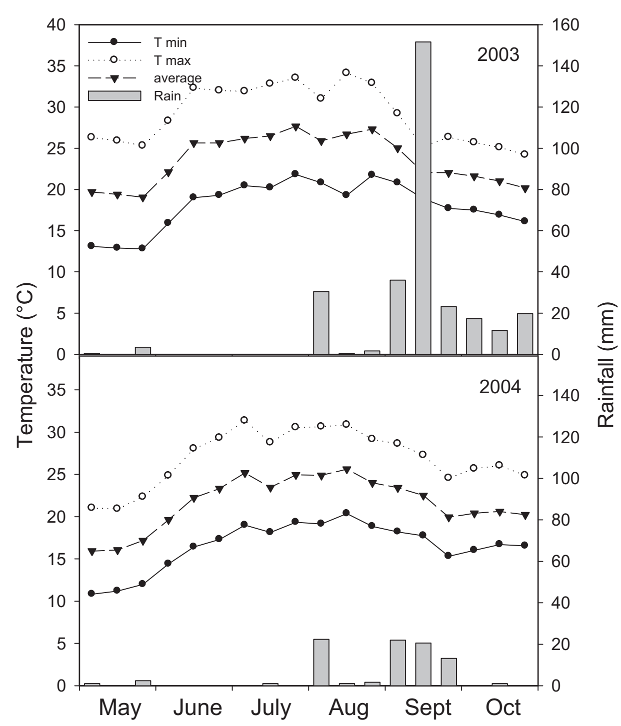


**Fig. 1.** Meteorological trend at the experimental site during the trial period.