Irrigation and N-fertilization effects on kenaf growth and biomass productivity in central Greece

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Abstract

The growth and the biomass productivity of the kenaf variety Tainnung 2 were investigated under optimal and sub-optimal irrigation and N-fertilization inputs in western Thessaly, Greece, in 2004. A 3x4 factorial completely randomized split-plot design was used in three blocks with the main plots comprising three irrigation treatments, and the subplots comprising four nitrogen dressings. The study soil was a deep, calcareous, fertile clayloam, classified as Aquic Xerofluvent, that represents large areas in the extensive Karditsa plain in central Greece. The crop was harvested periodically during the growing period and in each harvest, plant height, stem diameter, leaf area index, total dry, and stem dry biomass were measured. It was found that fertilization within the studied rates did not affect growth and biomass productivity of the crop, apparently due to the high fertility status of the study soil. Contrary to fertilization, a significant (*P=0.05*) effect of irrigation was found, with the fully irrigated plants (500 mm) reaching maximum growth rates in excess of 270 kg $ha^{-1}d^{-1}$ and dry biomass reaching 17.5 t ha^{-1} and by 9% and 21% lower productivity for irrigation inputs equal to 50% and 25% of the potential evapotranspiration, respectively. Stem biomass contributed to about 90% of the total dry biomass for all treatments by the end of the growing period. The leaf area index reached 4.3 (full irrigation), and remained above 3 (in all treatments) for large parts of the cropping period. Maximum height and stem diameter of the fully irrigated plants were 337 cm, and 2.5 cm, respectively.

Keywords: kenaf, biomass production, fiber crops, irrigation, fertilization, Greece.

1. Introduction

Kenaf (*Hibiscus cannabinus* L., *Malvaceae*) is a warm-season annual C_3-crop, relative to cotton, which has been suggested by several researchers for use as both fiber and fodder crop and particularly for the newsprint paper pulp and other paper industry products, as its fast-growing and high yielding pulp is easily obtained (Clark *et al.,* 1962; White *et al.,* 1970; Taylor, 1992; Webber, 1993). Data from literature report a large variation in biomass productivity, due to environmental conditions, sowing time, irrigation, plant density and fertilization. This study mainly focuses on the effect of irrigation and N-fertilization, on kenaf components. Recent data from kenaf trials in Greece and Spain (Danalatos and Archontoulis, 2004; Gonzalez Moreno *et al*., 2004) confirm that the crop does not respond to different N-applications, and an amount of 50 kg N ha^{-1} seems appropriate under various farming and environmental conditions. Kenaf is characterized by an extensive root system allowing water uptake from deep soil horizons. Previous relevant experimental results show that kenaf may reach potential production with only 350 mm of irrigation (22 t ha^{-1}) under central Greek conditions (Danalatos & Archontoulis, 2004). Considering that most traditional crops in the study region need by far more irrigation and fertilization inputs, the option of introducing low-input alternative crops such as kenaf should be seriously taken into consideration in future land use planning. The objective of this study is to investigate the growth and biomass productivity of kenaf variety Tainnung-2 under central Greek conditions in the light of data collected in the second year of a field experiment, under optimum and sub-optimum irrigation and N-fertilization inputs.

2. Materials and Methods

A field experiment was carried out on a deep, fertile, loamy soil located in Palamas, Karditsa (central Greece) in 2004 (coordinates: 39°25'43.4'' N, 22°05'09.7'' E, altitude 107.5 m). A 3x4 factorial completely randomized spit-plot design was used in three blocks with the main plots comprising three irrigation treatments (I_1=25, I_2=50, and I_3=100% of the potential evapotranspiration), and the subplots comprising four nitrogen dressings (N_0=control, N_1=50, N_2=100, and N_3=150 kg N ha^{-1}). The crop was sown on June 1st at distances of 0.50 m between the rows and 0.10 m within the rows. Emergence was recorded 7 days later, and 50% flowering was recorded in mid-October. Irrigation was applied using a drip irrigation system (I_1=125, I_2=250, and I_3=500 mm, until 1st decade of October). All plots had received a basal dressing of 50 kg P ha^{-1} and 100 kg K ha^{-1} at 29/5/2004. The growth parameters (plant height, basal stem diameter, and LAI) and dry biomass yield (leaves, stems, and storage organs) were measured in subsequent harvests throughout the growing period and particularly on the dates: 4/7, 21/7, 4/8, 22/8, 9/9, 3/10, 30/10, and 19/11/2004. Weather data (radiation, air temperature, rainfall, air humidity, wind speed and class-A pan evaporation rate) were recorded hourly on an automatic meteorological station installed next to the experimental site. All data were subjected to analysis of variance for each character using MSTAT-C (version 2.1, Michigan State University, 1991) software.

Standard soil physical and chemical analyses were carried out at the Institute of Soil Mapping and Classification, Larissa. The soil under study is an imperfectly drained, calcareous (pH=8-8.2) loam (sand 40-42%, silt 40-41%, clay 18-19%), developed in recent alluvial deposits and represents a large part of the west Thessaly lowland (central Greece). It is artificially drained, having groundwater table fluctuating from some 150-200 cm below the surface in May (180 cm during sowing) to deeper layers later in the summer, and is classified as Aquic Xerofluvent (USDA, 1975). The high fertility status (organic matter content >1% at 50 cm depth) and water availability of such soils may ensure high growth rates and productivity of summer crops under supplemental irrigation.

3. Results and Discussion

3.1 Climatic conditions

The study area is characterized by a typical Mediterranean climate with hot, dry summers and cool, humid winters. As illustrated in Fig. 1, the air temperature fluctuated 1-4 ^{o}C under the average climatic value for the most of the growing period. From mid-June to mid-July the average air temperature of 2004 were the same cooperating to climate value (26 ^{o}C) but decreased thereafter until the end of September to 22.8 ^{o}C (2.8 ^{o}C under the average climatic value). After this period and until crop maturation air temperature increased in regular levels for the area. The total rainfall (effective rainfall) during the growing period was 190 mm, 83 mm less than the climatic value (Fig. 1). A 35% of the effective rainfall was recorded at the end of July. In general, the growing period of 2004 was characterized by somewhat lower air temperatures and rainfall inputs than in an average year.

3.2 Plant height

Plant height (Fig. 2), kenaf performed in all treatments similar growth rates of about 3.4 cm d^{-1} from emergence until the 1st decade of August. From then on, and until crop maturation (end of October) a significant effect of irrigation (P=0.05) was recorded, with the I_3-irrigated plants performing growth rates in excess of 1.56 cm d^{-1} (1.2 and 1.01 cm d^{-1} for I_2 and I_1, respectively) and a final height of 337 cm (versus 306 and 275 cm for I_2 and I_1). In all cases, the growth rates gradually decreased after flowering. Contrary to irrigation, no effect of N-fertilization on plant height was observed.

3.3 Stem diameter

As illustrated in Fig. 3, base stem diameter was not influenced by the different nitrogen applications. A non-significant superiority of I_3-irrigated plants was found during the cropping period. Maximum increase in stem diameter was observed during the period from early June to early August with rate 0.05 cm d^{-1}, reaching an average value of about 1.91 cm. After this period and until the end of October, stem diameter was influenced by irrigation, reaching finally maximum values of 2.24, 2.42 and 2.5 cm for I_1, I_2 and I_3-irrigated plants, respectively (Fig. 3).

3.4 Leaf area index (LAI)

As presented in Fig. 4, a superiority *(P=0.05*) of the fully irrigated plants in LAI was observed throughout the cropping period. Leaf area index increased from crop's emergence to the 1st decade of September with high rates, reaching peak values in excess of 4.3, 4, and 3.5 in the case of I_3, I_2, and I_1 - irrigated plants. Later on, due to ageing and falling off of the older leaves, LAI deceased gradually, but until the end of September it remained at relatively high levels in the case of irrigation I_3, contrary to the driest treatment (I_1), which performed considerably lower LAI values. Contrary to the effect of irrigation, no significant effect of nitrogen fertilization on LAI was found (Fig. 4), confirming previous experimental results (Danalatos and Archontoulis, 2004).

3.5 Total dry biomass

As illustrated in Fig. 5, the growth and productivity of kenaf were not influenced by N-fertilization in the range of 0-150 kg N ha^{-1}. This is apparently due to the low nitrogen needs of the crop and the relatively high fertility status of the study soil.

These results confirm earlier experimental findings (Danalatos and Archontoulis, 2004) and demonstrate that kenaf is a low input alternative crop.

Contrary to fertilization, a significant effect (*P=0.05*) of irrigation was observed throughout the growing period with the I_3 treatment reaching a maximum growth rates until early August in excess of 273 kg $ha^{-1}d^{-1}$ and about 120 kg $ha^{-1}d^{-1}$ until the end of October, reaching maximum dry biomass production of 17.54 t ha^{-1} for treatment I_3, versus 15.97 and 13.86 t ha^{-1} for treatments I_2 and I_1, respectively (Fig. 5). As in the previous experimental year (2003), the I_2–irrigated plants (50% of potential evapotranspiration) yielded 85-90% of the maximum total dry biomass, which means that under the prevailing soil and climatic conditions of Western Thessaly, kenaf is a very promising alternative crop. The generally smaller biomass productivity potential in this year comparing to the previous one is attributed to the somewhat delay of sowing and emergence of the crop in 2004.

3.6 Dry stem biomass

Figure 6 present the evolution in dry stem biomass. As in the case of total dry biomass, stem growth was not influenced by N-fertilization in the studied range. A significant effect of irrigation (*P=0.05*) was observed during the growing period, with the I_3 irrigated plants reaching maximum growth rates in the period from late July to mid-August in excess of 181 kg $ha^{-1}d^{-1}$. Average stem growth rates (throughout the growing period) were about 118 kg $ha^{-1}d^{-1}$, and the maximum dry stem biomass was 15.93, 14.36 and 12.37 t ha^{-1} for I_3, I_2 and I_1 treatments respectively. At the early development stages, dry stem biomass comprised only 1/3 of total dry biomass; later on, this percentage increased to 67% by mid-August and reached around 90% (according to the treatment) by the end of November, which confirmed previous experimental results (Danalatos and Archontoulis, 2004) (Fig. 6).

4. Conclusions

It can be concluded that high kenaf productivity and final yields may be obtained with only small N-fertilization inputs in the range of 0-50 kg N ha^{-1} due to the minimal nitrogen requirements of the crop and the high fertility status of the soils in the extensive west Thessaly plain in central Greece. Under full irrigation the dry stem and total dry biomass production recorded were in excess of 15.93 and 17.54 t ha^{-1} respectively. Under irrigation inputs matching 50% of the potential evapotranspiration (i.e. 250 mm), crop yield productivity were near to 90% of the potential productivity, apparently due to the particular soil and climatic conditions of the study area and the high water amount stored in the rootzone. These findings demonstrate that kenaf could be an important alternative biomass crop with low nitrogen requirements and low to moderate water needs in deep fertile Aquic Xerofluvent and more generally Mediterranean soils and this should be considered in future land use planning of the Karditsa plain in Greece.

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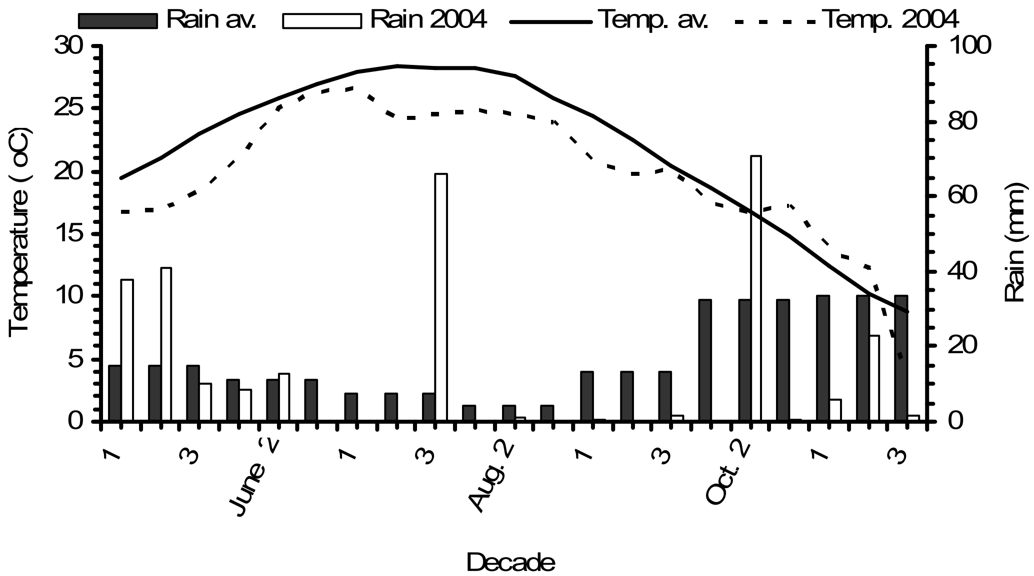


Figure 1: Air temperature and precipitation (10-day mean values) recorded in the study area in 2004 and in an average year (average of 30 years).

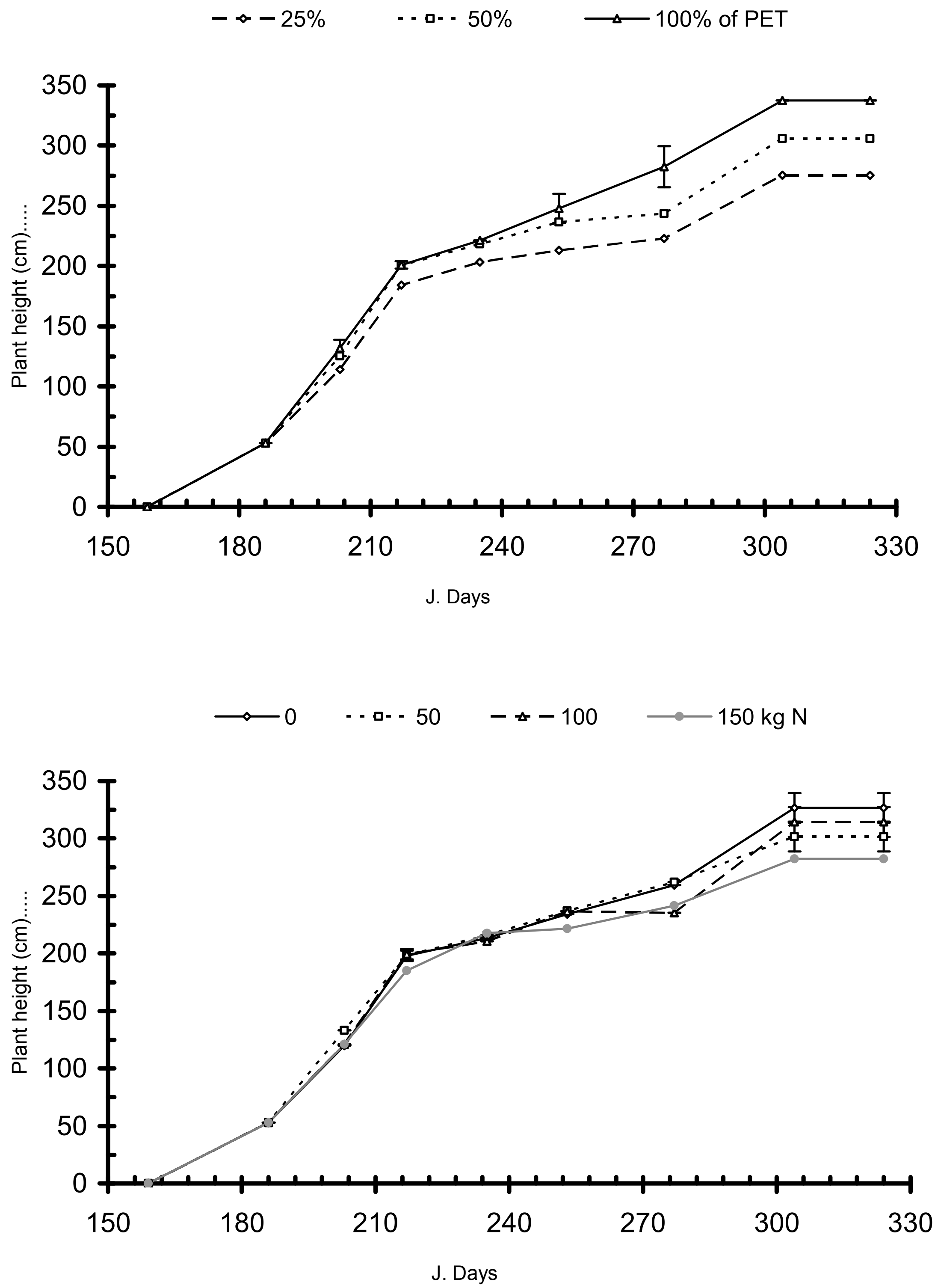
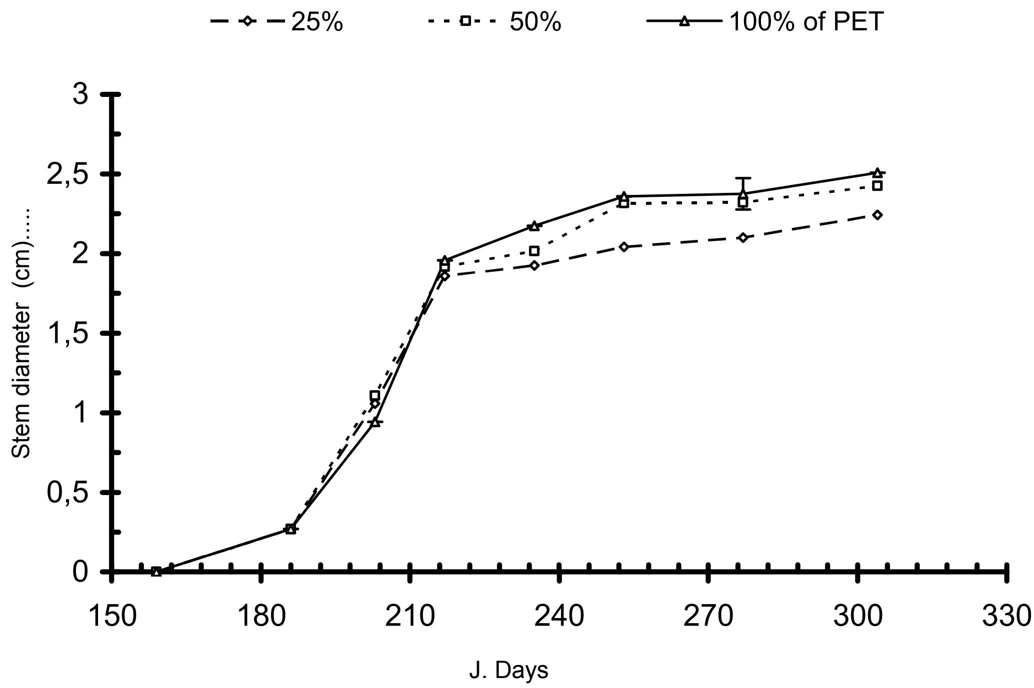
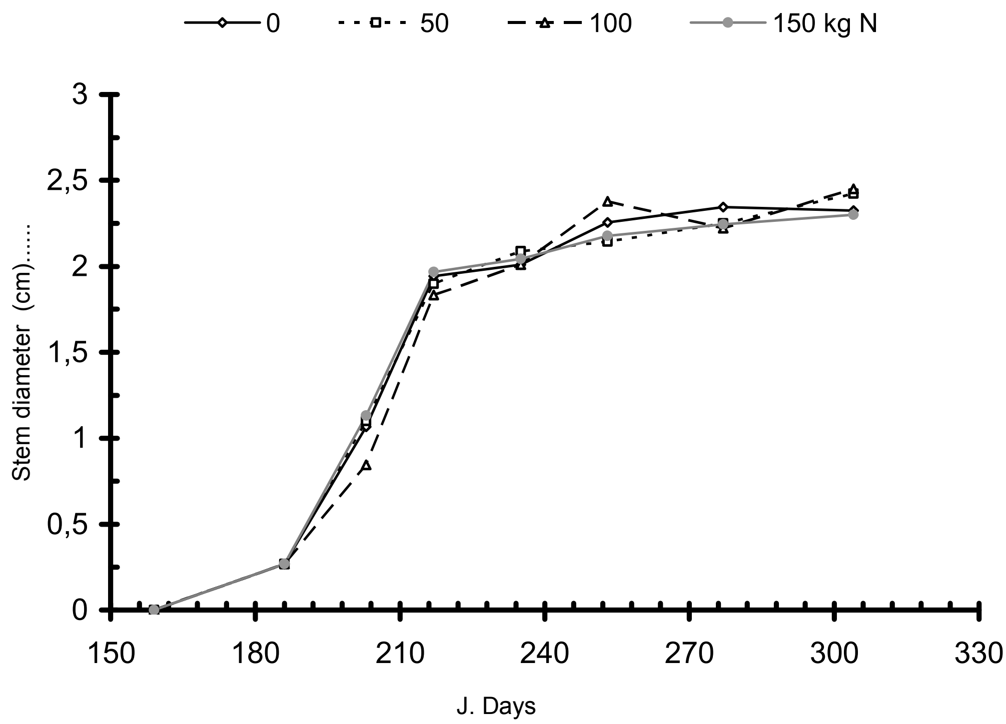


Figure 2: Plant height of kenaf grown in central Greece in 2004 as affected by three irrigation treatments (above) and two N-fertilization inputs (below). (Vertical lines represent $LSD_{0.05}$ if applicable).





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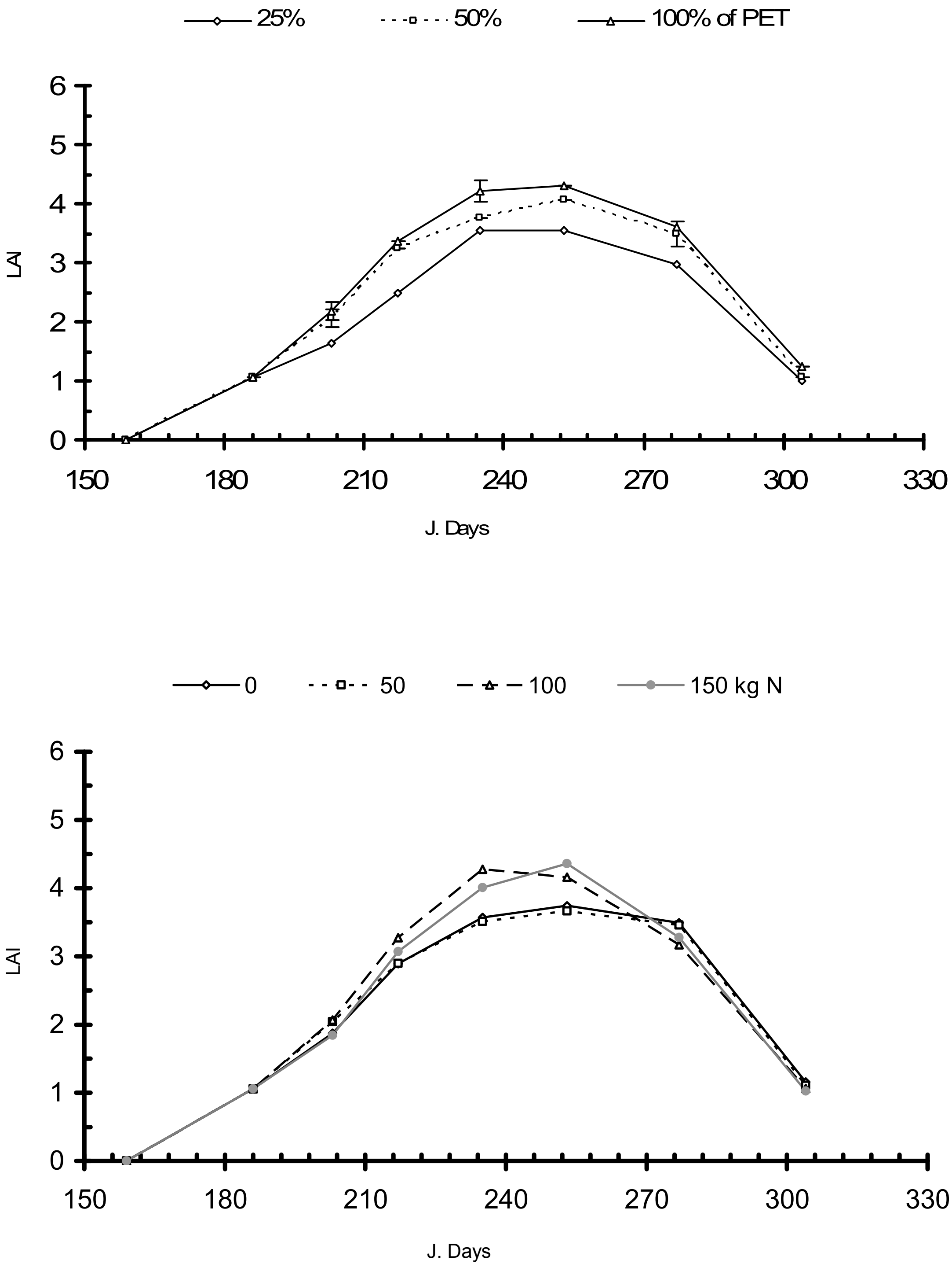

Figure 4: LAI-evolution of kenaf grown in central Greece in 2004 as affected by three irrigation treatments (above) and two N-fertilization inputs (below). (Vertical lines represent $LSD_{0.05}$ if applicable).

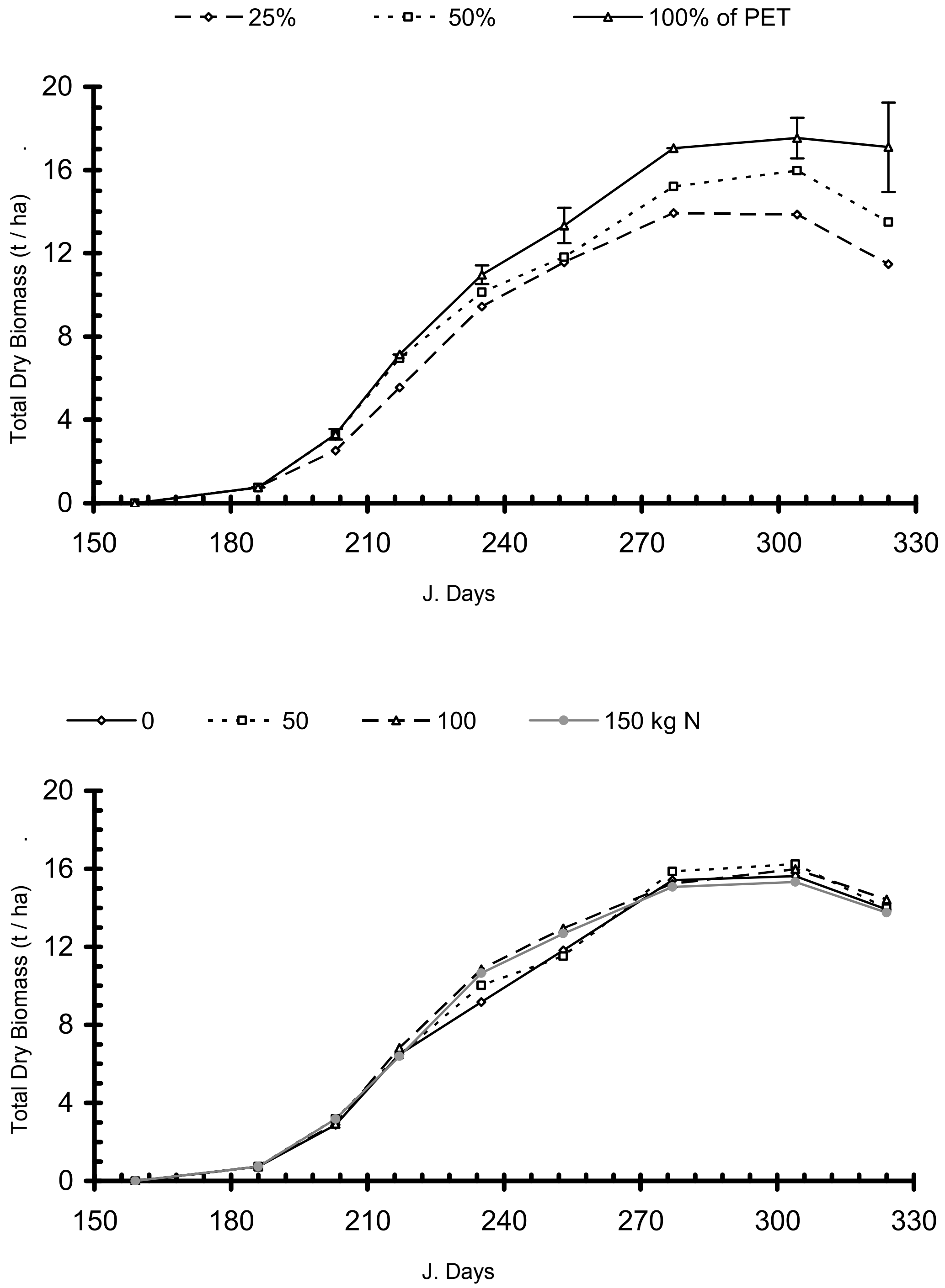

Figure 5: Evolution of total dry biomass of kenaf grown in central Greece in 2004 as affected by three irrigation treatments (above) and two N-fertilization inputs (below). (Vertical lines represent $LSD_{0.05}$ if applicable).

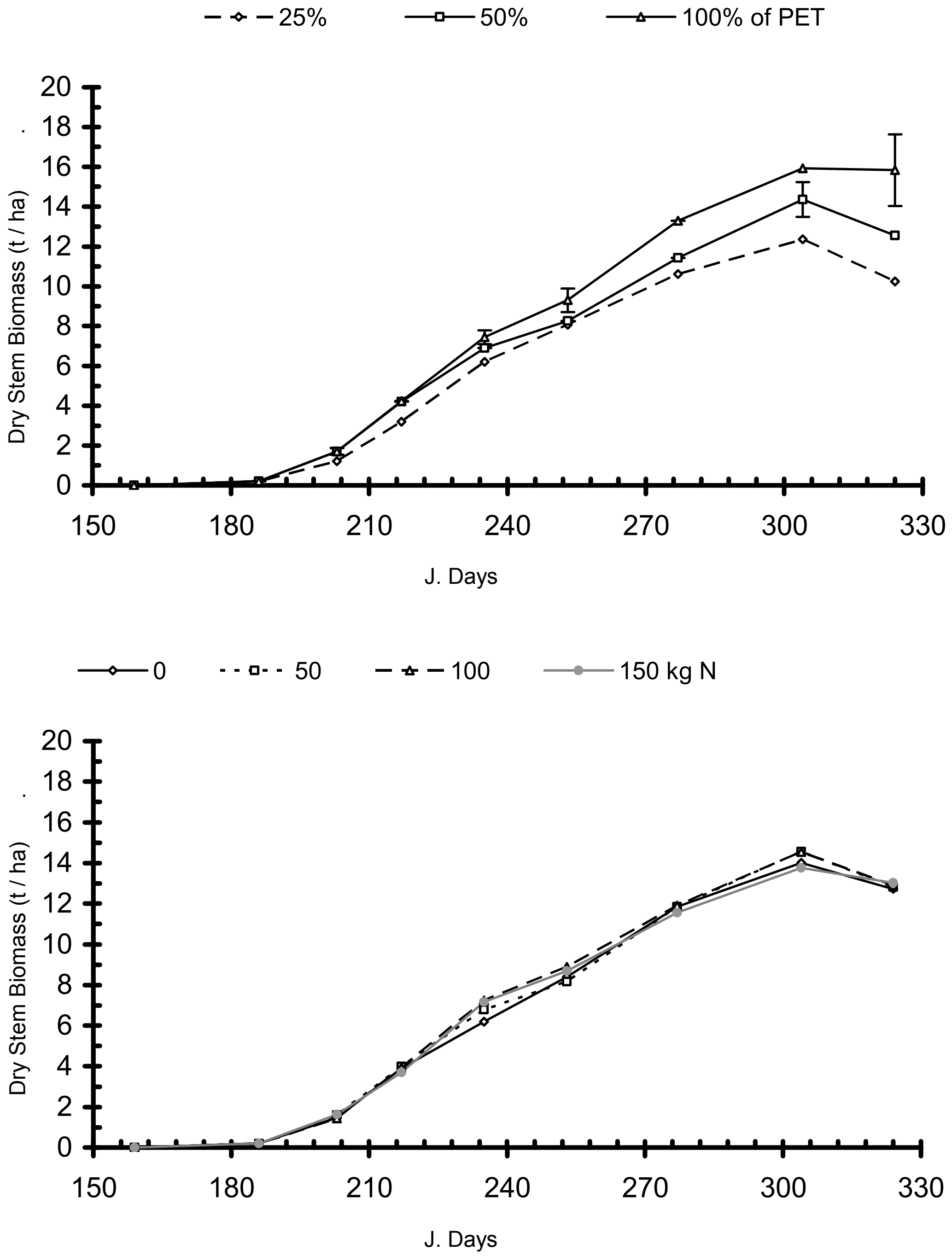

Figure 6: Evolution of dry stem biomass of kenaf grown in central Greece in 2004 as affected by three irrigation treatments (above) and two N-fertilization inputs (below). (Vertical lines represent $LSD_{0.05}$ if applicable).