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AUTOCHTHONOUS PEARL MILLET ECOTYPE (*Pennisetum glaucum L. R.BR.)* RESPONSE TO DIFFERENT SOWING DATES IN TUNISIA

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SUMMARY

Pearl millet *[Pennisetum glaucum (L.)R.Br.]* is a potential crop for the Great plains in Tunisia, but there are no any studies on production practices. The research objective was to determine the optimal planting time for pearl millet in Mediterranean environment.

Studies were conducted in Kairouan (centre of Tunisia) using an autochthonous pearl millet ecotype and seven sowing dates. The experimental design was a complete randomized block design with four replications.

Plant morphological variables as well as yield characteristics were measured and related to sowing date and air heat units. Optimal planting times were determined by relating yield components with calendar date and with GDD (growth day degree). Grain panicle yield related to air heat units was effective in determining the optimal planting time.

Optimal pearl millet planting times were between 1549 and 1441 GDD; base 10°C; or between 296 and 563 air heat units after 1 April for Kairouan.

Pearl millet had large planting time window, allowing flexibility in planting time. Very early sowing before early May did not generate any advantages for earliness and yield components.

Most suitable period for pearl millet sowing is between first May and early June for the Mediterranean region which offers a long and suitable environment for both main and double crop production.

Key words: Mediterranean climate, yield components, thermal units, pearl millet, planting date

INTRODUCTION

Pearl millet *(Pennisetum glaucum L. R.Br.)* is a drought-tolerant cereal grain typically grown as grain crop in Tunisia. All pearl millet production is used for a variety of food products.

Pearl millet can potentially be planted as a double crop after winter wheat or barley in southern areas. It is planted in early summer when soils have warmed up.

Many autochthonous pearl millet ecotypes have generated interest in millet as a substitute for sorghum because of its ability to reliably produce grain on sandy and low fertility soils of the south of Tunisia.

Plant breeding efforts to develop pearl millet as summer annual forage crop to replace forage sorghum for low water-holding soils and short growing season areas of the Great Plains will take place in the future.

Pearl millet in Tunisia is generally seeded early April through late June depending upon geographical location, physiological maturity of ecotypes, and environmental conditions in the region. Differences in response to planting date have been noted in late season plantings compared with early season planting dates.

Pearl millet is a potential crop for the Great Plains, but there are few studies on production practices. In the plain of Kairouan (centre of Tunisia with arid climate), farmers plant pearl millet early (mid April) and they do not have good yield. In this region, there is no clear optimum planting date for this crop.

Planting dates must be chosen within a window of opportunity defined by cropping system and available soil moisture.

Planting date dictates to a large degree how tall the plants will get, and the potential impact of certain insects and diseases on the crop. It also determines the size of the root system, which in turn determines how much stored water the plant can utilize.

Crop management practices such as cultivar selection, time of sowing and duration of cultivar’s life cycle may influence the growth, yield and seed quality of many crops (Caliskan et al., 2008). Sowing date is an important production component that can be manipulated to counter the adverse effects of environmental stress.

Planting date can have a dramatic effect on crop development and yield. In fact, proper planting date is important for maximizing cereal grain yields (Witt, 1996) because optimum seeding dates establish healthy and vigorous plants.

A significant reduction in grain yield has been shown to occur with delayed seeding for a wide range of climatic conditions (Knapp and Knapp, 1978, Dahlke et al., 1993)

In fact, Lawn et al. (1993) have argued that differences in development of cereals sown at different times may be explained by considering an optimum temperature T_0, above which rate of development decreases.

Planting time recommendations for pearl millet and grain sorghum are commonly made based on calendar day (day of the year) and/or soil temperature (Mick, 1997; Andrews et al., 1998).

A study has been undertaken on the growth, development, and yield potentials of KS pearl millet ecotype showing a large genetic variability in growth parameters in different sowing date. Therefore, research was conducted in 2005 at Kairouan to determine if relative maturity and grain yield of KS pear millet ecotype differed when seeded in late April through late June.

The research objective was to determine the optimal planting time for KS pearl millet ecotype and to determine the influence of planting date on morphological traits and yield components.

MATERIALS AND METHODS

The experiment was carried out at the farm of the Tunisian Agricultural Research Institute in Kairouan during the cropping season of 2005. The site is located at 35°40' latitude and 10° 06' longitude. It has the Mediterranean climate. The soil of the experimental site was clay loam.

Pear millet ecotype KS was sown at 15 day intervals. There were seven sowings in season (April through July): on 24 April (D1), 3 May (D2), 15 May (D3), 25 May (D4), 5 June (D5), 17 June (D6), 1 July (D7), which were divided into four replications each.

The pearl millet ecotype KS was planted into randomized block design with four replications.

The sampling area was 5.5 m², having rows five meters long was used. Sowing was done in hills and row to row distance of 50 cm and hill to hill distance of 30 cm were used.

A basal dose of 50 kg N in the form of ammonitrate 33% fertiliser was applied at sowing.

Irrigation and all other agronomic practices were carried out uniformly for all the experimental units. Total irrigation volume of 420 mm was applied for all dates.

Data were recorded on:

- days to maturity
- plant height
- panicle length
- panicle weight
- thousand-kernel weights

Data on days to maturity were recorded, when more than 50% of the plants matured in each plot. The data regarding plant height, panicle length, panicle weight and thousand-kernel weights were recorded on 50 plants at time of maturity.

Durations of intervals between stages were measured in days and thermal time was also used, with units of °Cd, calculated by accumulating daily mean screen temperatures above the base temperature of 10°C

Temperatures used to calculate air heat units were daily maximum and minimum temperatures obtained from Meteorology National Institute located within 1 km of the research plots.

Daily air heat units were calculated using the model developed by Ong and Monteith (1985) and summed over time as follows:

Air heat units = $[(T_{max} + T_{min})/2$ _ $(T_{base})]$

Where T_{max} is daily maximum air temperature (°C), T_{min} is daily minimum air temperature (°C) and T_{base} is base air row temperature set equal to 10C°C for pearl millet

Estimated air heat units after 1 April were calculated using the same methods as for cumulative thermal time (°Cd), with a base temperature of 10°C.

Data were statistically analyzed using analysis of variance techniques appropriate for randomized complete block design. Main and interaction effects were separated by LSD test at 0.05 level of probability, if the F-values were significant.

RESULTS

1. Days from seedling emergency to maturity

Statistical analysis revealed that planting dates had significant effect on days to maturity of pearl millet ecotype (table 1). Early planted crop took maximum number of days (108 days) to maturity. A steady decrease in number of days to maturity took place when planting was delayed to July. The plants of the D_7 sowing date had much shorter duration period than D_1.

Table 1. Main effect of sowing dates on days to maturity, plant height, panicle length, panicle weight, panicle yield and thousand grain weight of Pennisetum glaucum

Tablica 1. Glavni učinak datuma sjetve na dane do dozrijevanja, visinu biljaka, duljinu i težinu cvati te masu 1000 zrna Pennisetum glaucum

Sowing date *Datum sjetve*	Days to maturity *Dana do zriobe*	Plant height (cm) *Visina biljke (cm)*	Panicle length (cm) *Dužina cvati (cm)*	Panicle weight (g) *Težina cvati (g)*	Panicle yield (g) *Prinos cvati (g)*	Thousand grain weight (g) *Masa 1000* zrna (g)
D1	108 a	150 c	13.47 abc	21.73 c	14.72b c	12.0 b
D2	101 b	184 b	15.73 a	33.54 abc	21.76 a	13.9 a
D3	92 c	200 ab	14.17 ab	34.43 abc	21.86 a	12.0 b
D4	86 d	203 ab	14.37 ab	38.76 ab	22.21 a	12.5 b
D5	78 e	224 a	14.50 ab	45.66 a	20.81 ab	10.0 c
D6	76 e	197 ab	11.93 c	31.38 bc	15.05 bc	9.0 cd
D7	72 f	184 b	11.67 c	23.76 c	12.53 c	8.5 d
Probability > F *Vjerojatnost* Sowing date *Datum sjetve*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Within each column and sowing date, means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range tests

Vrijednosti u koloni za pojedine datume sjetve označene istim slovom statistički se ne razlikuju na razini od 5% po Duncanovovu multiple range testu

On average, KS ecotype planted in April and the first week of May required more than 100 days, whereas KS planted in July required less than 75 days.

The lag of phenological phases between D_1 and D_7, which was 67 days at sowing, decreased to nearly 30 days at maturity.

The concept of thermal time was used to describe days to maturity.

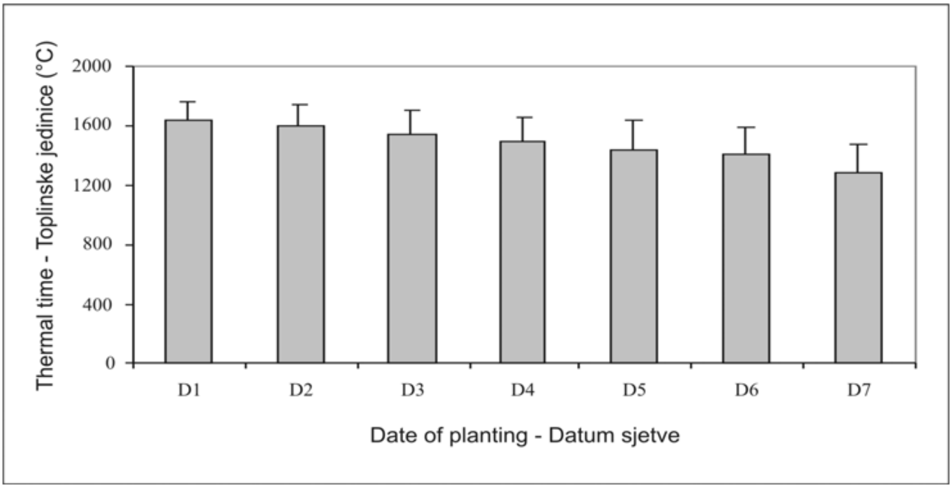
Duration from sowing to maturity, both in terms of number of days and degree-days, varied among sowing dates for KS pearl millet ecotype.

The duration of the growth phase from seedling to maturity was between 1643 and 1288 degree days (°Cd).

Cumulative thermal time between D_1 and D_7 gradually decreased due to delayed sowing.

Plants sown early accumulated more thermal time (Fig. 1).

Fig. 1. Thermal time of KS pearl millet ecotype dependent on sowing date
Graf 1. Toplinske jedinice KS ekotipa bisernog prosa ovisno o datumu sjetve



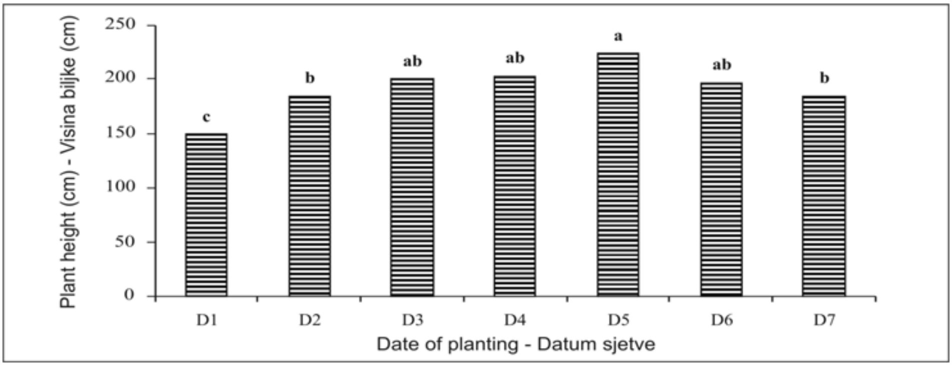
Pearl millet sown during higher temperature regimes takes less GDD from sowing to maturity than sowings carried out during low temperature regimes.

2. Plant height

The statistical analysis of the data indicated that planting dates had significant effect on plant height of KS pearl millet ecotype (Fig. 2).

HAT values increased linearly with increased day length until D_5-D_6 and decreased significantly after this date. Plant height was reduced in early and late planting dates.

Fig. 2. Plant height of KS pearl millet ecotype dependent on sowing date
Graf 2. Visina biljaka KS ekotipa bisernog prosa ovisno o datumu sjetve



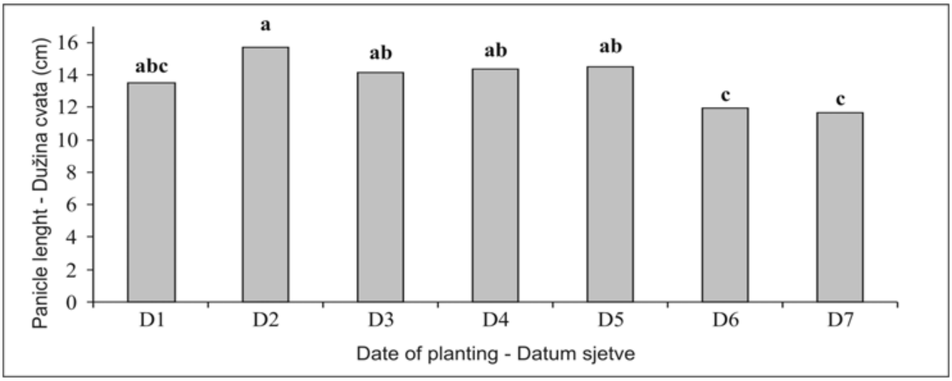
Different letters mean significant differences at p=0.05
Različita slova označavaju signifikantnu razliku uz p=0,05

Maximum plant height of 224 cm was attained by relatively late crop sown on 5 June; and plants sown on 24 April had the lowest mean HAT of 150 cm. Plant height for D_5 sowing date was 49% significantly higher ($P \leq 0.01$) than D_1 and 21.7% higher than D_2 and D_7. The rate of increase in plant height of KS was noted about 2.45 cm height augmentation with one day delay in sowing until D_5.

3. Panicle length

Panicle length was maximized on early May (D_2) and this parameter remained higher until D_5 (early June). After mid June, panicle length decreased by 26%. In early sowing, a decrease in panicle length was lower than on late planting date (Fig. 3).

Fig. 3. Panicle length of KS pearl millet ecotype dependent on sowing date
Graf 3. Dužina cvata KS ekotipa bisernog prosa ovisno o datumu sjetve

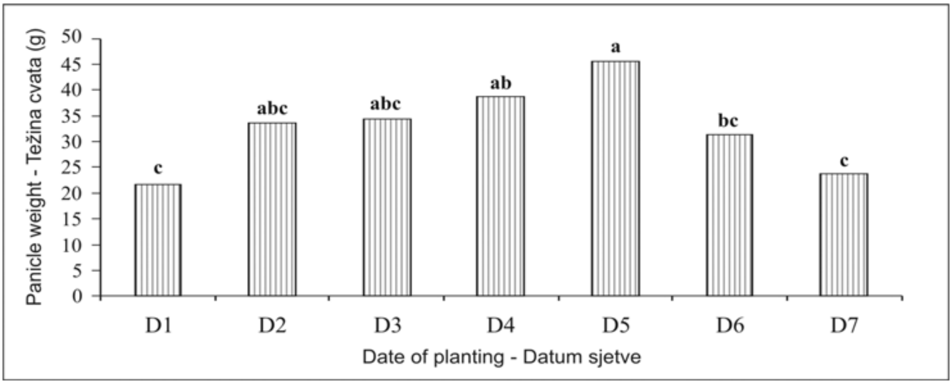


Different letters mean significant differences at p=0.05
Različita slova označavaju signifikantnu razliku uz p=0,05

4. Panicle weight per main shoot (g)

Delaying planting from late April to late May-early June increased KS ecotype kernel weight from 21.73 g to 45.66 g (Fig. 4). The lowest kernel weight for KS ecotype occurred similarly on the late April and first July planting dates. Optimum kernel weight was on 5 June with a little difference on 25 May.

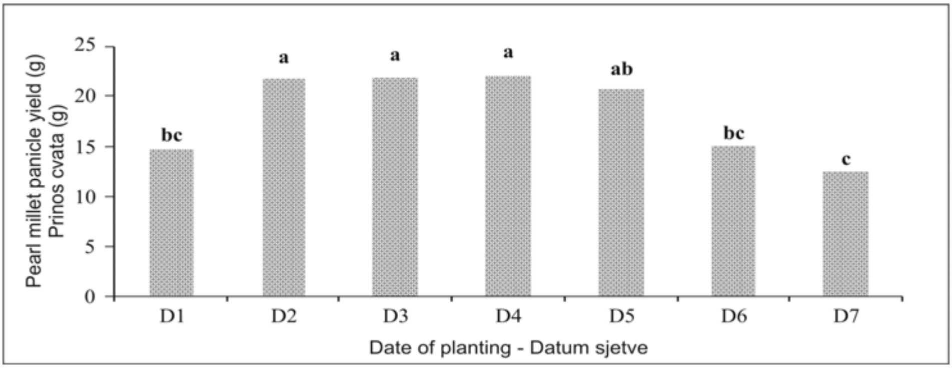
Fig. 4. Panicle weight of KS pearl millet ecotype dependent on sowing date
Graf 4. Težina cvata KS ekotipa bisernog prosa ovisno o datumu sjetve



5. Panicle grain yield

Grain head yield of KS ecotype continuously increased with delaying of sowing for all growth duration until 25 May, and then started to decrease (Fig. 5).

Fig. 5. Grain panicle yield of KS pearl millet ecotype dependent on sowing date
Graf 5. Prinos cvata KS ekotipa bisernog prosa ovisno o datumu sjetve



Different letters mean significant differences at p=0.05
Različita slova označavaju signifikantnu razliku uz p=0,05

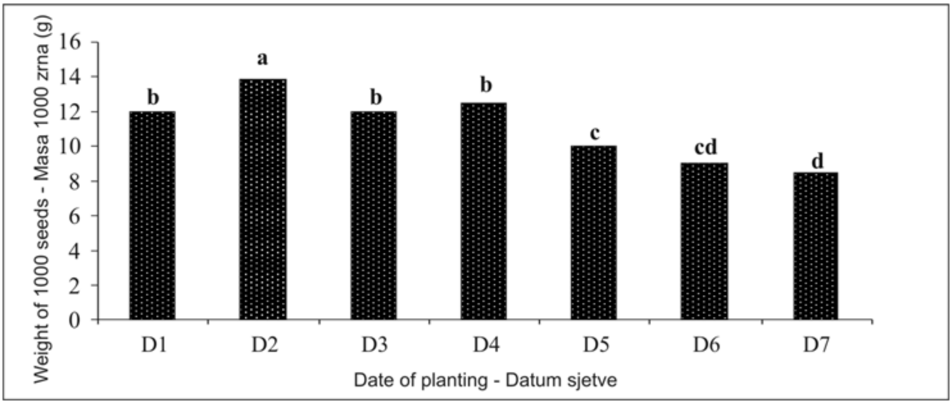
The lowest head yield for KS ecotype occurred on the first July planting date. Optimum head yield occurred between 3 and 25 May and grain yield did not change with planting date. Grain yield increased by 33% with the 30 days delay in planting from 24 April to late May, it was similar for 17 June and late April plantings, and declined by 45% as planting was extended to early July.

6. Thousand kernel weight

Thousand kernel weight differed across planting dates. It increased by 17% as planting was delayed from D_1 to D_2; but decreased by about 39% for D_7

Seed size was smaller than in earlier plantings (Fig. 6). The 01/07 planting date produced very little seed.

Fig. 6. Thousand kernel weights of KS pearl millet ecotype dependent on sowing date
Graf 6. Masa 1000 zrna KS ekotipa bisernog prosa ovisno o datumu sjetve



Different letters mean significant differences at p=0.05
Različita slova označavaju signifikantnu razliku uz p=0,05

DISCUSSION

Phenological traits such as photoperiod sensitivity and the duration of the crop's various growth phases are for dryland crops keys to agro-ecological adaptation to semi-arid environments (Folliard et al., 2004). This is partly a consequence of abiotic stresses affecting the crop when its cycle is poorly adjusted to local seasonal patterns of climate. Probably even more importantly, appropriate phenology help the plant to escape from biotic stress factors that are only indirectly related to climate (Tanzubil et al., 2002; Kouressy et al., 2008a)

Development and yield of pearl millet were markedly affected by temperature during plant growth: vegetative, stem elongation, and grain development (Pale et al., 2003)

1. Days from seedling emergency to maturity

For KS there was a progressive reduction in the number of days taken for the crop to complete its life cycle between seedling emergence and maturity as planting were delayed after D_1.

A steady decrease in number of days to maturity took place when planting were delayed to July and optimal planting period for grain pearl millet ecotype KS of 2 May to 5 June.

Martin and Vanderlip (1997) found similar planting dates for grain sorghum in Nebraska (25 May to 5 June).

Martin and Vanderlip (1997) reported that except for extreme planting dates (April or July), sorghum maturity did not affect yield. This result was found in our test.

The number of days between planting and maturity decreased as planting was delayed. This effect probably resulted from slower emergence and less rapid accumulation of heat units for early planting dates. These results agree with Martin and Vanderlip (1997).

Maximum days to maturity in early planting dates may be due to low soil temperature in April. Whereas, the minimum number of days to maturity in June and July planting may be due to high soil temperature because the germination is the result of many processes, which involve enzymes (Khan et al., 2003)

The base temperature for germination is around 10°C, while the optimum temperature for emergence is between 25 and 30°C for pearl millet (Radford and Henzell, 1990; Albuquerque et al., 2004). Mohamed et al., (1988) indicated that pearl millet growth was slowest as 19 °C and fastest at 31°C.

Although soil temperature was close to the minimum for germination in April and early May, it was still within the limits of optimum for germination and vegetative growth until 25 May in the experimental site. Cool temperature after sowing caused considerably longer emergence duration at the three earliest sowing dates, and plants exposed to sub-optimal temperatures for root and vegetative growth after emergence (Larson et al, 1994; Heiniger et al., 1997).

The cumulative GDD decreased gradually until the first of July. Pearl millet sown during higher temperature regimes takes less GDD from sowing to maturity than that sown during low temperature regimes. Low temperature increases the number of days between planting to maturity (Warrington and Kanemasu, 1983), while high temperature shortens the intervals of various phenological phases (Allison and Daynard, 1979).

The second factor that could have been affecting the response to maturity was photoperiod.

It has been shown that temperature and photoperiod can interact quite strongly to change phenological development (Slafer and Rawson, 1995). Thus, at short photoperiod, high temperature delays development, but at long photoperiod it accelerates it (Nanda et al., 1996). In fact, we found that the lag of phenological phases between D1 and D7, which was 67 days at sowing, decreased to nearly 30 days at maturity. This result was signalled by Bacci et al. (1999).

2. Plant height

This study demonstrated that a plant height was reduced in early and late planting dates. This may be due to changes in photoperiod which accelerated development towards reproductive stages and hence less time was available to vegetative growth.

Low temperature during April and first weeks of May may also be the reason for minimum plant height for early planting.

Plant height was different at maturity among sowing dates for sorghum (Kouressy et al., 2008b).

Other researchers also found that plant height generally decreased with delayed planting (Harris, 1996).

Karaguzel et al. (2005) found that photoperiod and sowing time affected independently the plant height and there was no significant interactive effect between these factors on plant height values.

3. Panicle length

Panicle length was maximized on early May (D_2) sowing. After mid June, panicle length decreased significantly. In early sowing, a decrease in panicle length was lower than in late planting date.

Pearl millet head length was found to be related to grain yield by Beninga (1993).

Environmental conditions affected panicle size on the main stem and yield on tillers in the same sense. Teare et al. (1993) found that panicle length was maximised between 5 and 17 May which agrees with our result.

4. Kernel weight

Kernel weight is another important factor affecting final yield of pennisetum grains.

A decrease kernel weight for early or late planting dates can be attributed to the duration of light interception (Craufurd and Bidinger, 1988b).

Pale et al. (2003) suggested that kernel weights for pearl millet were biggest in planting time of 454 air heat units after 1 April, which was 55 air heat units later than in optimal grain yield.

Maximum kernel weight at the relative later planting time could be the result of yield component compensation because pearl millet has great yield component compensation ability (Andrews et al., 1998).

5. Head yield

The lowest head yield for KS ecotype occurred on the late April and the first July planting dates. The yield reduction from late or early planting may be due to the plants being unable to attain optimum energy reserves, leaf area, or fall tillers per growth (Fowler, 1982).

The slow germination and growth problems due to cooler conditions at the early sowing dates limited head grain.

Martin and Vanderlip (1997) suggested that cool temperature (in April) may have limited grain filling and may have decreased test weight in the season.

With earlier sowing, durations of all vegetative and flower periods were also longer, so plants had shorter grain filling period and exposed to higher day/night temperature regime during grain filling period (Caliskan et al, 2008). Consequently, all yield components were also negatively affected by earlier sowing than 3 May

When sowing is early, pearl millet panicles are extremely susceptible to grain mold when exposed to excess moisture (when flowering occurs too early in the season, Ratnadass et al., 2003) and bird damage (occurring predominantly when the crop grains set is out of phase with that of the neighbouring cultivated and wild flora (Andrews, 1973)

Very early sowing in April did not create any advantage, not only for earliness but also for yield components.

For D_7, shortening of the cycle caused decrease in head yield. This result had previously been found by Reddy and Visser (1993) and Tanzubil et al., 2002 for pearl millet. Whereas, the positive lengthening of the vegetative phase, after April until early June, on the head yield is in agreement with other authors (Craufurd and Bidinger, 1988a)

Flowering at a later date, however, incurs risks of terminal drought which is also detrimental to grain filling (Kasei and Rudat, 1994; Borell et al., 2000)

Compared to the traditional sowing period (beginning of April), a relative later sowing date resulted in higher yields. On average, the three dates (D_2, D_3, D_4) or all May month provided the highest head yield.

In general, sowing of pearl millet ecotype between 3 and 25 May resulted in higher values for yield components than earlier or later sowings. Fribourg (1995) indicated that pearl millet had a large window for planting time, indicating flexibility in planting time.

In addition to delayed emergence, durations of all vegetative growth and flowering were also longer with earlier sowings. Yield and all yield components of plants exposed to higher day/night temperature regime during filling period were also negatively affected by earlier sowings than first May.

Pear millet head grain yield was maximized at accumulation between 1549 and 1441 GDD (base 10°C) in our Mediterranean conditions. We found a quadratic equation (Fig. 7).

In our experiment, we also found polynomial equation (quadratic) which demonstrated that the optimum planting time for pearl millet in Kairouan was between the confidence intervals of 296 and 563 air heat units after 1 April (Fig. 8).

Fig.7. Planting time indicated by air heat units after 1 April (base 10°C) and grain panicle yield of KS pearl millet ecotype

Graf 7. Vrijeme sjetve prema toplinskim jedinicama nakon 1. travnja (osnova 10°C) i prinos cvata KS ekotipa bisernog prosa

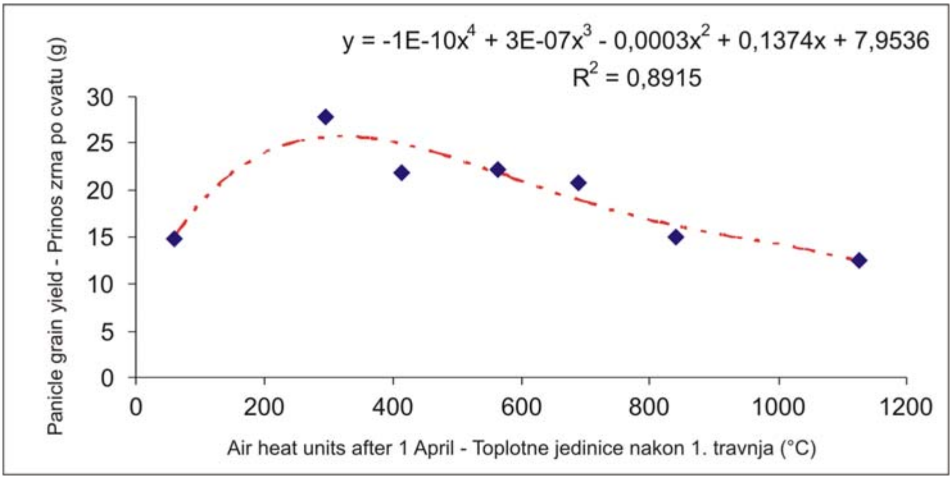
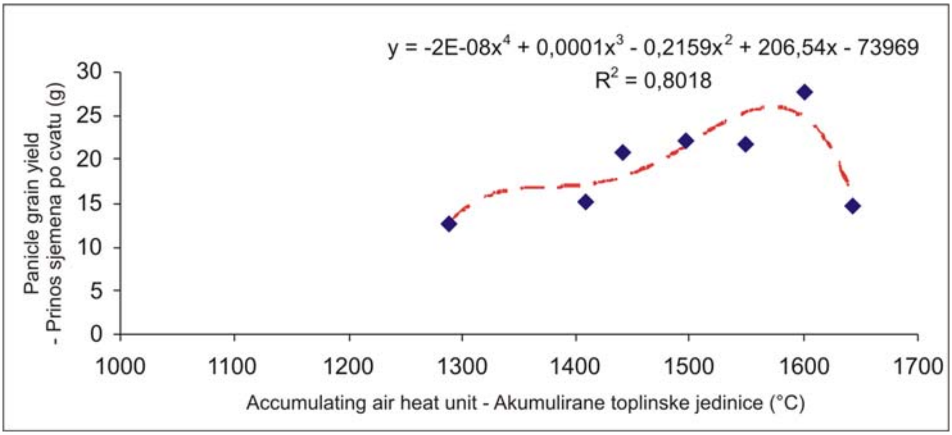


Fig. 8. Planting time indicated by accumulating air heat units (base 10°C) and grain panicle yield of KS pearl millet ecotype

Graf 7. Vrijeme sjetve prema akumuliranim toplinskim jedinicama (osnova 10°C) i prinos cvata KS ekotipa bisernog prosa



A significant relationship between air heat and grain panicle yield was found and had greater R^2 value. This result was close to that found by Pale et al. (2003) who suggested that optimum planting time for pearl millet in Nebraska was between the confidence intervals of 239 and 501 air heat units after 1 April .

Therefore, it was concluded that air heat measurement for determining planting time was superior to day of year or GDD.

6. Thousand kernel weight

Seed size in relation to planting date indicates that environment affects grain yield. Contrary to Mahalakshmi et al. (1988) we found differences in seed size due to planting date.

Heat stress is known to have a detrimental effect on kernel weight in wheat (Gibson and Paulson, 1999) and may serve as an explanation for several of the reductions in pearl millet kernel weight in our study. In fact, later maturation of pearl millet grains caused by delayed planting hinders reproductive development during unfavourably hot and dry conditions (Witt, 1996) causing shrivelling and shrinking of the kernels.

Teare et al. (1994) show that 15 July planting date produces very little seed.

This may have been related to environmental changes (reduced length of day, or paucity of pollinators) Bumble bees, the primary pollinators for the first three planting dates, were essentially absent during flowering of PD. It probably was not the lack of available water (water was similar for all planting dates).

CONCLUSION

We conclude that planting date has a big effect on grain pearl millet yield. Our study reveals that the most suitable period for pearl millet KS ecotype is between early May and early June in the central Mediterranean region in Tunisia. When sown in this period, plants are exposed to suitable temperature regimes during the vegetative and the reproductive growth stages and receive more solar radiation and sunshine during the entire growing period. However, the effects of planting earlier or later than mid-May on yield were great and consistent. Early crop planted in April and in first week of May took maximum number of days in all morphological parameters and yield components of pearl millet ecotype than late crop planted in July and this longer growth duration did not generate any advantage not only for earliness but also for yield and its components and could increase the production cost.

Our study showed that satisfactory yield level could be achieved with 86 days growth using KS ecotype which is an advantage in double crop production.

Adjustment of sowing date is very important to optimize climatic conditions in respect to growth and yield of pearl millet crop. However, further breeding and management studies should also be conducted to maximize yield and profitability of the pearl millet production in this type of environments.

In conclusion, the Mediterranean climate allows both main and double crop production of the pearl millet with acceptable yield components.

REAGIRANJE AUTOHTONOG EKOTIPA BISERNOG PROSA (*Pennisetum glaucum* L.R.BR.) NA RAZLIČITE DATUME SJETVE

SAŽETAK

Biserno proso (*Pennisetum glaucum* L.R.Br.) je potencijalni usjev za Velike ravnice u Tunisu, ali nema radova o njegovoj agrotehnici. Cilj ovog istraživanja bio je odrediti optimalno vrijeme sjetve bisernog prosa u mediteranskom okruženju.

Istraživanja su provedena u Kairouanu (središte Tunisa) s autohtonim ekotipom bisernog prosa sijanog u sedam rokova. Pokus je postavljen po shemi randomiziranog bloknog rasporeda u četiri ponavljanja.

Morfološka obilježja biljaka kao i značajke uroda mjerene su i povezane s datumom sijanja i jedinicama topline zraka. Optimalna vremena sijanja određena su povezivanjem komponenata uroda s kalendarskim datumom i toplotnim jedinicama. Prinos cvatova povezan s jedinicama topline zraka bio je učinkovit u određivanju optimalnog vremena sjetve.

Optimalna razdoblja za sjetvu bisernog prosa bila su između 1.549 i 1.441 toplotnih jedinica (osnova 10°C) ili između 296 i 563 jedinica topline zraka iza prvog travnja za Kairouan. Biserno proso imalo je veliki vremenski okvir za sjetvu, omogućavajući fleksibilnost u vremenu za sjetvu. Vrlo rana sjetva prije početka svibnja nije dala nikakvu prednost za rano dozrijevanje i komponente uroda. Najpovoljnije razdoblje za sjetvu bisernog prosa bilo je između prvog svibnja i početka lipnja u mediteranskom području koje pruža dugo i povoljno okruženje za glavnu i naknadnu proizvodnju usjeva.

Ključne riječi: mediteranska klima, komponente uroda, toplinske jedinice, biserno proso, datum sjetve

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