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EFFECT OF DIFFRENT PLANT DENSITIES ON THE YIELD AND SOME SILAGE QUALITY CHARACTERISTICS OF GIANT KING GRASS (*Pennisetum hybridum*) UNDER MEDITERRANEAN CLIMATIC CONDITIONS

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ABSTRACT

The aims of this study were to determine the adaptability of giant king grass (*Pennisetum hybridum*) under Mediterranean climate conditions, and also to determine whether proper plant densities could improve growth and yield. Study site was located at Bornova, Turkey (38°27.236 N, 27°13.576 E and 20 m). Treatment consisted of four densities of plant population (D_1:57,143; D_2:28,571; D_3:19,048 and D_4:14,286 plant ha^{-1}) with three replicates per treatment in a randomized block design. Setts were planted in mid June of 2010 and allowed to grow for 4 full growing seasons. Average result of four years indicated that there were significant effects of plant densities on the dry matter yield and other yield characteristics of giant king grass but not on silage pH. It was recommended that the production of giant king grass using D_2 (70x50 cm) was the most successful planting density regarding the dry matter (32.6 t ha^{-1}) and crude protein yield to the regions with Mediterranean-type climates under irrigation.

Key words: Giant king grass, plant density, dry matter yield, silage quality.

INTRODUCTION

The most unusual handicap of Turkish animal husbandry sector is providing cheap and high quality roughage production for the farmers. Since the roughages are 70% of general expenditures in animal production, there is an urgent need to improve forage lands in the country (Acar et al., 2015). Remembering the Mediterranean conditions of west and south part of Turkey which represents many favorable factors for crop growth, it must be emphasized that any attempt to benefit from new forage crop production alternatives are of vital importance. Corn (*Zea mays*) silage plays an important role as a winter feed in the livestock industries of many countries. The main reasons for the popularity of corn for silage purposes are the high yield obtained in a single harvest, the ease with which it can be ensiled and its high energy value as a feed source (Çarpıcı et al., 2010). However, its major shortcoming is undoubtedly its production costs (seed, soil preparing, etc). Farmers have tried to reduce production costs by better use of grazing and silage making. Giant king grass (*Pennisetum hybridum*) cultivation under field conditions in this Mediterranean environment may be one of those alternatives to produce large amount of high quality roughage (feed) instead of corn.

Giant king grass (GKG) as an interspecific hybrid (6n) has been formed between Napier grass (*Pennisetum purpureum*) (2n=4x=28 chromosomes) and pearl millet (*Pennisetum glaucum*) (2n=2x=14 chromosomes) the resulting hybrid is sterile due to the triploid condition (2n=3x=21 chromosomes) and restored by chromosome duplication with the use of colchicine (Hanna et al., 1984). *P.hybridum* is also referred to as “Maralfalfa”, “Elephant grass” or sometimes “*P.violaceum*”.

GKG as a field crop is a perennial grass and native to Africa, and has been the most promising and high yielding fodder giving dry matter yields that surpass most other tropical grass (Mannetje, 1992). It mostly used for “cut and carry” system over the tropical and sub-tropical area of the world (Santos et al., 2013). Giant king grass can adapt to a wide range of soil types from sandy to clayey. It can also grow in soils in the pH range of highly acidic to alkaline. The maximum growth is attained on well-drained loamy soils with high organic matter content, but it is susceptible to water logging (Singh et al., 2013). GKG has a perennial life cycle (C4) and is propagated vegetatively. It has a profuse root system, penetrating deep into the soil, and an abundance of fibrous roots spreading into the top soil horizons. The rhizomes are short and creeping, and, nodes develop fine roots and culms. The plant forms clumps and grows upwards, profusely branched with thick cane-like stems. The culms are erect and tall, varying in height from 2 to 6 m.

The propagation of giant king grass is by stem cuttings (setts), rooted stems or splitting of rhizomes (Singh et al., 2013). The most common way of planting is using setts. The mature stems in the basal 2/3 zone with well-developed leaf buds are cut into sections of three nodes and planted upright by burying two basal nodes into the soil.

Numerous field experiments carried out on *Pennisetum* genus indicated that yield and forage quality of the crop depends on cultivar, plant density, cutting interval and harvesting purpose. Optimum plant density is an important factor in maximizing yields of tall grasses such as *Pennisetum* or *Miscanthus* (Danalatos et al., 2007; Zewdu, 2008; Ansah et al., 2010). Thus, the optimum plant density or plant population for any given situation results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive (Lyon, 2009). At this population, production from the entire field is optimized, although any individual plant might produce less than would have occurred with unlimited space.

For forage production in *Pennisetum purpureum*, intra-row and inter-row spacing of 0.5 m × 1 m in Ghana (Ansah et al., 2010), 1 m × 1 m in Kenya (Nyambati et al., 2010) and 50 cm × 50 cm in Japan (Ishii et al., 2005) have been suggested. Mukhtar et al. (2003) found that where plants have to go through overwintering, high population density impacted adversely the number of stubble tillers emerging from underground stems. Wijitphan et al. (2009) pointed out that there was a significant effect of plant spacing on total DM yield among 50x40, 50x60, 50x80 and 50x100 cm plant spacing of *Pennisetum purpureum*, and the highest total DM yield with 70.84 t ha^{-1} was obtained from 50x40 cm planting spaces under Thailand condition. A field trial in Greece (Danalatos et al., 2007) showed that no significant response of *Miscanthus giganteus* to nitrogen levels (50 and 100 kg N ha^{-1}) but, a significant effect of plant density was found, with the denser populated plants (10,000–20,000 plant ha^{-1}) performing growth rates, reaching maximum dry biomass yields in excess of 38 t ha^{-1} compared to 6,700 plant ha^{-1}.

Zewdu (2008) tested different treatments with 1.5, 1 and 0.5 m spacing between rows and 0.75, 0.5 and 0.25 m spacing between plants, which consisted of 8,889, 13,333, 26,668, 13,333, 20,000, 40,000, 26,668, 40,000 and 80,000 plants ha^{-1} on *Pennisetum purpureum* in Ethiopia reported that the number of tillers per plant, dry matter yield were significantly affected by plant density but not crude protein content and, higher DM yields were obtained from 80,000 (7.80 t ha^{-1}) and 40,000 (39.9 t ha^{-1}) plant density in 2004 and 2005 respectively.

Giant king grass has the potential to grow with fewer inputs, water and tolerate a variety of biotic and abiotic stresses as compared to corn, and the fact that it is perennial which means that replanting every year is not required (Kukkonen, 2009), and is a new introduction to Turkey. Therefore, getting to know the possibility of production of this crop is important not only in Turkey, but also in all over the world. Nevertheless, information on the productivity and quality of giant king grass under intensive farming management in Mediterranean environment is not well documented. The objective of this research was to evaluate the influence of different planting densities on the yield, some yield and silage quality components of giant king grass under irrigated conditions of Mediterranean climate.

MATERIAL AND METHODS

Location of Experiment

The experiment was carried out during four growing seasons (2010-2013) at Bornova experimental fields (38°27.236 N, 27°13.576 E) of Agricultural Faculty of Ege University, Izmir, Turkey, at about 20 m above sea level with typical Mediterranean climate characteristics (Table 1). The soil was a silty-clay loam (30.6% clay, 36.7% silt, and 32.7% sand) with pH 7.32, organic matter 1.16%, salt 0.074%, 0.123% total N, available phosphorus (1.4 ppm) and available potassium (350 ppm).

Table 1. Some meteorological parameters of experimental area at Bornova in 2010-2013.

	------- Average temperature (°C) -------					------- Total precipitation (mm) -------				
Months	2010	2011	2012	2013	LYA	2010	2011	2012	2013	LYA
January	10.6	9.0	6.8	9.4	9.0	142.3	100.9	127.7	252.5	112.2
February	12.6	10.3	7.6	11.2	9.2	301.3	107.3	128.2	187.0	99.7
March	13.3	12.0	11.3	14.0	11.8	16.1	18.8	34.7	56.8	82.9
April	17.4	14.5	17.5	17.3	16.1	20.4	65.3	105.0	30.2	46.4
May	21.8	20.1	20.5	22.7	21.0	27.1	29.0	86.6	43.7	25.4
June	25.5	25.4	27.3	25.7	26.0	76.3	0.6	19.9	27.1	7.5
July	28.8	28.9	30.1	28.4	28.3	0.0	0.0	0.0	0.0	2.1
August	30.2	28.1	29.2	28.7	27.9	-	0.0	0.0	20.2	1.7
September	24.8	25.6	24.3	24.0	23.9	12.3	8.6	0.0	5.1	19.9
October	18.8	17.1	21.7	17.2	19.1	232.5	90.3	22.1	94.1	43.2
November	18.1	11.1	16.4	15.0	13.8	32.4	0.0	56.9	128.9	109.7
December	13.3	10.7	10.7	8.5	10.5	155.7	140.5	218.2	9.1	137.9
$\bar{x}$ - Σ	19.6	17.7	18.6	18.5	18.1	1016.4	561.3	799.3	854.7	688.6

LYA:Long year average, $\bar{x}$: mean, Σ:total

Field applications and experimental design

"Paraíso" cultivar of giant king grass (*Pennisetum hybridum*) was used as crop material. The experiment was carried out with a randomized complete block design with three replication; four plant spacings where 70 cm among the rows and 25, 50, 75 and 100 cm within the rows (D_1:57,143, D_2:28,571, D_3:19,048 and D_4:14,286 plant ha^{-1}, respectively) were tested. Each plot was consisted of 4 rows with 5 m length (14 m^2).

The grasses were grown from stem cuttings (setts) having 4 nodes and 40-60 cm length taken from basal part of *P.hybridum* rootstock on 15th June, 2010. The setts were buried into a well-prepared seedbed with one sett per hill. Before planting, the additional leaves of the setts were trimmed and dipped at 4000 ppm indole-3-butyric acid (IBA) concentrations of hormone for 3-4 seconds up to 10-15 cm height (Hartmann et al., 2002).

The recommended dose of 90 kg N ha^{-1} was applied for all plots in two equal doses at establishment year (Ruviaro et al., 2008). Half a dose of nitrogen fertiliser (urea) was applied before planting, and the rest of nitrogen was applied when the crops were 50-60 cm plant height as NH_4NO_3. All plots were fertilised using 100 kg ha^{-1} P_2O_5 before planting. In the following years (2011, 2012 and 2013) of the field trial, the same amount of N fertilization was applied in mid April (plus again phosphorus), as ammonium sulfate, and the other half at the beginning of stem elongation, as ammonium nitrate.

Drip irrigation system was installed on the field during the establishment and growing seasons. Weed control was performed by manual hoeing only during the establishment year. No evident crop diseases or insects were detected. Harvests were made only once a year on 8 November 2010, 31 October 2011, 5 November 2012 and 30 October 2013, respectively.

Measurements, silage making and chemical analysis

In each plot, plant height was measured from in the mid two rows and area of 1-3 m (30 plants) at the day of cutting. Tiller density was also determined by counting the plant in the same area in each plot at the same day of cutting. Forage on a central area of 3 m^2 in each plot was cut at 15-20 cm above ground level and fresh weight recorded. Harvested fresh forage (2 kg) was dried to a constant weight at 65ºC during 72 h for calculating dry matter (DM).

In each plot, about 5 kg of fresh whole crop material were wilted overnight (14–16 h) prior to ensiling. The wilted herbage was then chopped, using a static precision-chop forage harvester to give a chop length of 5–10 mm. The final dry matter content was approximately 30%. 250 g chopped samples were vacuum-packed into polythene bags (dimensions 250-200 mm) (Johnson et al., 2005) with addition of 0.5% salt. The vacuum bag silos were kept in storage without light for 60 days for anaerobic fermentation.

pH value of matured silage samples was also determined (Alcicek and Ozkan, 1996). Matured silage samples of each component were dried at 65ºC for 48 h. The dried samples were reassembled and ground in a mill passed through a 1 mm screen. The crude protein (CP) was calculated by multiplying the Kjeldahl N concentration by 6.25. The neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations were measured to Ankom Technology to determine the Relative Feed Value (RFV) which was estimated according to the following equations adapted from Trotter and Johnson (1992): DM intake (DMI)=(120/$NDF_{\%}$), Digestible DM (DDM)=88.9-(0.779x$ADF_{\%}$), RFV=$DDM_{\%}$ x $DMI_{\%}$ x 0.775.

Statistical analysis

All data were statistically analyzed using analysis of variance (ANOVA) with the Statistical Analysis System (SAS, 1998). Probabilities equal to or less than 0.05 were considered significant. If ANOVA indicated differences between treatment means a LSD test was performed to separate them (Stell et al., 1997).

RESULTS AND DISCUSSION

Experimental area is located in the Mediterranean zone of the country with quite mild & warm winters and hot & dry summers (Table 1). Field studies were started in mid June with high air temperature and satisfactory moisture levels supported by drip irrigation and owing to IBA, therefore, stands were excellent. No winter injury on the crops was detected during the experimental years. The results are summarized in Table 2. The year and plant density effects were the main sources of variation in all tested characters, while the interactions (YxD) were not significant except plant height.

Number of tiller

There were statistically significant differences among plant densities regarding average number of tiller per square meter (Table 2). Minimum plant density being D_4 (14,286 crop ha^{-1}) had the highest average number of tiller (237 tiller m^2), whereas maximum plant density being D_1 (57,413 crop ha^{-1}) was the lowest (199 tiller m^2). Year effect was also significant and average number of tiller of first year (44 tiller m^2) was quite lower than the following years (2011:262, 2012:287 and 2013:291 tiller m^2, respectively), but there was no significant difference between 2012 and 2013.

In the present study, number of tillers of giant king grass in the last 3 years was approximately 6-7 times higher than the first year tillers. Four years average result indicated that decreasing plant density from D_1 to D_4 increased the number of tiller per square meter; however there was no significant difference between D_2 (70x50 cm) and D_3 (70x75 cm). This might be due to the fact that plants with relatively wider spacing (D_3 and D_4) compared to D_1 or D_2 produced many fine-stemmed tillers and showed vigorous growth and development because of reduced competition for space, moisture and nutrients during the growing period as reported by many researchers (Mukhtar et al., 2003; Zewdu, 2008; Wijitphan et al., 2009).

Table 2. Effect of different plant densities on the yield and some yield components of GKG.

Density	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
	-------- Tiller number (m^{-2}) --------					**---------- Plant height (cm) ----------**				
D_1	35	232	259	270	199	212	327	409	388	334
D_2	40	259	292	294	221	229	352	410	394	346
D_3	45	271	295	296	227	257	374	420	403	364
D_4	54	287	302	303	237	278	382	426	404	372
Mean	44	262	287	291	221	244	359	416	397	354
LSD(.05)	Y:10 D:11 YxD:ns CV(%):15.3					Y:11 D:14 YxD:17 CV(%):12.9				
	------- Dry matter yield (t ha^{-1}) -------					**--------------- Silage pH ---------------**				
D_1	15.6	32.2	35.5	36.9	30.1	3.86	3.77	3.65	3.65	3.73
D_2	18.4	35.1	37.4	39.4	32.6	3.80	3.59	3.63	3.64	3.67
D_3	17.7	33.1	35.5	37.8	31.0	3.78	3.57	3.61	3.62	3.65
D_4	17.7	31.6	33.4	35.2	29.5	3.60	3.54	3.60	3.61	3.59
Mean	17.3	33.0	35.5	37.3	30.8	3.76	3.62	3.62	3.63	3.66
LSD(.05)	Y:1.3 D:1.4 YxD:ns CV(%):15.4					Y:ns D:ns YxD:ns CV(%):4.1				
	------- Crude protein content (%) -------					**------- Relative Forage Value -------**				
D_1	7.7	7.0	6.5	6.3	6.9	125	96	91	89	100
D_2	7.2	6.4	6.3	6.2	6.5	118	94	89	88	97
D_3	6.5	5.7	5.8	6.1	6.0	111	89	87	86	93
D_4	6.4	5.6	5.7	6.0	5.9	105	86	85	85	90
Mean	6.9	6.2	6.1	6.2	6.3	115	91	88	87	95
LSD(.05)	Y:0.4 D:0.3 YxD:ns CV(%):6.7					Y:3 D:4 YxD:ns CV(%):4.5				

D_1:57,143, D_2:28,571, D_3:19,048 and D_4:14,286 plant ha^{-1}, Y: year, D: density, YxD: interaction, ns: not significant.

These results generally displaying the high growth rates, showed that giant king grass was capable of growing in the experimental site. Singh et al. (2013) emphasized that giant king grass grows vigorously, providing the extensive stem structure for leaf formation needed for photosynthesis, starting from the first year, and in this respect the crop differs from many other vigorously growing grasses such as *Miscanthus*, which needs the first year for establishment.

Wijitphan et al. (2009) informed that number of tillers per hill of *Pennisetum purpureum* was affected by plant configuration, and plant spacing of 50x40 cm with 16 tiller $hill^{-1}$ had the highest compared to other spacing of 50x60 cm (14 tiller $hill^{-1}$), 50x80 cm (12 tiller $hill^{-1}$) and 50x100 cm (10 tiller $hill^{-1}$), respectively. Another study with *Pennisetum purpureum* by Mukhtar et al. (2003) informed that with the increasing plant density from 4, 8 to 16 plant m^{-2}, number of tillers increased from 50, 55 and 76 per plant in the establishment year, and 114, 110 and 147 per plant in the third year, respectively. Zewdu (2008) reported that the number of tillers per plant was significantly affected by plant density, and wider rows were more productive than narrow rows, and number of tillers of *P.purpureum* in the second years was approximately 7 times higher than the first year tillers. Our findings are in accordance with those researcher's results.

Plant height

The plant height of GKG was affected by YxD interaction. The highest plant height (426 cm) was obtained from D_4 in 2012, whereas the lowest was 212 cm for D_1 in 2010 (Table 2). Year effect was also significant and average giant king grass height of third year (416 cm) was higher than the other years (2010:244 cm, 2011:359 cm and 2013:397 cm, respectively).

In the study, four years average result displayed that the plant height of giant king grass increased noticeably by decreasing plant density most probably due to the thick-stemmed plants developed at wider rows and less competition compared to narrow spacing. Zewdu (2008) informed that there was no significant effect on plant height of *P.purpureum* due to the plant density during the establishment year, however, plant height was significantly affected by plant density in the following year, and plant height in lower plant densities were taller than higher densities. Mukhtar et al. (2003) reported that there was a highly significant difference between normal and dwarf type of *P.purpureum* varieties, and plant height of *P.purpureum* crops in low-density plots were higher than higher-density plots in Japan. Danalatos et al. (2007) indicated that plant height was not affected by plant density (6,700-10,000-20,000 plant ha^{-1}) of *Miscanthus giganteus* in Greece. Živanović et al. (2014) informed that planting density (G_1:2 and G_2:3 rhizomes $m\text{-}^{2}$) and year affected the *M.giganteus* plant height. G1 was taller than G2, and in the first year of the G_1 density were higher by 10%, and during the second year by 4%, but nitrogen (0-60-100 kg ha^{-1}) had a higher influence on plant height compared to the planting density in Serbia. Our findings for *P.hybridum* were in agreement with the indications of above mentioned researchers under typical Mediterranean environmental conditions.

Dry matter (DM) yield

The DM yield was not affected by interaction. There were statistically significant differences among plant densities regarding DM yield per hectare (Table 2). The highest average DM yield of giant king grass was obtained from D_2 (70x50 cm) being 32.6 t ha^{-1}, whereas the lowest average yield obtained from D_4 (70x100 cm) being 29.5 t ha^{-1}, but there was no significant difference between D_1 (70x25 cm) and D_3 (70x75 cm). Year effect was also found to be significant and the first year (17.3 t ha^{-1}) was quite lower than the following years (2011:33.0 t ha^{-1}, 2012:35.5 t ha^{-1} and 2013:37.3 t ha^{-1}, respectively).

Many factors influence the optimum plant population density for a crop: availability of water, nutrients and sunlight; length of growing season; potential plant size; and the plant's capacity to change its form in response to the varying environmental conditions (Lyon, 2009; Singh et al., 2013). According to the four years result, the maximum DM yields occurred at D_2, being quite higher than other densities. This result suggests that number of tiller per unit area and plant height and stem thickness can cause a strong competition among the crops and depress the yield components of individual plant in lower or wider densities. Nevertheless, since the numbers of tiller per unit area in sparsely populated stands (D_3-D_4) were quite higher than the other densities which were densely populated stands (D_1-D_2), it was also suggested that DM yields were the highest at D_2. Even thought, number of tiller per unit area and plant height was increased with the decreasing rate of plant density.

It was also concluded that data related to DM yield and yield components of D_2 also indicated that giant king grass in this planting density was highly adaptable to the experimental area. Highly significant differences among the years were an indication of the yield variation of plant densities depending on establishment year and the changes of climatic parameters of years.

Zewdu (2008) reported that there was a significant difference in DM yield among the different plant densities in *P.purpureum* in Ethiopia, and DM yield increased as plant density increased, and higher DM yields were obtained from 80,000 plant ha^{-1} (7.80 t ha^{-1}) and 40,000 plant ha^{-1} (39.9 t ha^{-1}) in the first and second crop seasons, respectively. Mukhtar et al. (2003) informed that total annual DM yield increased as planting density increased in both years in Japan, and higher plant density (16 plant m^{-2}) was superior than other densities (8 or 4 plant m^{-2}, respectively). Wijitphan et al. (2009) stated that there were significant effects of spaces of planting on total DM yields, and the highest DM yield of 70.84 t ha^{-1} was obtained from a 50x40 cm planting treatment. This was significantly higher than that from other planting treatments in Northeast Thailand, and the 50x100 cm space DM yield was significantly lower than other spaces of planting and the yield was 55.8 t ha^{-1}. However, narrower row spacing may facilitate stand establishment and increase forage production in the early life of the crop. Our findings are in accordance with those researcher's results.

DM yield variation in giant king grass has been attributed to many factors such as climatic conditions, soil water availability, nutrients availability, plant density, harvest time and method, etc. Some cutting experiments with giant king grass also revealed in tropic countries that the choice of cutting interval or frequency is crucial to their performance and were found to be the main factor affecting growth, yield and persistence of swards (Tegami Neto and Mello, 2007; Zewdu, 2008; Wijitphan et al., 2009).

Except establishment year, generally annual DM yields of giant king grass in the experimental area were almost twice that of corn which was the most and largely used silage crop in the region (Geren and Kavut, 2009; Çarpıcı et al., 2010). Masuda et al. (1991) found growth rate of *P.purpureum* superior to that of corn, and the final DM yield was twice that of corn. Considering the enormous amount of research effort and resources spent towards making corn more productive to where it is now, chances of large initial biomass gain in giant king grass with concentrated research effort are promising.

Silage pH

Plant density did not show any significant effect on the silage pH of giant king grass silage in the study (Table 2). The values of silage pH ranged from 3.54 to 3.86 depending on the plant densities and years. Year effect was not also significant on pH values and average pH of 3.66.

The most important physicochemical parameter for the evaluation of silage quality is a pH below 4, which was observed for all the silages tested. All indicators were characteristic of good silage conservation whatever the treatments were. The silage quality was especially confirmed by the proportion of fermentation products at the end of the storage period (Ferrari Junior et al., 2009). This might be due to the fact that all the crops used in the study were from the same genetic material and all the treatments were harvested at the same growth stage. Many research (Bernardino et al., 2005; Ruviaro et al., 2008; Ferrari Junior et al., 2009; Shen et al., 2012) reports revealed that plant height at cutting and variety differences are the major factors that affect the chemical composition and digestibility of *P.purpureum*. Woodard et al. (1991) reported that mean pH values of *P.purpureum* silages ranged from 3.8 to 4.0 made from plants harvested at the different frequencies, and the ease with which *P.purpureum* was preserved as silage was attributed to adequate levels of water soluble carbohydrate concentrations and inherently low buffering capacities in standing forages.

Crude protein (CP) content of silage

There was significant effect on CP content of silage of GKG due to the plant density during the study (Table 2). The highest average CP content (6.9%) recorded at D_1 (70x25 cm), whereas the lowest CP content was 5.9% at D_4 (70x100 cm). Mean CP content was significantly higher in 2010 (6.9%) than the following years which were no significant differences among them.

The four years average value in the study indicated that plant density practices affected CP content of giant king grass significantly, and densely populated stands gave higher CP content compared to sparsely populated stands during the study. The higher CP content at higher plant densities was mainly due to the structural role of thinner and taller tillers of the crop. Some research workers (Zewdu, 2008; Wijitphan et al., 2009) reported that CP content of *P.purpureum* was not influenced by different plant densities. Meanwhile, Wijitphan et al. (2009) informed that CP content (13.9%) of *P.purpureum* was higher in densely populated stands (50x60 or 50x80 cm) compared to sparsely populated stand (50x100 cm, 13.2%).

Numerous research reports revealed that plant height at cutting or plant age is the major factor that affects CP content and digestibility of giant king grass (Woodard et al., 1991; Nyambati et al., 2010). In our study, CP contents of giant king grass silage were relatively low compare to corn silage because of the cutting made only once at the end of the growing season in each year. However, this CP content should be improved by adding some protein-rich crop material (cowpea, alfalfa, etc) or concentrates (soybean cake, crushed vetch, etc) (Bernardino et al., 2005; Ferrari Junior et al., 2009; Pires et al., 2009). Accordingly, the addition of leguminous hays in the rates of 25% or 50% to giant king grass at the time of ensiling resulted in good fermentation and raised the CP content of the silage from 6% to 12% and reduced fibres content (Geren, 2014).

These results illustrated that giant king grass emerged as one of the best candidates in the perennial forage crops group that thrives in temperate continental climate areas, and, as C4 photosynthetic pathway species, it is characterized by high photosynthesis efficiency.

Relative forage value (RFV)

The RFV was not affected by year-plant density interaction. Higher plant densities being D_1 and D_2 had the higher average RFVs (100 and 97, respectively), whereas RFV of lower plant densities being D_4 and D_3 were the lower (90 and 93, respectively), while the differences between them were not significant. Year effect was also significant on RFV, and average RFV of the first year (115) was higher than the following years (2011:91, 2012:88 and 2013:87, respectively).

As it is well known, the RFV is an index used to predict the intake and energy value of the forages and it is derived from the DMI and DDM (Ball et al., 1996). The RFV makes marketing on the basis of feeding value possible. This practice aids the seller in pricing hay or silage and provides valuable information to buyer about how to use forage most effectively. Forages with a RFV are described as that over 151 (prime), between 150-125 (premium), 124-103 (good), 102-87 (fair), 86-75 (poor) and fewer than 75 (reject), respectively (Rohweder et al., 1978). RFV, though not a reflection of the nutrition of forage, is also important in estimating the value of forage, and all treatments had RFV ranging from 125 (good) to 85 (poor) in our experiment which densely populated stands gave higher RFV compared to sparsely populated stands.

There is very little or no information available regarding the plant density on the effect of RFV of giant king grass. Kukkonen (2009) stated that young giant king grass first harvested at a height of 90 to 120 cm tall had a CP level of 19.5% of DM, with 34% ADF, 56% NDF. These figures are comparable to alfalfa which is the top forage crop and commands the highest prices. But later, harvest of third growth the crop at a height of 120 to 220 cm on November had CP of 10.5%, 37% ADF, 66% NDF. Shen et al. (2012) reported that feeding value of king grass silage affected by different harvest time and wilting process with mean of 60% NDF and 30% ADF. Previous studies (Bernardino et al., 2005; Tegami Neto and Mello, 2007; Geren, 2014) about improving RFV of giant king grass silage displayed the cutting management (plant height or age) or some additives to the crop at the time of ensiling had greater effect on RFV.

CONCLUSION

It should be emphasized that giant king grass, a new introduction to the Mediterranean coastal part of Turkey, is a promising perennial forage crop material with an high level of adaptability and forage yield and quality pecularities.

The results of our four-year study testing the effect of four plant density (57,143; 28,571; 19,048 and 14,286 plant ha^{-1}, respectively) on the crop showed that based on dry matter and crude protein yield, the planting of giant king grass using 28,571 (70x50cm) plants ha^{-1} should be recommended in the regions with Mediterranean-type climates and in similar agro-ecologies of the country.

Future experiments on giant king grass crop should be conducted at different locations with various agronomical treatments and especially cutting intervals, to be sure that results are relatively consistent over time.

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