MAIZE RESPONSE TO WATER DEFICIT

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ABSTRACT

The influence of drought on maize hybrids was studied through one line source sprinkler system. Six maize hybrids were used in this investigation conducted in the years 1994 – 1996, the droughtest period of the last time. The plant water consumption under dryland conditions had values ranging between 259.4 mm (hybrid Danubiu) and 389.2 mm (hybrid Robust). The highest reduction of plant water consumption under dryland conditions was 40.2% (Danubiu), as a mechanism of maize stress adaptation. Under limited water supply conditions (60 % AW), grain yields ranged between 8950 kg/ha (Volga) and 13249 kg/ha (Robust). A good correlation (r = 0.912) between plant water consumption and grain yield was found. The hybrid Danubiu registered the smallest yield reduction (30.9%). Under severe water stress, the highest WUE value (28.0 kg/mm) was found to Danubiu. The most resistant to water stress were the maize hybrids Danubiu (Ky = 0.66), Fundulea 365 (Ky = 0.78) and Dacic (Ky = 0.86)

Key words: irrigation efficiency, maize water stress, water use efficiency (WUE), yield response factor (Ky).

INTRODUCTION

Substantial reduction in maize grain yield has been attributed to unfavourable production environments of which water stress was a major limiting factor (Boyer 1982; Christiansen, 1982). Crăciun and Crăciun (1984) found, due to water deficit, an evapotranspiration reduction (ET) between 0-40%, a grain yield diminution up to 92% and a water use efficiency variation between 3.1 kg/mm and 24.5 kg/mm. Drought is a complex phenomenon, in which water deficit is the most important factor for yield reduction, so that its profound study is of a great importance.

For drought evaluation of maize hybrids it is necessary to discriminate their performances in areas where water stress is obvious. An assessment of such a variability may be obtained by conducting yield trials in several dry environments by “line source sprinkler system” which delivers a continuous and linear declining amount of water (Hanks and al., 1976). This system has been extensively used for screening crop genotypes (Garrity et al., 1982; O’Neill et al., 1983 ; Crăciun and Crăciun, 1991, 1993).

The aim of this study was to evaluate the influence of water deficit on evapotranspiration (ET), grain yield, and water use efficiency (WUE), and to quantify the effect of water stress by means of the relationship between relative yield decrease and relative evapotranspiration deficit given by empirically derived yield response factor (Ky), in order to get more information regarding the adaptation of the new maize hybrids to drought conditions.

MATERIALS AND METHODS

The experiments were conducted on a cambic chernozem soil at Fundulea, during the 1994-1996 years.

A line-sources sprinkler design was established each year, with four genotypes in four replications. The following hybrids were used: Dacic, Danubiu, Fundulea 365, Progres, Robust, Șoim and Volga. The well irrigated treatment received water at the level of 50% available water (AW), in the first 80 cm of the root zone, avoiding plant water stress. The quantity of soil water was measured with neutron moisture gauge on the soil profile.

Water use efficiency is a common parameter in agricultural researches, providing more information about the relation between grain yield and plant water consumption.

In order to quantify the effect of water stress, the plant yield response factor (Ky) was calculated using the following formula:

$$Ky = \frac{1 - \mathrm{Ya} / \mathrm{Ym}}{1 - \mathrm{ETa} / \mathrm{ETm}} \qquad \text{where:}$$

Ya = actual harvest yield
Ym = maximum harvest yield
Eta = actual evapotranspiration
Etm = maximum evapotranspiration

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RESULTS AND DISCUSSIONS

The years 1994-1996 were very droughtest, with the the sum of precipitations during the maize vegetation period of 329 mm, with a good distribution in the vegetative period of 1994, and not so good in 1995 and 1996 (298.2 mm and 243.1 mm respectively), with 91.9 mm less than multiannual average on 35 years (335.0 mm).

Because the maximum evapotranspiration is higher than the precipitations during the vegetation period, irrigation application appears necessary (Figure 1).

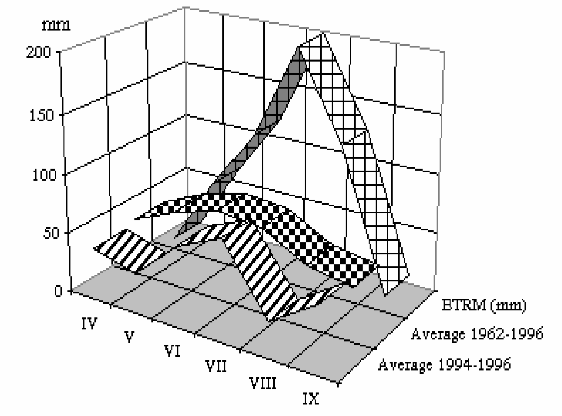


Figure 1. Rainfall distribution and real evapotranspiration, during the vegetation period
Fundulea, 1994 – 1996

Temperature was over the multiannual average of 18.1°C: 19.9°C in 1994, 18.4°C in 1995 and 18.7°C in 1996 (Figure 2).

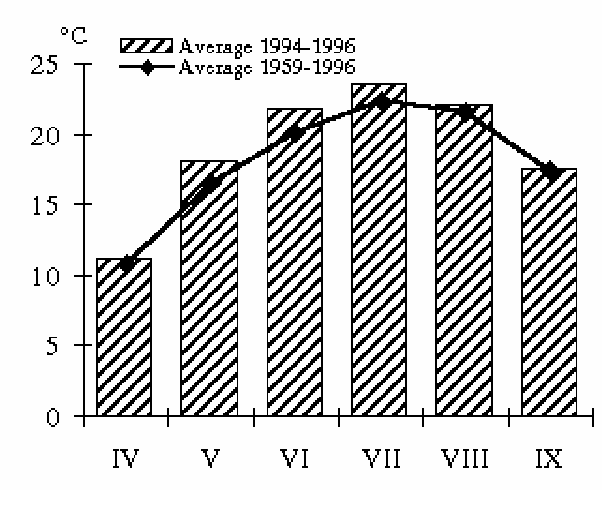


Figure 2. Thermic conditions under maize vegetation period. Fundulea, 1994 – 1996

Water plant consumption (ET)

The method of ET determination was based on the soil - water balance. The dynamics of soil moisture was estimated with the neutron gauge Troxler 4300. A good correlation between soil moisture measured by neutron moisture gauge and gravimetric method was found ($r= 0.862^{**}$ with the linear equation: $y = 0.7167x + 2.7966$).

Depending on precipitation distribution in time and space, hybrid and irrigation level, plant water consumption increased with rising the irrigation amount.

Under dry conditions, the plant water consumption had values ranging between 259.4 mm at Danubiu hybrid and 389.2 mm at Robust. Under well irrigated conditions the ET had values between 405.6 mm at Robust and 478,4 mm at Fundulea 365. The highest reduction of plant water consumption under dryland conditions was 40.2% at Danubiu hybrid, as a mechanism of maize adaptation to water stress.

In 1996, a dry year in June - July, with a sum of rainfall of 243 mm during the vegetation period, the ET variation was 45-50% as a function of irrigation and genotype. The hybrids Dacic and Danubiu registered a small ET, i.e. 410 mm and 434.2 mm respectively, as an average on three years. The hybrids Robust and Progres (1994) registered in well irrigated treatment (100% from the total amount) the smallest ET, i.e. 405.6 mm and 409.6 mm respectively.

The variation of plant water consumption and behaviour of maize hybrids at different irrigation levels is synthetically represented in figure 3.

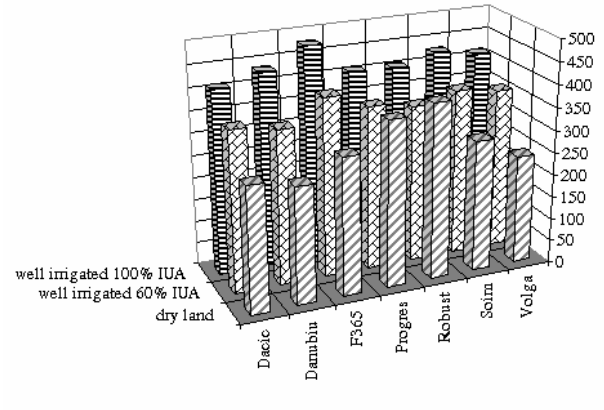


Figure 3. Maize water consumption on vegetation period. Fundulea, 1994 - 1996

The ET increasing during the vegetative period is presented in figure 4, by soil moisture decreasing in all three variants, depending on plant water consumption.

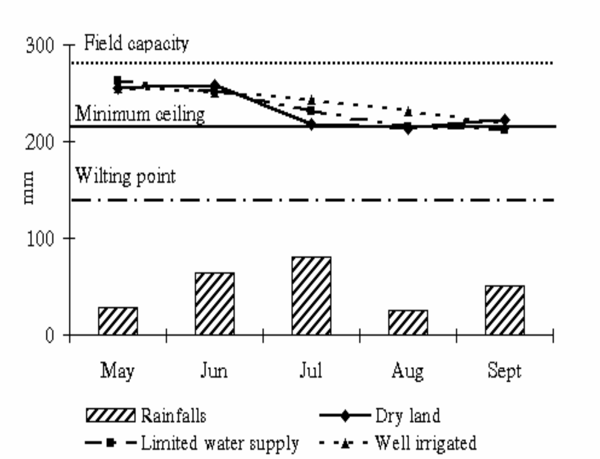


Figure 4. Evolution of soil moisture at 0-80 cm depth, under maize vegetation period. Fundulea, 1994 - 1996

Maximum ET values registered in June and July ranged between 7.3 mm/day (Danubiu), 6.0 mm/day (Şoim) and 5.6 mm/day, values in lysimeters.

Maize grain yield (kg/ha)

The experimental results confirm that grain yield variation under irrigated conditions is very little, because the water stress is a major factor in grain yield variation (Crăciun and Crăciun, 1993).

The variation of maize grain yield depends on the genotype and irrigation level. The experimental results obtained in this period showed a yield increase proportionally with the increase of irrigation level. Under dry land conditions the grain yield variation had values between 4,403 kg/ha (hybrid Progres) and 9,127 kg/ha (hybrid Robust).

Under limited water supply (60% AW) the grain yield ranged between 8,950 kg/ha (hybrid Volga) and 13,249 kg/ha (hybrid Robust). Under well irrigated conditions (100% AW) the grain had value between 10,539 kg/ha (hybrid Danubiu) and 13.881 kg/ha (hybrid Robust) (Figures 5, 6 and 7).

In 1994, when rainfall was near to the normal local level, an important grain yield increase was registered in two irrigation treatments, a significant contribution having the rainfall during the vegetative period (298 mm).

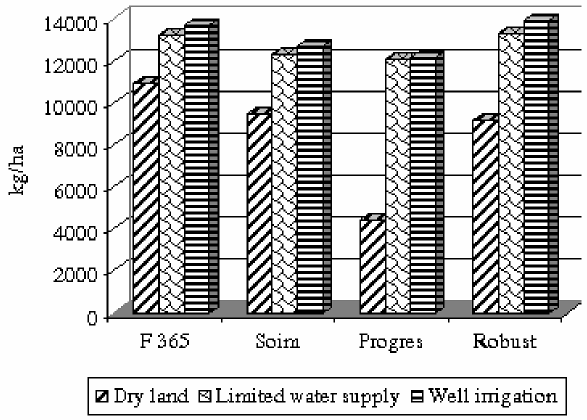


Figure 5. The influence of irrigation under maize grain yield. Fundulea, 1994

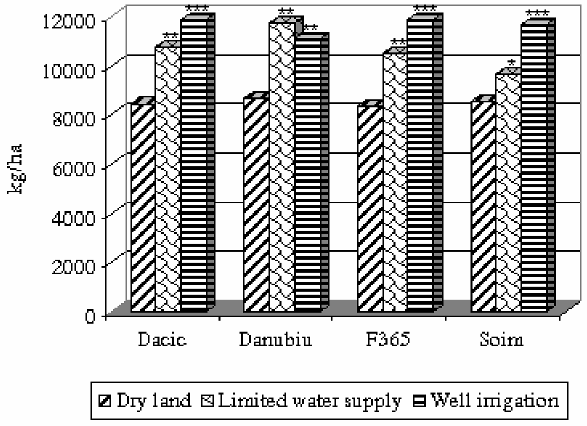


Figure 6. The influence of irrigation under maize grain yield. Fundulea, 1995

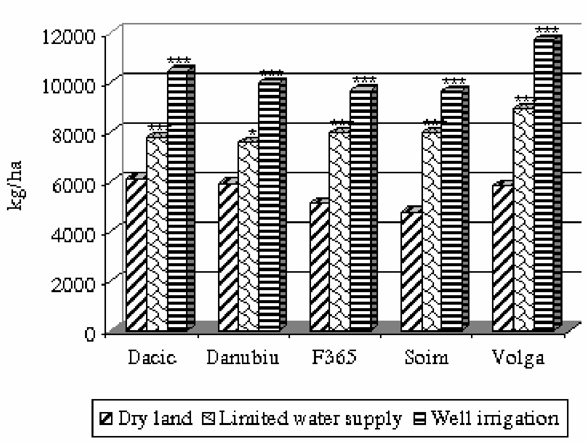
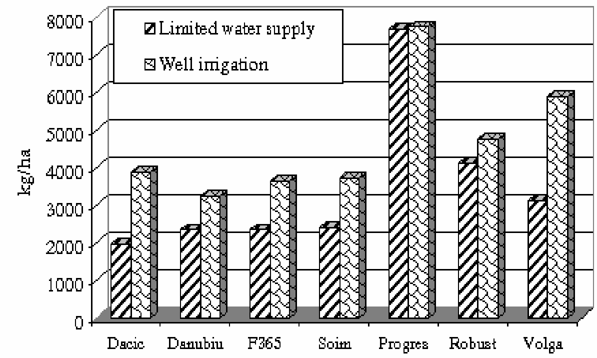


Figure 7. The influence of irrigation under maize grain yield. Fundulea, 1996

In 1996, the droughtest year, the grain yield had values between 4,778 kg/ha (Şoim) under dryland conditions and 11,704 kg/ha (Volga) in optimum irrigated treatment. Irrigation application, in this year, determined a higher and significant yield increasing, due to the existence of a good correlation between plant water comsumption and grain yield (r = 0.912) (Figure 7).

The influence of water deficit is evident also by analysing yield returns. The reduction of irrigation amount with 40% determined a reduction of yield returns up to 50% (Dacic), 47% (Volga), 36% (Şoim), 35.8% (Fundulea 365). The smallest decrease of yield returns was registered by Danubiu with 28%, compared to the well irrigated treatment.

The grain yield returns obtained by irrigation application ranged from 1,947 kg/ha (Dacic) under limited water supply to 7,748 kg/ha (Progres) in well irrigated treatment (Figure 8).



1994 - F 365, Soim, Progres, Robust; 1995 - Dacic, Danubiu, F 365, Soim; 1996 - Dacic, Danubiu, F 365, Soim, Volga

Figure 8. The influence of irrigation on maize grain yield returns. Fundulea, 1994 – 1996

The yield losses due to water stress were over 30% in dryland treatment with Progres having the highest value (63.7%). The lowest yield reduction was registered by Danubiu (30.6%) and Fundulea 365 (30.9%), (Figure 9).

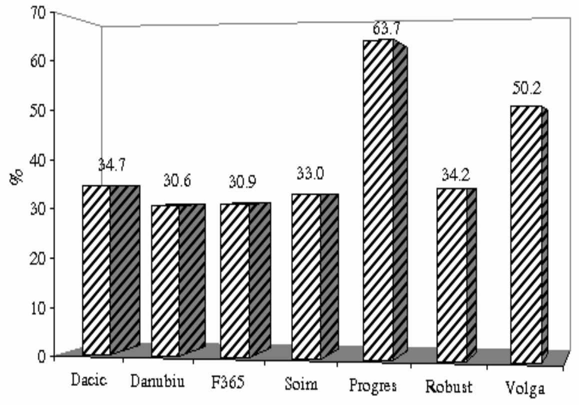


Figure 9. The influence of hidric stress on maize grain yield loses. Fundulea, 1994 – 1996

Water use efficiency (WUE)

The relationship between maize hybrids and water stress was studied, in the attempt to determine the breeding progress in WUE.

Under severe water stress, the highest WUE value was registered by Danubiu (28 kg/mm). WUE values in the vegetation period, considering the irrigation level and seven genotypes studied, ranged between 11.9 and 37.8 kg/mm. The maize hybrids Robust and Progres registered the highest values in well irrigated treatment, being the most sensitive to drought (Figure 10).

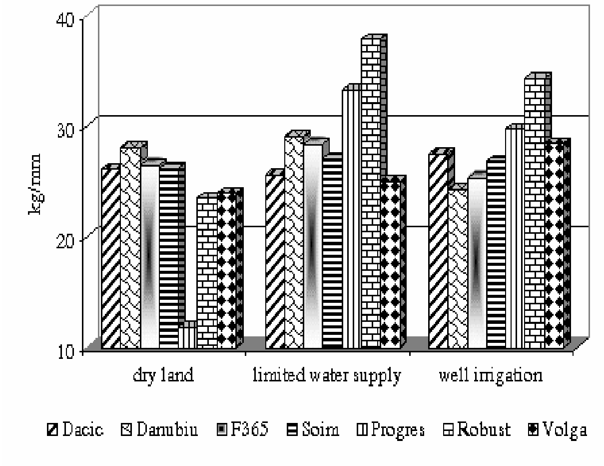


Figure 10. Maize water use efficiency Fundulea, 1994-1996

Irrigation efficiency (IWE)

Irrigation efficiency represents the ratio between the grain yield returns and the irrigation amount. In this experiment, IWE values varied according to the irrigation amount and the genotype. The highest IWE was registered in well irrigation treatment, the maize plant using better the water applied in small quantities and often.

In 1994-1996 period IWE values ranged from 21.3 kg/mm (Danubiu-well irrigated treatment) and 85.1 kg/mm (Progres under limited water supply). In 1996 dry year, IWE registered values from 19.4 kg/mm (Danubiu) to 37.6 kg/mm (Şoim). The highest IWE value under limited water supply, i.e. 37.9 kg/mm, was observed to the maize hybrid Şoim (Figure 11).

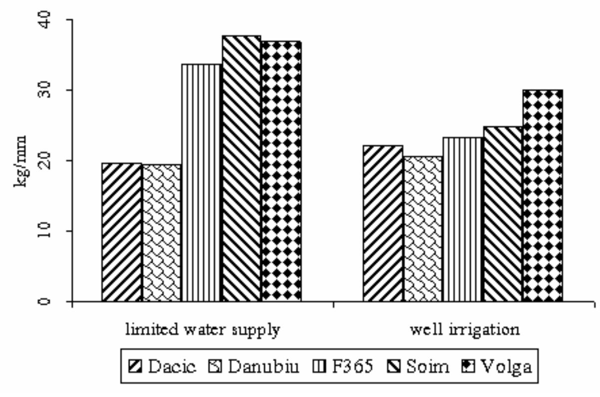


Figure 11. Maize irrigation efficiency. Fundulea, 1996

Maize yield response factor (Ky)

The yield response to water supply is quantified through the response factor (Ky) which expresses the relative yield decrease (1-Ya/Ym). In maize, generally, yield losses are proportionally greater with water stress, when Ky>1. The yield response factor is very important for planning the maize production.

During 1994-1996 period, yield response factor under dryland conditions had values between 0.66 (Danubiu) and 1.88 (Progres) (Figure 12).

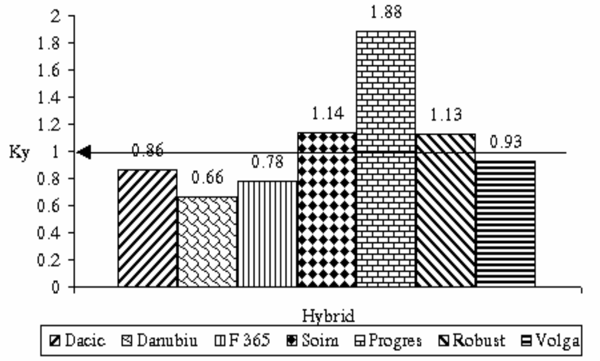


Figure 12. Maize yield response factor (Ky)
Fundulea, 1994-1996

CONCLUSIONS

Testing the maize response to water deficit is necessary for a good distribution of hybrids in different agro-ecological regions.

Certain hybrids such as Fundulea 365, Danubiu and Dacic have a higher grain yield potential both under dryland and optimum conditions. The highest WUE values were registered by Danubiu (29.0 kg/mm), Fundulea 365 (28.3 kg/mm), Progres and Robust (33.2 and 37.8 kg/mm respectively).

Maize response to water deficit has a major importance for establishing the priorities in water application in the driest zones of the country. The drought resistant hybrid Danubiu has a Ky=0.66, followed by Fundulea 365 (Ky=0.78) and Dacic (Ky=0.86). The hybrids with the highest Ky values such as Progres, Robust and Soim have priority in irrigation application.

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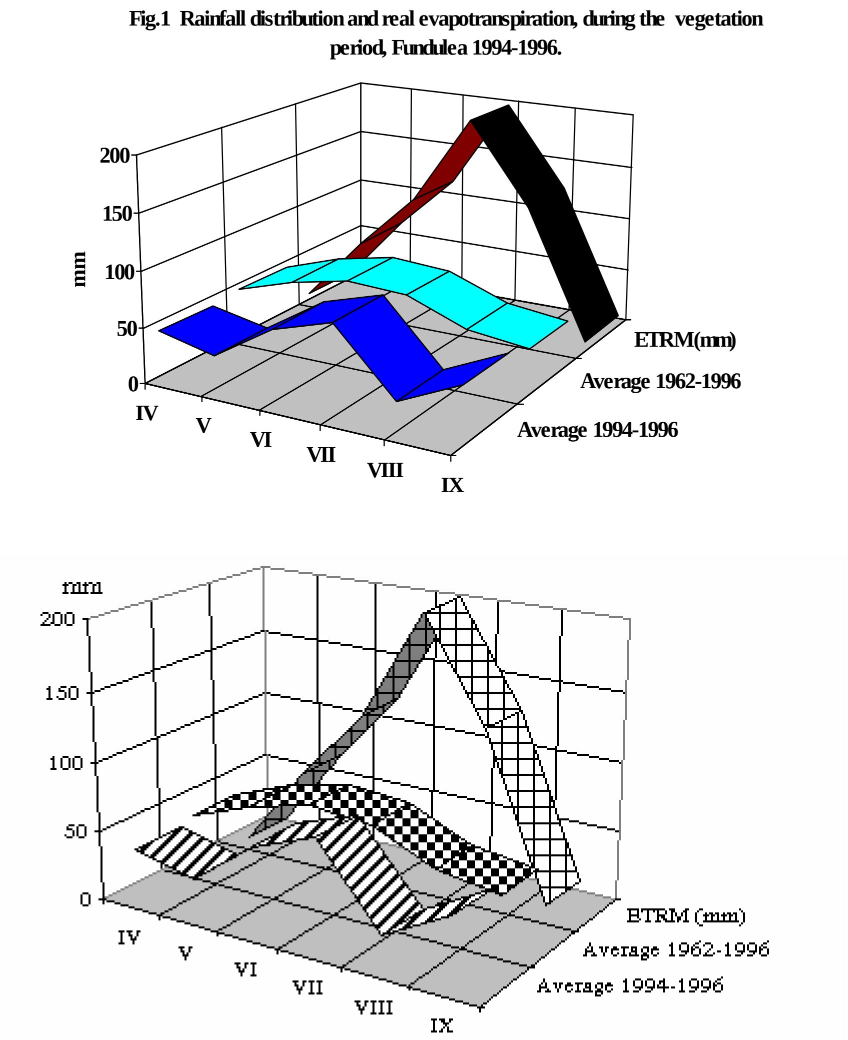


Figure 1. Rainfall distribution and real evapotranspiration, during the vegetation period, Fundulea 1994 – 1996

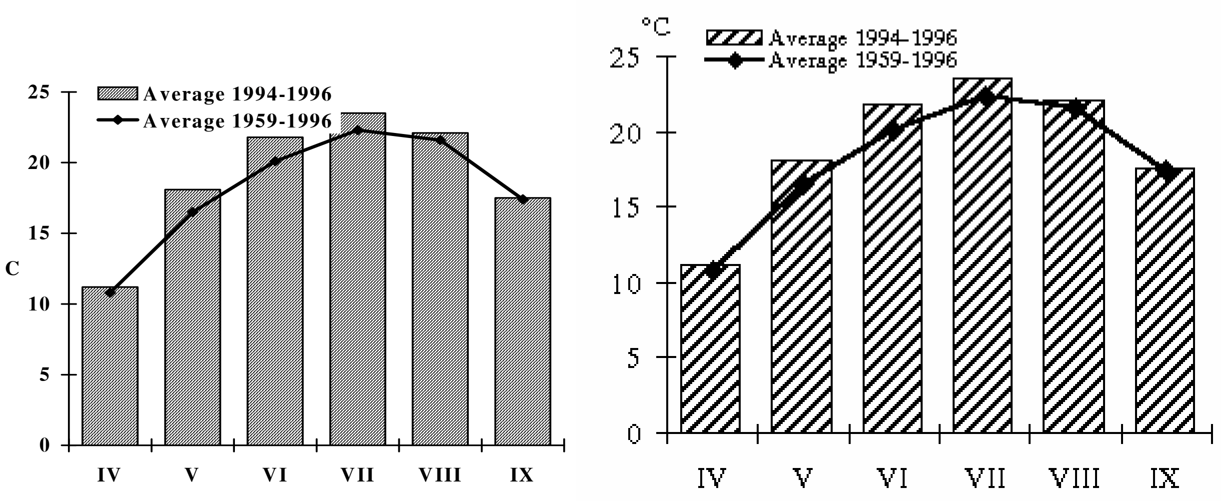
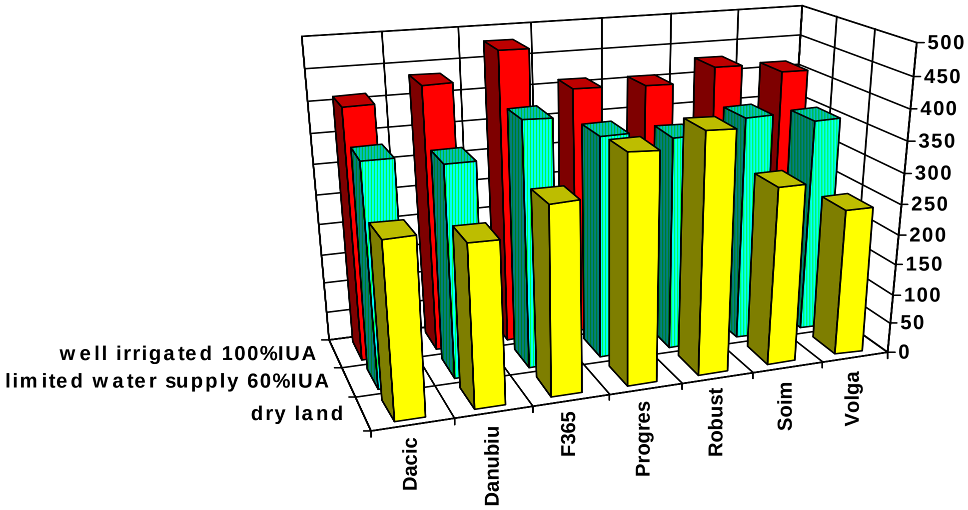


Figure 2. Thermic conditions under maize vegetation period, Fundulea 1994 – 1996

Fig. 3 Maize water consumption on vegetation period, Fundulea 1994-1996



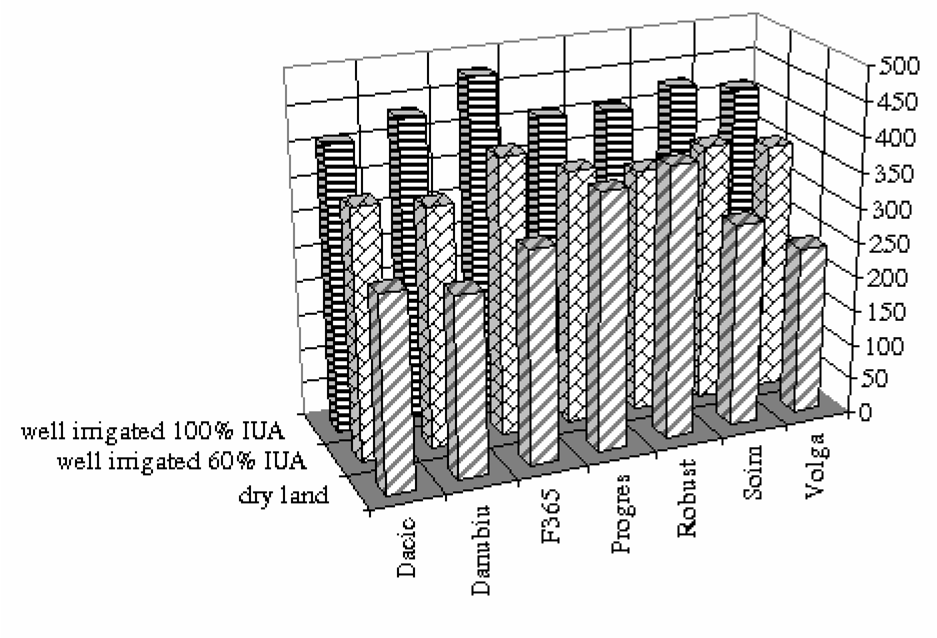
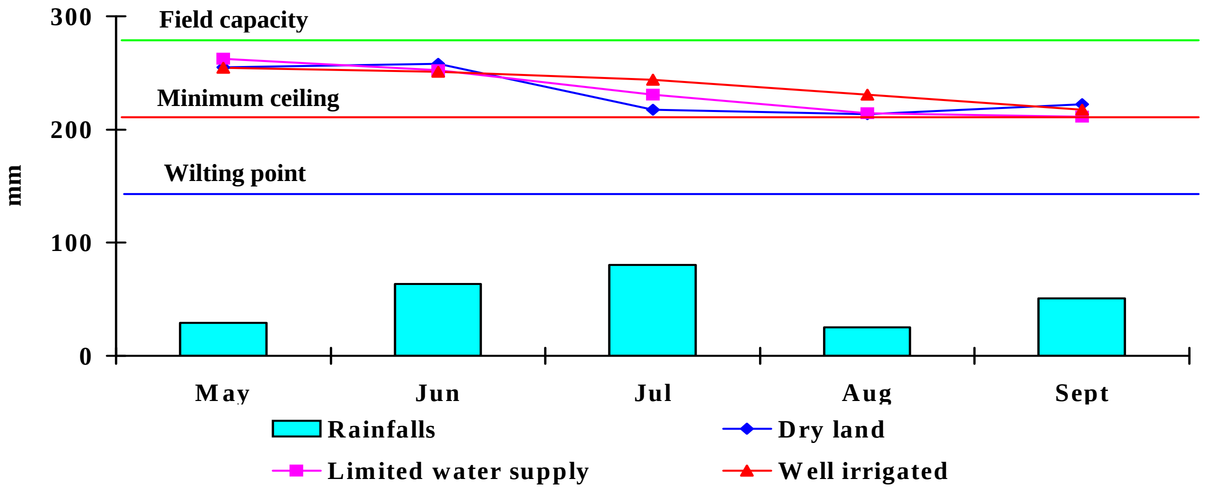


Figure 3. Maize water consumption on vegetation period, Fundulea 1994 - 1996

Fig. 4 Evolution of soil moisture at 0-80 cm depth, under maize vegetation period, Fundulea 1994-1996.



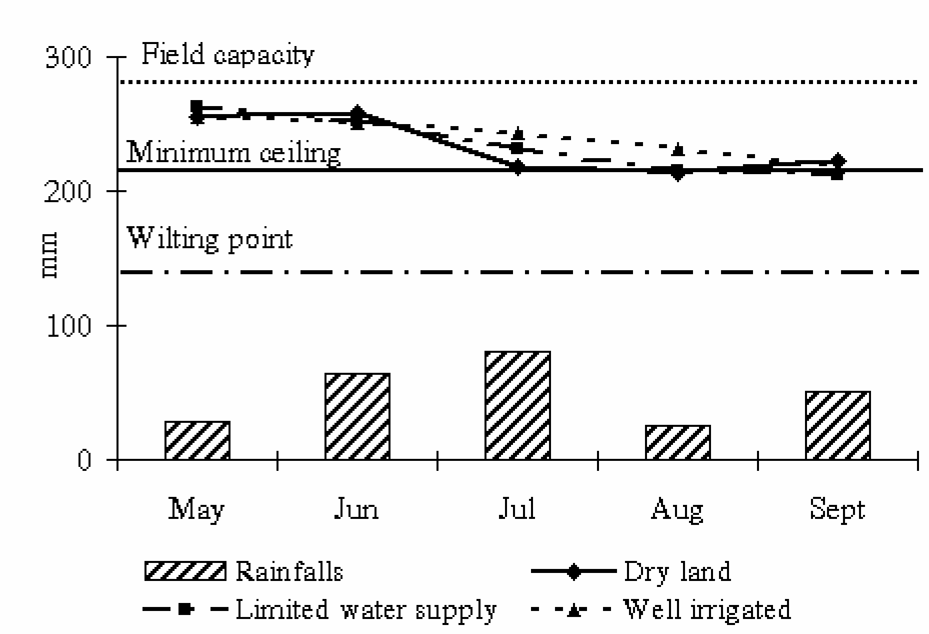
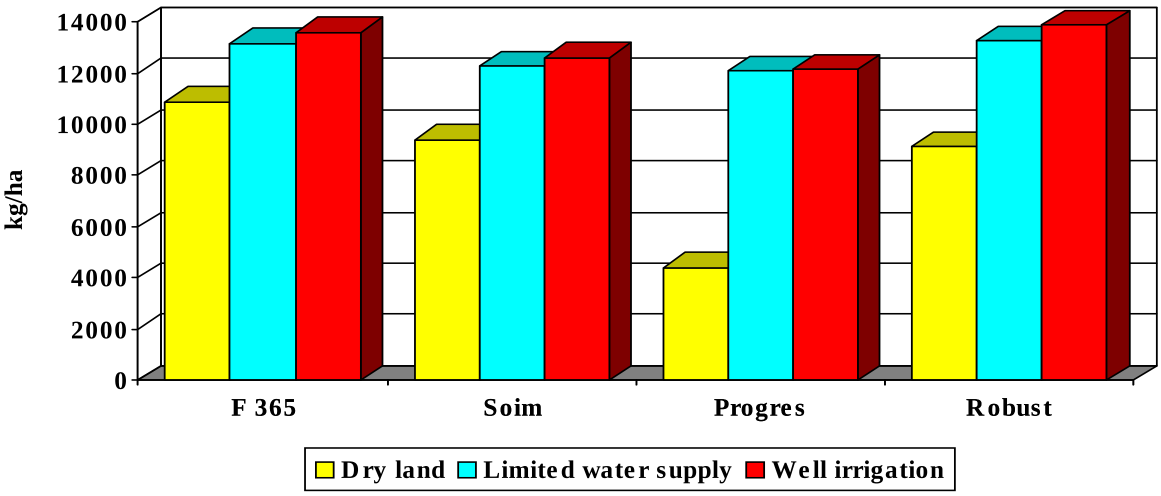


Figure 4. Evolution of soil moisture at 0-80 cm depth, under maize vegetation period, Fundulea 1994 - 1996

Fig. 5 The influence of irrigation under maize grain yield, Fundulea 1994.



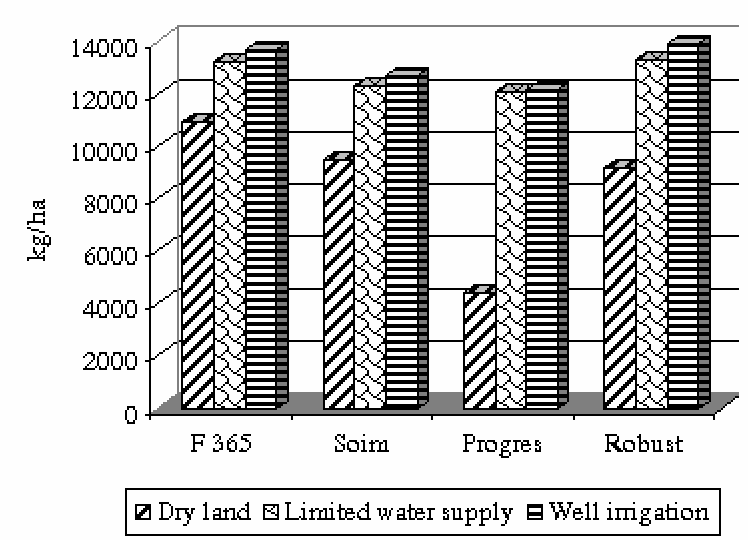
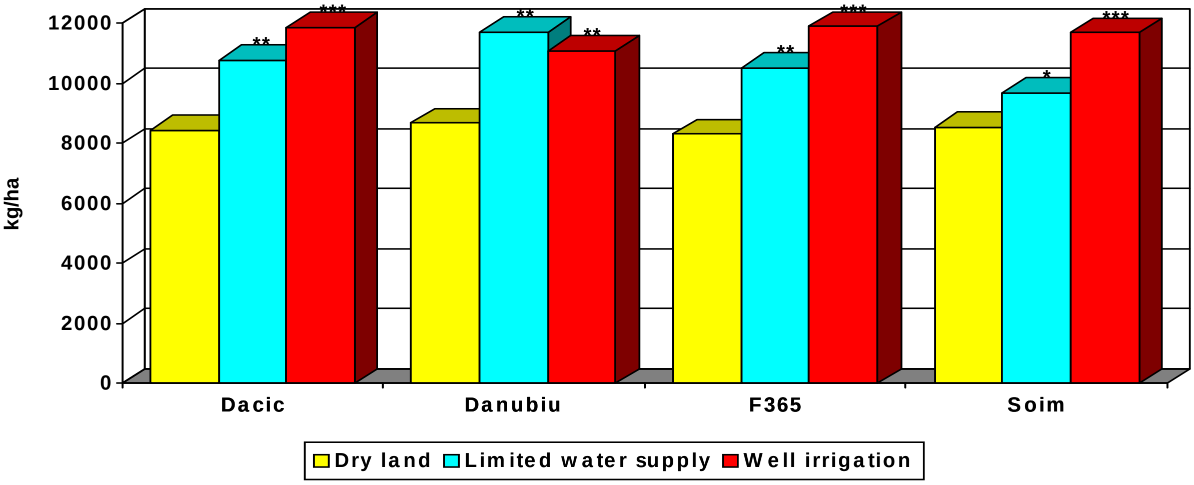


Figure 5. The influence of irrigation under maize grain yield, Fundulea 1994

Fig. 6 The influence of irrigation on maize grain yield, Fundulea 1995



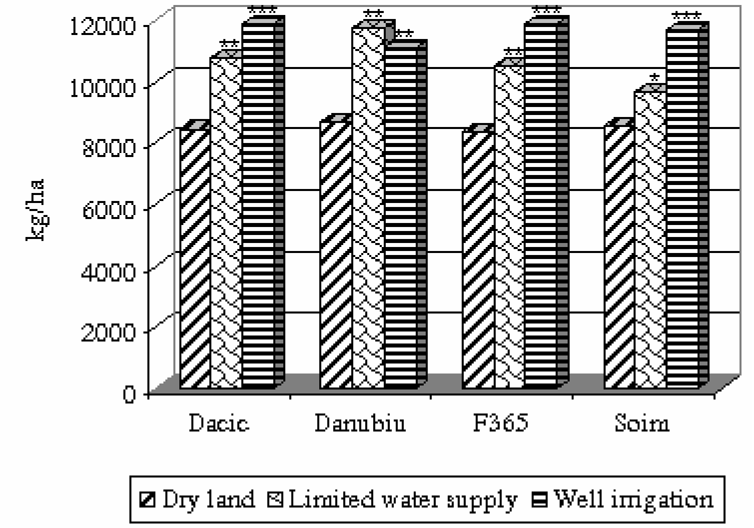
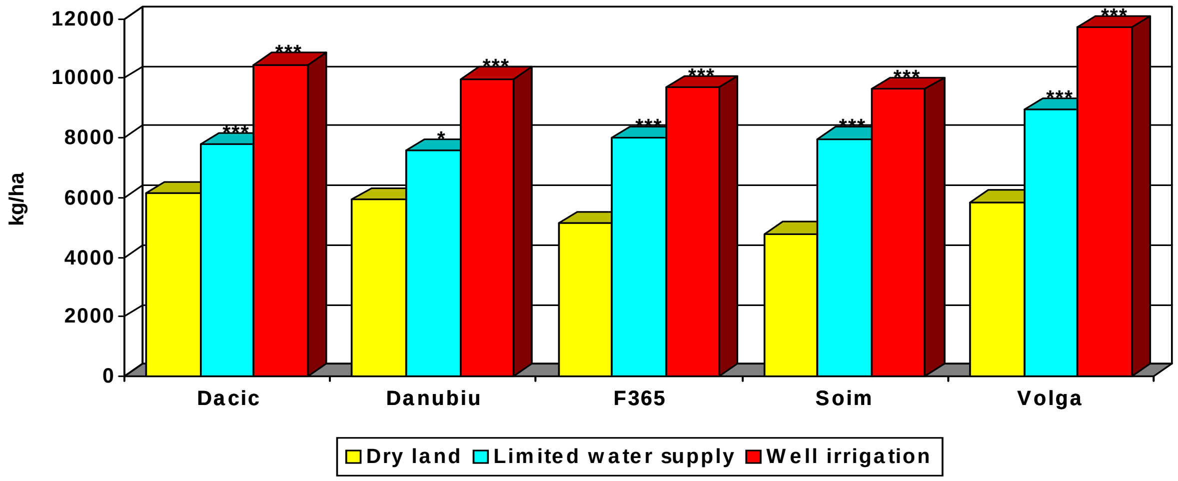


Figure 6. The influence of irrigation under maize grain yield, Fundulea 1995

Fig. 7 The influence of irrigation on maize grain yield, Fundulea 1996



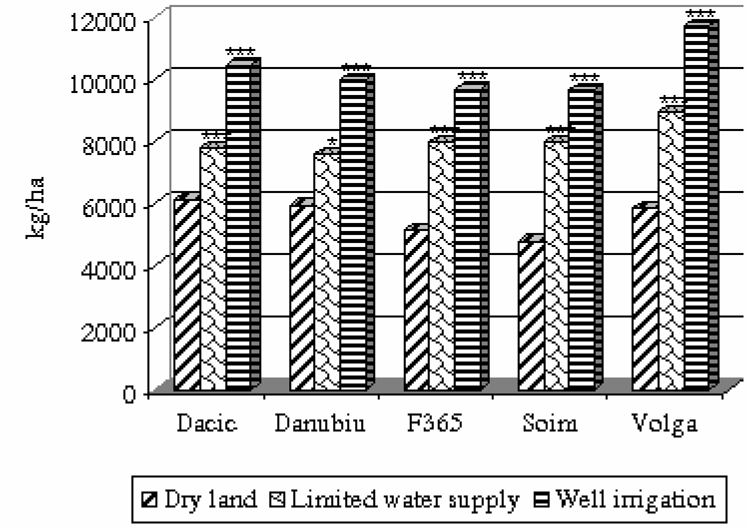
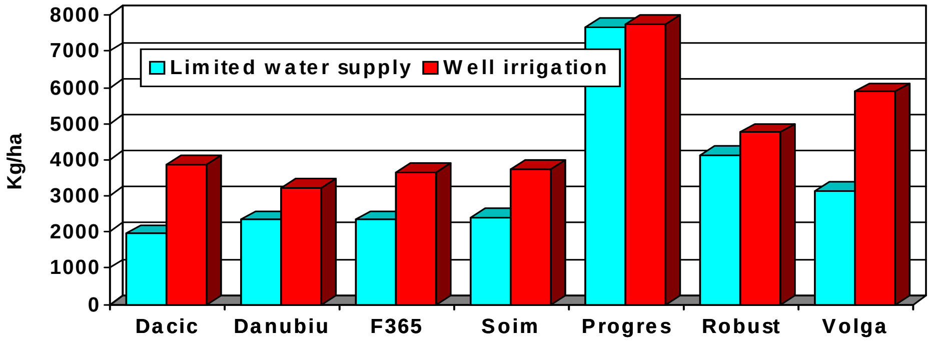


Figure 7. The influence of irrigation under maize grain yield, Fundulea 1996

Fig. 8 The influence of irrigation on maize grain yield returns, Fundulea 1994 - 1996.



1994-F365,Soim, Progres, Robust; 1995-Dacic, Danubiu, F365, Soim; 1996-Dacic, Danubiu, F365, Soim, Volga

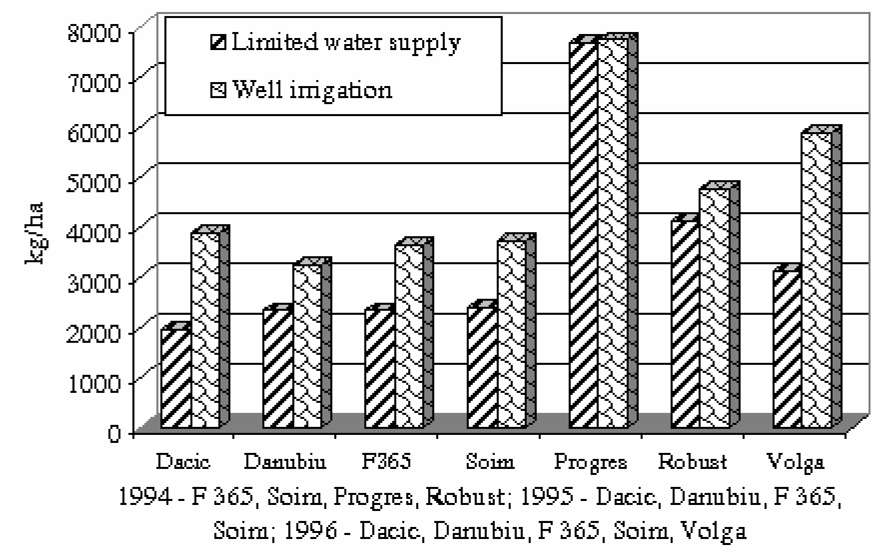
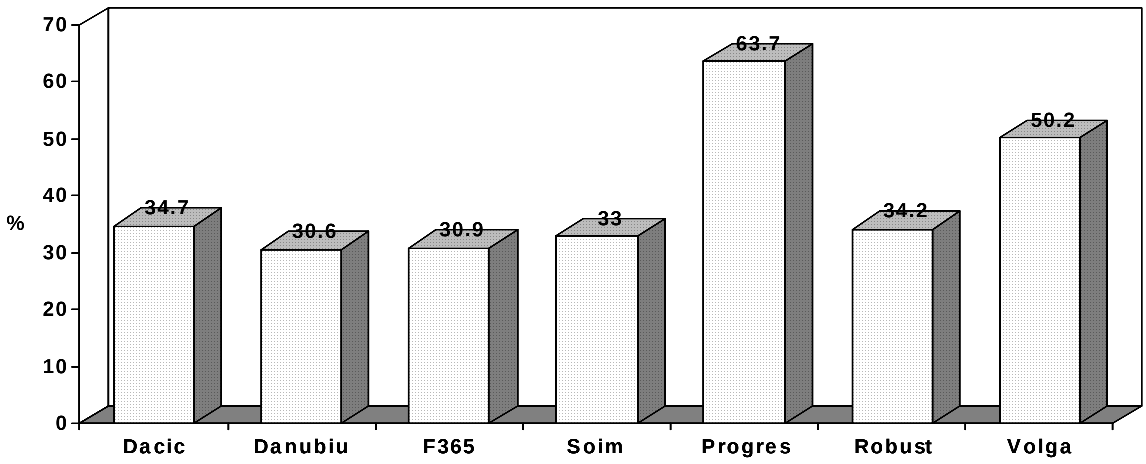


Figure 8. The influence of irrigation on maize grain yield returns, Fundulea 1994 – 1996

Fig. 9 The influence of hidric stress on maize grain yield loses, Fundulea 1994-1996



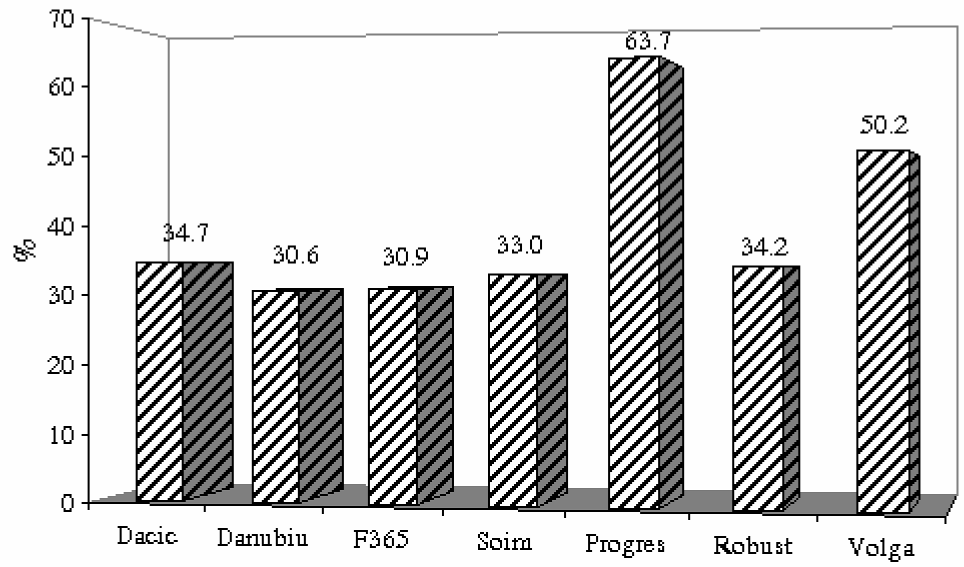


Figure 9. The influence of hidric stress on maize grain yield loses, Fundulea 1994 - 1996

Fig. 10 Maize water use efficiency, Fundulea 1994-1996

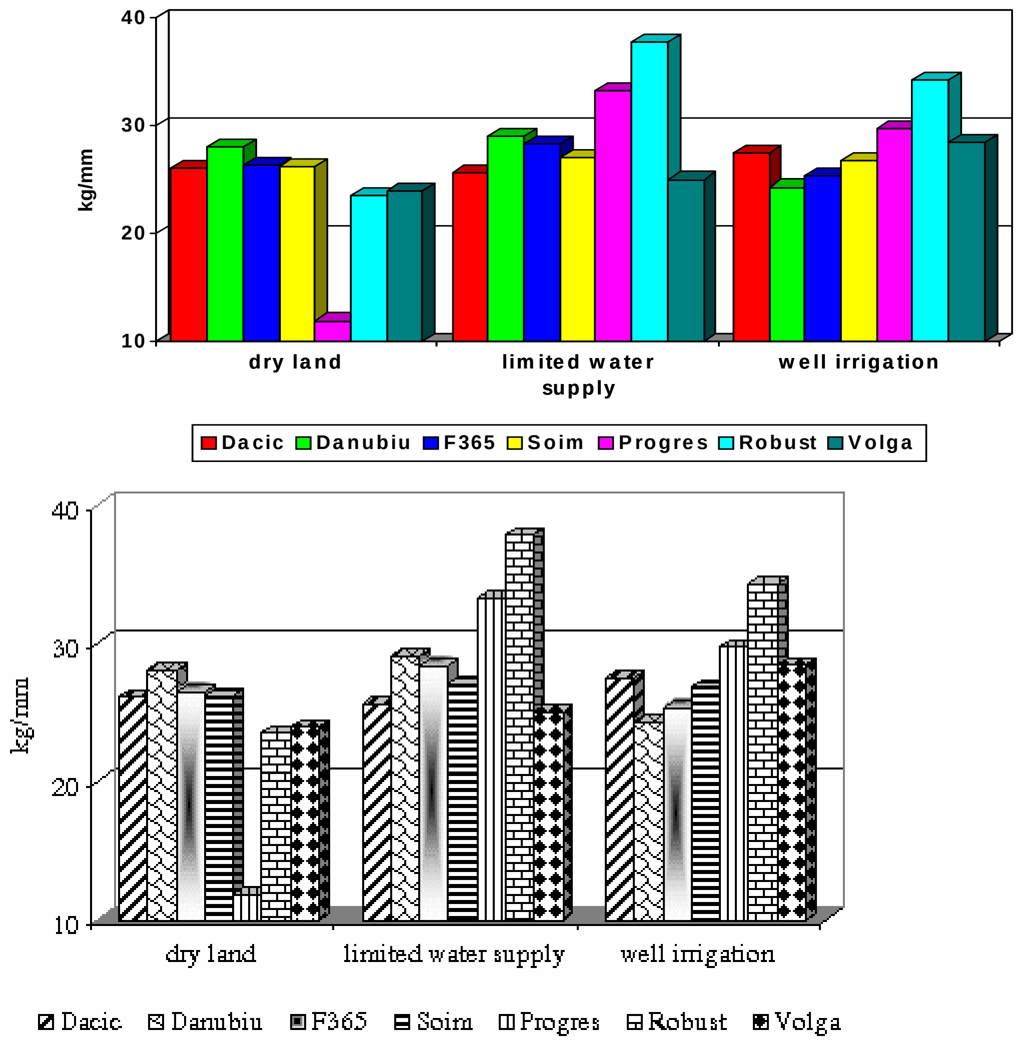
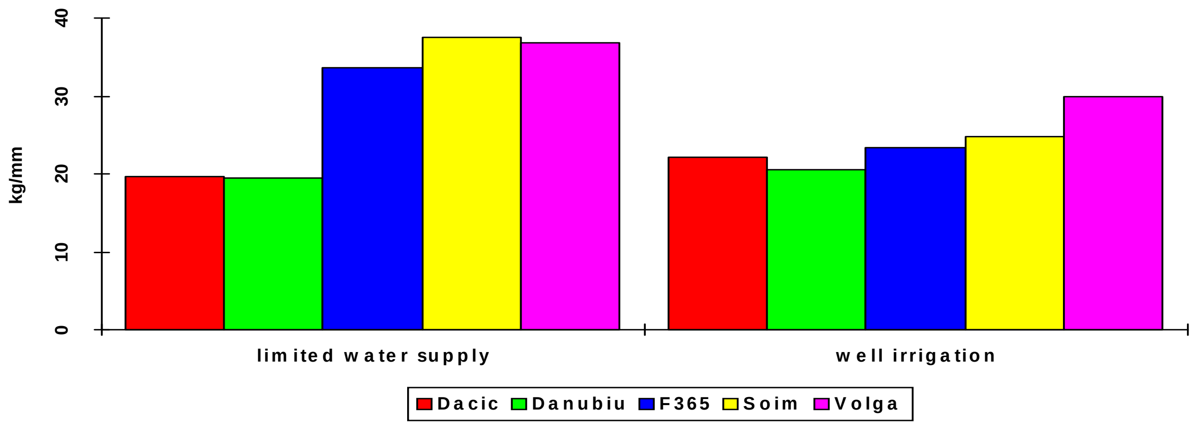


Figure 10. Maize water use efficiency, Fundulea 1994-1996

Fig. 11 Maize irrigation efficiency, Fundulea 1996



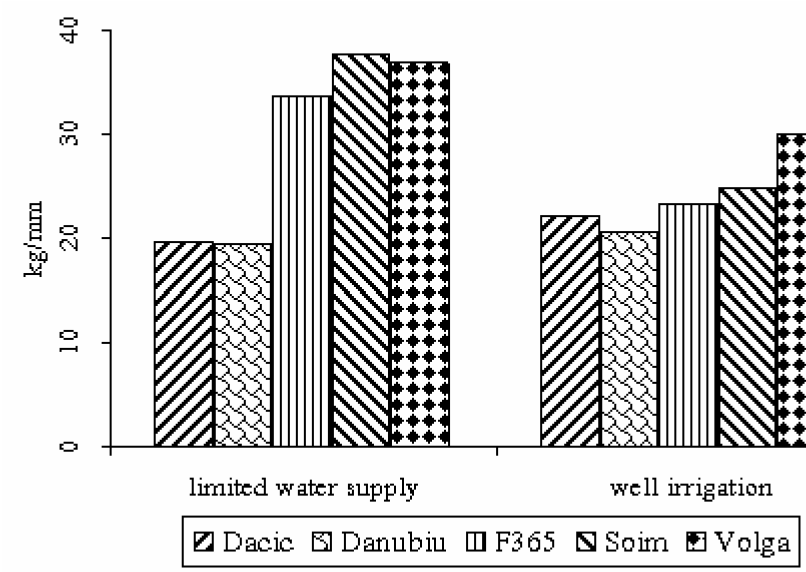
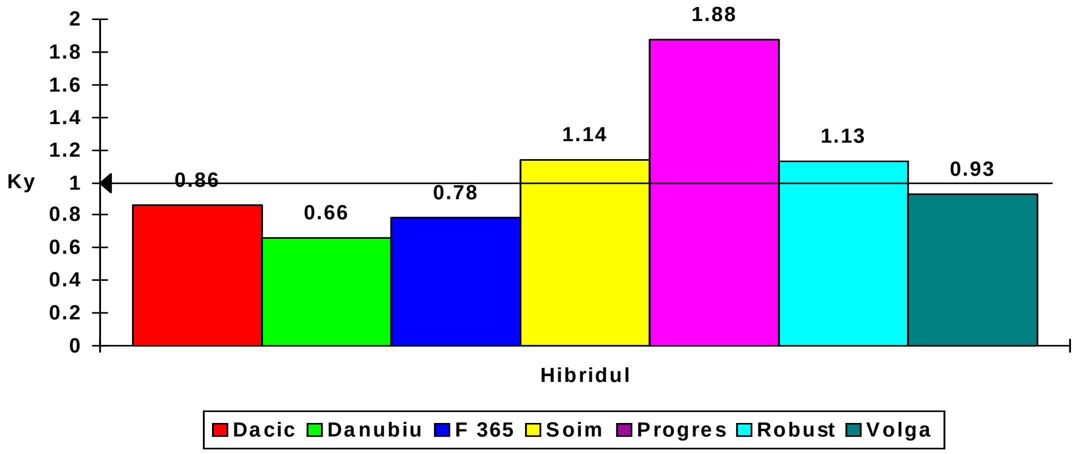


Figure 11. Maize irrigation efficiency, Fundulea 1996

Fig. 12 Maize yield response factor(Ky), Fundulea 1994 - 1996.



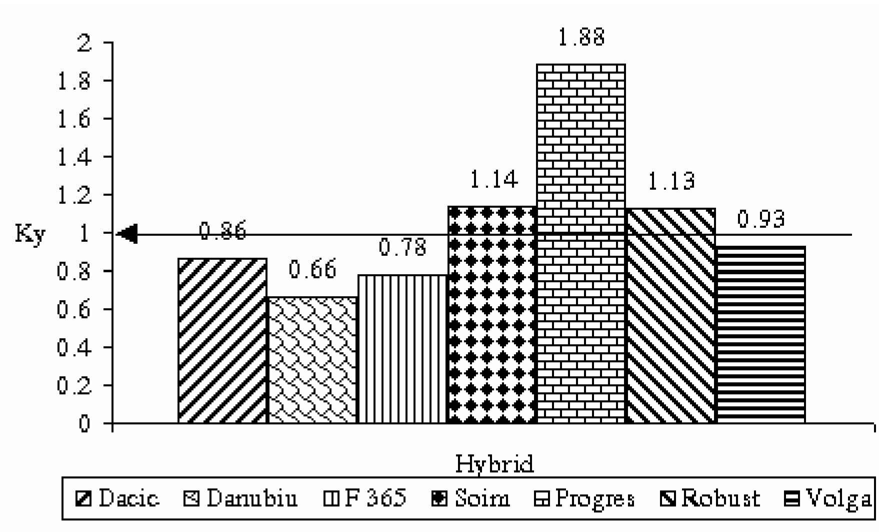


Figure 12. Maize yield response factor (Ky), Fundulea 1994-1996