ANNUAL DOUBLE CROPS SYSTEM FOR FORAGE PRODUCTION IN MEDITERRANEAN CLIMATE ENVIRONMENTS. A CASE OF BUFFALO BREEDING

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ABSTRACT

Buffalo livestock represents profitable economy and sustainable farming activity in the Mediterranean area. The main claim of dairy farming is requirement of forage for sustaining buffalo feeding, particularly during lactation time. In land of EU Mediterranean environments, feeding forage is provided by cultivation of annual double sown crops. The most popular cropping system (referred as model) is based on irrigated Italian ryegrass and corn. The continuous cultivations of model, indeed the favourable economic and technical advantages, promotes constrains of biochemical parameters in topsoil and fitness of buffalo popularity in environments. Furthermore, survey of challenge for enlarging the popularity of buffalo breeding in harsh Mediterranean land, has been determined by cultivation of double sown models under rainfed condition. Sowing time, irrigation treatment and crops of the model influenced the production of dry matter (DM) and milk forage unit (MFU). The production of MFU ha⁻¹ among models range from 3594 to 7438 in winter and 10256 to 15266 in spring under rainfed and 5042 to 9035 in winter and 11940 to 24003 in spring under irrigated. The total MFU ha⁻¹ of winter-spring models range from 16962 to 30815 under irrigated and 13951 to 18097 under rainfed. Three years of continuous growing models reduced the beginning content of organic matter (OM), in winter and spring sown grasses models, by 4.3 g kg⁻¹ under irrigated and 3.1g kg⁻¹ under rainfed while the models based on annual legumes the reduction was lower (2.2 and 1.4 g kg⁻¹, respectively). The experiments evidenced variability among models and singled out equipotent models able to satisfy the MFU, sustain biochemical soil parameters and allow opportunity to enlarge the fitness of buffalo in EU Mediterranean-type climate environments.

Keywords: Dry matter, Cropping system, Feeding value, Irrigation, Legume-grass rotation, Mediterranean environments, MFU, Soil characteristics.

INTRODUCTION

Buffalo livestock represents a profitable economy and sustainable farming activity for the Mediterranean environments. The buffalo livestock of utilised agricultural area (UAA) of the EU Mediterranean climate, amounts to 9238 hectares and represent the 1.5% of total dairy farm surface for animal grazing in Italy. The largest proportion of the buffalo population is located in Campania region (Borghese, 2005; ANASB, 2008). In the EU Mediterranean lands, the agronomic soil used by buffalo dairy farming for providing forage requirements to sustain the animal production (mostly mozzarella cheese) are cultivated on well-structured topsoil with double winter-spring crop sown under irrigated condition (Martiniello et al., 2007a, 2007b).

The weather condition of Mediterranean environment is characterized by mild winter (min and max mean temperature of the months November-February range from 0 to 18 °C), hot summer (mean temperature of the months June-September exceeded 25 °C) and with a mean of 383 mm of rainfall (whose 70% of total amount fell in the period September-May) (Fig. 1). In this environment, the water source availability favours successful forage production for livestock growth.
under irrigated condition of the UAA land reducing the main claim of forage availability for sustain buffalo breeding requirement for milk (Barile et al., 2007) and for meat (Borghese et al., 2010) production. The cropping systems established in buffalo husbandry farmers in the UAA of EU Mediterranean southern environments are mostly based on continuous cultivation under irrigated condition of two crops per year sown in winter (Italian ryegrass, Lolium multiflorum Lam.) and spring (corn, Zea mays L.). The grown of this cropping system offers agronomic (availability of varieties in the market), technical (mechanical equipment for crop growing and silage making) and economic [cheapest milk forage unit (MFU)] advantages than the models made by others crop species (Martiniello et al., 2007b). However, instead the financial and technical benefit of fodder production, the Italian ryegrass-corn cropping system strongly affect the chemical parameters of soil fertility (Martiniello et al., 2007a; Tanaka et al., 2002). Furthermore, because the greatest exploitation of cropping system is linked to water supply during spring and summer months, water availability of buffalo farms represents a limit of forage production in EU Mediterranean environments. Thus, investigation on agronomic approaches of double fodder crops cultivation per year, planned for assessing alternative cropping system models to Italian ryegrass-corn cultivation under irrigated and genotypes adapted to climatic condition of Mediterranean environments under rainfed, favour better exploitation of weather resource in UAA promoting economic and ecological advantage of the environment (Pierce and Rice, 1988; Zentner et al., 2001; Stockdale et al., 2001; Goulding et al., 2008). Knowledge on intensive cropping system suitable to rainfed weather condition are useful for providing fodder crops in dry land, enlarging the area of adaptability of buffalo breeding in UAA Southern Mediterranean lands. So, agronomic investigation on cropping systems, based on fodder genotypes with short vegetative cycle endowed with genetic peculiarity able to escape the harsh weather condition of summer season, allows the opportunity to broaden the fitness of buffalo in Mediterranean area.

The experiments aimed to investigate the effects of cropping systems in dairy buffalo farms on dry matter and nutritive feeding values of the forage and on biochemical topsoil characteristics. The study evaluated four winter-spring sown forage continuous cropping systems under irrigate and rainfed condition of growing. The comparison established among rainfed and irrigated condition, investigates the potentiality of cropping system on silage and seed yield biomass, feeding nutritive value and chemical characteristics in the Ap horizon of topsoil. In addition, the results collected on cropping systems under rainfed achieve information on the possibility to increase the adaptability and to extend buffalo livestock in UAA Southern EU Mediterranean lands.

**MATERIALS AND METHODS**

**Field experiments:** The experiment was established in "A. Menichella" farm of Agricultural Research Council located in Foggia (41°31’ N; 15°33’ E) through the period 2006 to 2008. The soil was a Chromic Vertisol (FAO-ISRIC-ISSS, 1998) with arid climatic conditions (aridity index =15) (de Martonne, 1926). The monthly mean of trait: mean of rainfall, temperature, ET from a Class A water pan evaporimeter and global solar radiation from radiometer, recorded during the period of experiments are shown in Figure 1. The soil properties, in the 0-35 cm Ap horizon, prior to the beginning of the experiment, had the following characteristics: sand (2-0.2 mm), 200 g kg⁻¹; fine sand (0.2-0.02 mm), 350 g kg⁻¹; silt (0.02-0.002 mm), 190 g kg⁻¹; clay (<0.002 mm), 260 g kg⁻¹ (Day, 1965); total nitrogen (N), 1.43 g kg⁻¹ (Kjeldahl, 1983); OM, 25.3 g kg⁻¹ (Walkley and Black, 1934); C/N, 9.8; phosphorus (P), 26 mg kg⁻¹ (Olsen et al., 1954); potassium (K), 1388 mg kg⁻¹ (UNICHIM, 1985); and pH (water), 8.1; cation exchange capacity, 456 cmole g⁻¹ (Géhu and Franck, 1954). The previous field, where the experiment took place, was grown by two years of continuous durum wheat (Triticum durum Desf.) and one year of fallow (oats, Avena sativa L. + common vetch, Vicia sativa L.) rotation (Rizzo et al., 1993).

The crops were evaluated in a cropping system based on two cultivations per year under irrigated and rainfed growing condition. The two crops belong to cropping system with winter and spring sown referred further, in text, figures and tables, as forage crop model (Martiniello et al., 2007a). The four winter and spring sown genotypes belong to forage crop model used in the cropping system are reported in Table 1. Field experiments were established on plot of 120 m² (6 m wide and 20 m long).
The total number of experimental plots were 32 under irrigated and as many as under rainfed treatment. Before seedbed preparation, samples of soil were harvested for chemical analysis. At the beginning of September of 2005, seedbed was prepared by a 35 cm mouldboard plough, fertilized and refined with field cultivator and tine-harrow. Two roved barley (Hordeum vulgare L.) and Italian ryegrass winter sown crops were seeded in rows 0.186 m a part, respectively at seed density rate, under both condition of growing, of 180 and 40 kg ha\(^{-1}\), respectively. The crops were planted using a seed drill in equally spaced rows. Seed legume of lucerne (Medicago sativa L.) and squarrose clover (Trifolium squarrosum L.) were sown in rows spaced of 0.186 m while pea (Pisum sativa L.) and broad bean (Vicia faba minor L.) at 0.50 m. The seed density of the crop was 40 kg ha\(^{-1}\) for lucerne and clover, 80 kg ha\(^{-1}\) for pea and 129 kg ha\(^{-1}\) for broad bean.

The experiment was arranged in a split-plot design with rainfed and irrigation treatments as whole plots. The winter models were drawn up as subplots in a randomized block design with four replications. The biomass and seed production of winter-sown (barley, broad bean and pea) and spring-sown crops (corn and sorghum (Sorghum bicolor L.)) were evaluated by splitting the plot of the crops into two equal parts which one of them is used for silage and other half part for seed production. However lucerne, Italian ryegrass, sorghum silage and squarrose clover are crops evaluated only for biomass production, the data regarding seed production are not reported in tables and figures.

Throughout the experiments, the continuous winter and spring sown crop models were randomly established at the beginning of the experiment, remaining unchanged throughout the time of trials. To minimize the interaction effect of genotypes with agronomic treatments, the varieties used in the experiments remained the same throughout the period of the trials.

Prior to seedbed preparation, the experimental field was weeded and straw was removed. In the 3rd week of September 2005, a fallow area was plowed using a moldboard plow that turned soil over to a depth of 35 cm in the Ap horizon for preparing seedbed for sowing the winter crops of the models. The ploughed soil was smoothed with a field cultivator and tine harrow a week later. Grass genotypes were fertilized during seedbed preparation using 36 kg ha\(^{-1}\) of N and 40.1 kg ha\(^{-1}\) of P and annual and perennial legumes with 41.9 kg ha\(^{-1}\) of P. In February, when the grass crops reached the beginning of heading, a further 60 kg ha\(^{-1}\) of N as urea was topdressed while the two- and three-year old lucerne meadow was topdressed with 41.9 kg ha\(^{-1}\) of P.

On plot basis were assessed the following traits: plant height, fresh biomass and seed yield (SY). Prior to harvest was determined plant height (cm) by measuring at random six values taken from ground level to main tillers apex. The biomass of the crops was harvest when over 60% of tillers of plot were flowered while the crops used for SY determination were threshed when the moisture of kernel had about 130 g kg\(^{-1}\) of humidity. The DM of forage biomass and SY (t ha\(^{-1}\)) at harvest, in winter and spring sown, was assessed from each experimental half plot. The DM forage biomass and SY of crops were mowed by experimental machinery. The herbage and seed moisture content at harvest of winter sown crop and lucerne was determined from a sample of about 500 g of harvested biomass, dried at 65 °C with forced ventilation for 72 h and then weighted, for DM and humidity determination. The yield components (stems m\(^{-2}\), fructiferous organs stem\(^{-1}\), seed per fructiferous organs and harvest index (HI), seed weight from stems ratio as a percentage of biomass cut at ground level) and chemical analyses for MFU in barley, broad bean, lucerne, pea and squarrose clover were determined on samples of tillers manually picked up from two 0.5 m sections of rows prior to harvest the plot while in spring sown corn and sorghum, the DM and MFU were determined on samples of two plants taken at random from those used for biomass and seed determination.

Suddenly after winter crops harvests of cropping system models, the plots were ploughed, fertilized with nitrogen and phosphorous (respectively, 36 and 96 kg ha\(^{-1}\)) and tinned with cultivator and harrow. The corn and sorghum were oversaw in rows (0.60 m within rows) and at seeding stage (2 developed leaves) thinned at density of 10 for maize and 40 plants for silage sorghum; and 25 plants for grain sorghum under irrigated condition and 35 and 20 under rainfed. At 4 whorl leaves phonological stage, the plots were toodressed with urea, corn 160 kg ha\(^{-1}\) and sorghum with 130 kg ha\(^{-1}\) under irrigated and 110 kg ha\(^{-1}\) under rainfed. The sown spring crops under rainfed were not irrigated after seeding while those under irrigation
treatment, water was applied when ET from the crops determined according Doorenbos and Kassam (1979) procedure, reached 80 mm. The amount of water supplied by irrigation was a fixed volume (500 m³ ha⁻¹). During the vegetative cycle of crops, was made 1 irrigation to winter sown crops while to the spring sown were applied 8 irrigations in corn and lucerne and 5 in sorghum. In all winter-spring sown crops, water supplied was made with a horizontal bar 16 m long and 125 cm above the soil surface applying a fix volume of water (500 m³ ha⁻¹). Nozzle pressure was 0.19 MPa and the apparatus was moved by hydraulic system. During the vegetative cycle of crops weeding was made when necessary by hand.

**Laboratory qualitative biomass and seed characteristics:** The chemical parameters were assessed from samples harvested in each year of evaluation, from two 0.5 m sections of rows picked up prior to harvest (biomass and seed) the plot. After mowed a samples of about 1000 g of kernels and stem biomass were air dried in chamber with forced ventilation and afterwards ground, with Cyclotec mill with a mesh screen with ø of 1 mm, were hermetically sealed and stored at -20 °C until laboratory analysis. The traits assessed were crude protein (Kirsten, 1983), crude fibre (Henneberg and Stohmann, 1863), ash, fat (Sukhija and Palmquist, 1983), neutral detergent fibre, acid detergent fibre and acid detergent lignin (Goering and van Soest, 1970). All determinations were carried out in duplicate. The chemical data of stems and seed analysis were used for MFU determination according to Demarquilly et al. (1980). The number of MFU per hectare (n. MFU ha⁻¹) of crop silage and seed grain was computed multiplying the value (express in kg m⁻²) of DM or SY by their respective MFU by 10000. The total number of MFU ha⁻¹ of model was given by summing the MFU ha⁻¹ of winter and those of spring sown models. According to the modality of the crop utilization of fodder crops, three MFU ha⁻¹ determination have been assessed: silage-silage (sum of MFU ha⁻¹ of crop used for silage utilization in winter and spring sown models), silage-seed (sum of MFU ha⁻¹ of winter seed and MFU ha⁻¹ of silage spring sown models) and seed-seed (sum of MFU ha⁻¹ of crop used for seed consumption in winter and spring models).

**Chemical soil determinations:** In September 2005 before fertilization and in November 2008 (beginning and end of experiment) a soil samples were collected for chemical determinations. The samples were taken from the soil surface (0-35 cm Ap horizon) using a 60 mm diameter core sampler.

On grid points of soil appointed for experiments were made 4 harvests in 2005 before ploughing for seedbed preparation while at the end of experiment, from each replication of the spring sown model, was picked up one soil sample. The soil samples picked up from the experiment were 20 (4 before the beginning and 16 at end of experiment) under irrigation and as many as under rainfed treatments for a total of 40 samples. Each sample was made mixing 4 cores soil drilled from grid point of plot surface, after thorough manual root separation, were air-dried, sieved with a 2 mm Ø mesh screen after that air-tight sealed and stored at -20 °C in a cool room until they were used for laboratory determinations.

Soil chemical parameters assessed were: N (Kjeldahl, 1983), OM (Walkley and Black, 1934), P (Olsen et al., 1954), K (UNICHIM, 1985), cation exchange capacity (Géhu and Franck, 1954) and pH on liquid extract of 1:2.5 soil/water solutions.

**Statistical analyses:** Statistical analyses were conducted, in all herbage and seed yield traits, by using PROC ANOVA procedure of the SAS (1997). The statistical inferences were carried out in all data on four (model I to model IV) and on two (model III and model IV) cropping system models for DM and SY consumption, respectively (Table 1).

The statistical method adopted for analysing data was a factorial experimental design arranged in a split-plot in time (year of evaluation) and space (irrigation treatments) where year, irrigation and model was assumed as the first, the second and the third factors of the analyses (Steel and Torrie, 1980). The ANOVA used a mixed model with irrigation, cropping systems and replication as fixed effect and year of evaluation as random effects. The levels of first, second and third factor were 3, 2 and 4, respectively. The data of the years, in all traits, not expressed significant variation at Bartlett (1937) homogeneity test. Mean comparison among traits were tested by Duncan’s Multiple Range Tests and by least significant difference (LSD). These two parametric statistics were computed utilising the appropriate error term of ANOVA (Steel and Torrie, 1980). The ANOVA mean square results of statistical inferences of main factor and their interaction with 1 freedom degree (df) in DM [(irrigation (I), seeding data (S) and interaction (IxS)] and SY [(irrigation (I), seeding
data (S), cropping models (M) and interaction: (IxM), (IxS), (MxS) and (IxMxS)) were not reported in the tables (Tables 2, 3). The chemical parameters of topsoil were analysed according factorial experiment arranged in split-pot design with irrigation as main plot and cropping system models and determinations made at the beginning of experiment in subplot with four replications. In the statistical analysis, the irrigation was assumed as first factor with 2 levels and cropping system models and beginning determination as second factor with 5 levels. Mean comparison among cropping system models and previous determination were made using the LSD at P> 0.05 and 0.01 probability levels computed on error term of the ANOVA.

RESULTS
The mean squares of traits of main factors: irrigation, seeding data and cropping models in DM and SY were statistically significant (Tables 2, 3). Although the ANOVA of main factors were significant in all traits, the lack of statistical significant of two-, three- and four way interaction factors in some of them (moisture, plant height and stem m^{-2} in IxM in DM; and moisture and MFU in MxS and MFU in IxMxS in SY), was due to reduced effect of weather impact on plant development during the years of evaluation. As consequences of reduced effect of interaction among agronomic treatments, the statistical analysis of experimental data to the homogeneity Bartlett’s test (1937) did not express significant variation, thus the result reported further in the text, tables and figures are the mean over the years of evaluation. The mean of winter models under irrigated condition was higher 28.9% in DM and 4.5% in moisture than those under rainfed. Further increase of DM and moisture traits was observed under irrigation and spring sown models (DM and moisture of irrigated treatment was 32.2% and 7.1% higher than rainfed) (Figs 2a, 2b). The values of DM among winter sown models range from 4.86 t ha^{-1} in model IV to 10.33 t ha^{-1} in model III under rainfed; and 9.86 t ha^{-1} in model II to 12.56 t ha^{-1} in model III under irrigated while under spring sown models the DM production was increased (11.13 t ha^{-1} model I to 21.81 t ha^{-1} model III under rainfed and 17.56 t ha^{-1} model IV to 28.92 t ha^{-1} model II under irrigated) (Fig. 2a).

The highest moisture at harvest (77.8%) was observed in model I of spring sown under irrigated treatment while in other models, the humidity at harvest was reduced by 13.1%. The moisture of irrigated winter and spring sown models was 4.4% and 7.0%, respectively higher than rainfed (Fig. 2b). The MFU of model II of irrigated winter sown was 12.9% higher than rainfed while opposite trend was observed in the model IV (rainfed 17% higher than irrigated).

The MFU values among models were related to irrigation treatment and sown data (Fig. 2c). The effect of water supply, in comparison to rainfed, increased the gap between lower and higher value of MFU in the models (range from 0.68 in model IV to 0.83 model II under irrigated vs 0.70 in model IV to 0.79 model I under rainfed) (Fig. 2c). The larger DM mean values of MFU in the spring sown models (model II, III and IV) under irrigated treatment (0.78) than those under rainfed (0.70) was a consequences of reduced impact of weather on plant development (Fig. 2c). The reduced gap of variation (0.70 under irrigated and 0.67 under rainfed) observed in the mean values of MFU of winter sown models (model II, III and IV), evidenced low effect of weather on plant development of models under rainfed (Fig. 2c).

The benefit in term of percentage of irrigation treatment on MFU mean of spring sown models (model II, III and III) in comparison to those of rainfed (model II, III and IV) was 10.1% and 4.0%, respectively (Fig. 2c). In models with the same genotypes (models II and III in winter and models III and IV in spring sown), the effect of irrigation increased plant height (11.5% in model II and 20.1% in mode III in winter; and 11.3% in model III and 9.2% in model IV of spring sown) and stem density (3.7% in model II and 5.6% in model III in winter and 7.3% and 6.3% in model III and model IV of spring sowing models, respectively) (Figs 3a, 3b).

The SY of irrigated cropping models with winter sown was lower than those of spring sown models (model III 18.20% in model III and 36.9% of winter and 78.1% in model II and 73.7% in model IV of spring sown) (Table 4). The mean of moisture at harvest of irrigated winter sown models did not differ from those of rainfed while in spring sown, significant change was evident in the model II and model IV under irrigated condition (model II 16.5% higher than model IV) (Table 4). The mean of MFU in SY under irrigated winter sown was 15.0% lower than those of spring models while within those of winter and spring sown, no significant variation were found (Table 4).
Table 1. Winter and spring sown genotypes and forage crop species evaluated in cropping system models under the irrigated and rainfed treatment in environment with a Mediterranean climate.

<table>
<thead>
<tr>
<th>Model</th>
<th>Winter sown model under irrigation</th>
<th>Spring sown model under irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td><strong>Crops</strong></td>
<td>Lucerne</td>
<td>Italian ryegrass</td>
</tr>
<tr>
<td><strong>Variety</strong></td>
<td>Bella</td>
<td>Andrea</td>
</tr>
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</table>

Table 2. Mean squares of the herbage trait DM (kg m\(^{-2}\)), moisture at harvest (%), plant height (cm), stems m\(^{-2}\) (n), MFU (MFU kg DM\(^{-1}\)), MFU ha\(^{-1}\) (n). The source of mean square of herbage traits with 1 df [irrigation (I), seeding data (S) and IxS interaction] are omitted.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Dry matter</th>
<th>Moisture</th>
<th>Plant height</th>
<th>Stem m(^{-2})</th>
<th>MFU</th>
<th>MFU ha(^{-1})</th>
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<td>36.1**</td>
<td>977**</td>
<td>71171**</td>
<td>0.08**</td>
<td>727**</td>
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<tr>
<td>Model (M)</td>
<td>3</td>
<td>4109**</td>
<td>449**</td>
<td>1143**</td>
<td>212166**</td>
<td>0.03**</td>
<td>2917**</td>
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<table>
<thead>
<tr>
<th>Interaction</th>
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<th></th>
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<tbody>
<tr>
<td>IxY</td>
<td>2</td>
<td>1893**</td>
<td>311**</td>
<td>1704**</td>
<td>83545**</td>
<td>0.006*</td>
<td>66*</td>
</tr>
<tr>
<td>IxM</td>
<td>3</td>
<td>1460**</td>
<td>21 ns</td>
<td>163 ns</td>
<td>5299 ns</td>
<td>0.12**</td>
<td>813**</td>
</tr>
<tr>
<td>MxY</td>
<td>6</td>
<td>67 ns</td>
<td>134**</td>
<td>1096**</td>
<td>21373**</td>
<td>0.004 ns</td>
<td>319**</td>
</tr>
<tr>
<td>SxM</td>
<td>3</td>
<td>432**</td>
<td>25**</td>
<td>6051**</td>
<td>286026**</td>
<td>0.04**</td>
<td>295**</td>
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<tr>
<td>SxY</td>
<td>2</td>
<td>1514**</td>
<td>109**</td>
<td>1870**</td>
<td>47747**</td>
<td>0.006*</td>
<td>686**</td>
</tr>
<tr>
<td>IxSxM</td>
<td>3</td>
<td>426**</td>
<td>5.3 ns</td>
<td>499 ns</td>
<td>8668 ns</td>
<td>0.06*</td>
<td>1330**</td>
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<tr>
<td>IxMxY</td>
<td>6</td>
<td>90 ns</td>
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<td>5438 ns</td>
<td>0.004 ns</td>
<td>172 ns</td>
</tr>
<tr>
<td>IxSxY</td>
<td>2</td>
<td>61 ns</td>
<td>22 ns</td>
<td>493 *</td>
<td>1197 ns</td>
<td>0.09**</td>
<td>3 ns</td>
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<td>0.03 ns</td>
<td>38 ns</td>
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<tr>
<td>IxMxSxY</td>
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<td>70 ns</td>
<td>3.5 ns</td>
<td>186 ns</td>
<td>5230 ns</td>
<td>0.004 ns</td>
<td>37 ns</td>
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<tr>
<td><strong>Error</strong></td>
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<td>42</td>
<td>9.47</td>
<td>162.7</td>
<td>2673</td>
<td>0.002</td>
<td>30</td>
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* and ** Statistically significant at P > 0.05 and P > 0.01 probability level, respectively. ns, not significant.
Table 3. Mean squares of the seed grain traits: SY (kg m$^{-2}$), moisture at harvest (%), plant height (cm), stems m$^{-2}$ (n), MFU (MFU kg DM$^{-1}$) and MFU ha$^{-1}$ (n). The source of mean square of seed yield traits with 1 df [irrigation (I), seeding data (S), models (M) and interaction IxM, IxS, MxS and IxMxS] are omitted.

<table>
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<tr>
<th>Source</th>
<th>df</th>
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<th>Seed weight</th>
<th>Harvest Index</th>
<th>MFU</th>
<th>MFU ha$^{-1}$</th>
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<td>125 **</td>
<td>20813 **</td>
<td>2417 **</td>
<td>0.025 **</td>
<td>82706 **</td>
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<tr>
<td>Interaction</td>
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<td></td>
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</tr>
<tr>
<td>IxM</td>
<td>1</td>
<td>8.9 *</td>
<td>61 **</td>
<td>1080 *</td>
<td>814 **</td>
<td>0.01 **</td>
<td>4465 **</td>
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<tr>
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<td>208 **</td>
<td>10253 **</td>
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<td>457 **</td>
<td>16058 **</td>
<td>553 **</td>
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<td>61762 ns</td>
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<td>MxS</td>
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<td>408 **</td>
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<td>484 **</td>
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</tr>
<tr>
<td>MxY</td>
<td>2</td>
<td>39 ns</td>
<td>182 **</td>
<td>9610 **</td>
<td>406 **</td>
<td>0.005 **</td>
<td>4677 ns</td>
</tr>
<tr>
<td>SxY</td>
<td>2</td>
<td>491 **</td>
<td>170 **</td>
<td>4059 **</td>
<td>253 **</td>
<td>0.02 **</td>
<td>61762 **</td>
</tr>
<tr>
<td>IxMxS</td>
<td>1</td>
<td>556 **</td>
<td>213 **</td>
<td>17725 **</td>
<td>134 **</td>
<td>0.001 ns</td>
<td>71572 **</td>
</tr>
<tr>
<td>IxMxY</td>
<td>2</td>
<td>581 **</td>
<td>39 *</td>
<td>8869 **</td>
<td>173 **</td>
<td>0.005 **</td>
<td>76007 **</td>
</tr>
<tr>
<td>IxSxY</td>
<td>2</td>
<td>839 **</td>
<td>114 **</td>
<td>5435 **</td>
<td>446 **</td>
<td>0.01 **</td>
<td>13942 *</td>
</tr>
<tr>
<td>MxSxY</td>
<td>2</td>
<td>15 ns</td>
<td>29 ns</td>
<td>1445 **</td>
<td>583 **</td>
<td>0.002 ns</td>
<td>16126 *</td>
</tr>
<tr>
<td>IxMxSxY</td>
<td>2</td>
<td>62 ns</td>
<td>65 **</td>
<td>682 ns</td>
<td>6871 **</td>
<td>0.001 ns</td>
<td>8219 ns</td>
</tr>
<tr>
<td>Error</td>
<td>69</td>
<td>26.6</td>
<td>9.8</td>
<td>232.1</td>
<td>21.6</td>
<td>0.001</td>
<td>3738</td>
</tr>
</tbody>
</table>

* and ** Statistical significant at P> 0.05 and P> 0.01 probability level, respectively. ns, not significant.

Table 4. Mean of SY, moisture at harvest, seed weight, HI and MFU in winter and spring sown cropping system models under rainfed and irrigated treatment of the experiment.

<table>
<thead>
<tr>
<th>Model</th>
<th>Irrigated crop models</th>
<th>Spring sown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter sown</td>
<td>IV</td>
</tr>
<tr>
<td>Crop / Trait</td>
<td>II</td>
<td>IV</td>
</tr>
<tr>
<td>Seed yield (kg ha$^{-1}$)</td>
<td>Two row barley</td>
<td>Broad bean</td>
</tr>
<tr>
<td>Two row barley</td>
<td>5456**</td>
<td>3457**</td>
</tr>
<tr>
<td>Pea</td>
<td>12.5 ns</td>
<td>13.1 ns</td>
</tr>
<tr>
<td>Seed sorghum</td>
<td>33.5**</td>
<td>277.1**</td>
</tr>
<tr>
<td>HI (%)</td>
<td>23**</td>
<td>29**</td>
</tr>
<tr>
<td>MFU [n (kg DM$^{-1}$)]</td>
<td>1.03 ns</td>
<td>1.07 ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Rainfed crop models</th>
<th>Spring sown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter sown</td>
<td>IV</td>
</tr>
<tr>
<td>Crop / Trait</td>
<td>II</td>
<td>IV</td>
</tr>
<tr>
<td>Seed yield (kg ha$^{-1}$)</td>
<td>Two row barley</td>
<td>Pea</td>
</tr>
<tr>
<td>Two row barley</td>
<td>4467**</td>
<td>2181**</td>
</tr>
<tr>
<td>Pea</td>
<td>12.1 ns</td>
<td>13.0 ns</td>
</tr>
<tr>
<td>Seed sorghum</td>
<td>32.2**</td>
<td>146.4**</td>
</tr>
<tr>
<td>HI (%)</td>
<td>35.1**</td>
<td>17.9**</td>
</tr>
<tr>
<td>MFU [n (kg DM$^{-1}$)]</td>
<td>1.17 ns</td>
<td>1.19 ns</td>
</tr>
</tbody>
</table>

* and ** Statistical significant at P> 0.05 and P> 0.01 probability level, respectively. ns, not significant.
Table 5. MFU ha\(^{-1}\) produced by model (sum of winter and spring model) according to the modality of forage utilization (silage-silage, silage-seed and seed-seed) and difference between OM content of model at the beginning and those at the end of experiment.

<table>
<thead>
<tr>
<th>Crop utilization</th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
<th>Model IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silage-silage</td>
<td>16962</td>
<td>30815</td>
<td>30363</td>
<td>18097</td>
</tr>
<tr>
<td>Silage-seed</td>
<td>-</td>
<td>22993</td>
<td>27611</td>
<td>15622</td>
</tr>
<tr>
<td>Seed-seed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15100</td>
</tr>
<tr>
<td>OM reduction (g kg(^{-1}))</td>
<td>- 2.6</td>
<td>5.0</td>
<td>3.6</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Rainfed (n MFU ha\(^{-1}\))

<table>
<thead>
<tr>
<th></th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
<th>Model IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silage-silage</td>
<td>13951</td>
<td>14856</td>
<td>18538</td>
<td>11771</td>
</tr>
<tr>
<td>Silage-seed</td>
<td>8526</td>
<td>-</td>
<td>-</td>
<td>5574</td>
</tr>
<tr>
<td>Seed-seed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>OM reduction (g kg(^{-1}))</td>
<td>0.9</td>
<td>3.1</td>
<td>3.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Table 6. Mean soil parameters at the beginning vs the content at end of winter and spring sown forage crop models established under rainfed and irrigated condition of growing.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rainfed</th>
<th>Irrigated</th>
<th>LSD 0.05</th>
<th>Rainfed</th>
<th>Irrigated</th>
<th>LSD 0.05</th>
<th>Rainfed</th>
<th>Irrigated</th>
<th>LSD 0.05</th>
<th>Rainfed</th>
<th>Irrigated</th>
<th>LSD 0.05</th>
<th>Rainfed</th>
<th>Irrigated</th>
<th>LSD 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>OM (g kg(^{-1}))</td>
<td>N (g kg(^{-1}))</td>
<td>C/N</td>
<td>OM (g kg(^{-1}))</td>
<td>N (g kg(^{-1}))</td>
<td>C/N</td>
<td>OM (g kg(^{-1}))</td>
<td>N (g kg(^{-1}))</td>
<td>C/N</td>
<td>OM (g kg(^{-1}))</td>
<td>N (g kg(^{-1}))</td>
<td>C/N</td>
<td>OM (g kg(^{-1}))</td>
<td>N (g kg(^{-1}))</td>
<td>C/N</td>
</tr>
<tr>
<td>Beginning</td>
<td>25.3 a</td>
<td>25.3 b</td>
<td>1.44 a</td>
<td>1.44 b</td>
<td>-</td>
<td>9.8 a</td>
<td>9.8 b</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Model-I</td>
<td>24.3 b</td>
<td>27.9 a</td>
<td>1.28 d</td>
<td>1.10 d</td>
<td>**</td>
<td>11.3 a</td>
<td>12.1 a</td>
<td>**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Model-II</td>
<td>22.2 d</td>
<td>20.3 a</td>
<td>1.36 C</td>
<td>1.21 c</td>
<td>**</td>
<td>9.8 b</td>
<td>9.1 c</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Model-III</td>
<td>22.2 d</td>
<td>21.7 d</td>
<td>1.31 b</td>
<td>1.06 d</td>
<td>**</td>
<td>9.8 b</td>
<td>9.1 c</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Model-IV</td>
<td>23.5 c</td>
<td>23.1 c</td>
<td>1.30 b</td>
<td>1.36 b</td>
<td>*</td>
<td>10.6 c</td>
<td>9.9 b</td>
<td>ns</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mean models</td>
<td>23.1 a</td>
<td>23.3 a</td>
<td>1.3 a</td>
<td>1.2 a</td>
<td>ns</td>
<td>10.4 a</td>
<td>10.3 a</td>
<td>ns</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil</th>
<th>P (mg kg(^{-1}))</th>
<th>K (mg kg(^{-1}))</th>
<th>pH</th>
<th>Soil</th>
<th>P (mg kg(^{-1}))</th>
<th>K (mg kg(^{-1}))</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning</td>
<td>26.0 a</td>
<td>1388 a</td>
<td>8.2 a</td>
<td>Beginning</td>
<td>26.0 a</td>
<td>1388 a</td>
<td>8.2 a</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Model-I</td>
<td>21.3 d</td>
<td>449 d</td>
<td>8.2 a</td>
<td>Model-I</td>
<td>21.3 d</td>
<td>449 d</td>
<td>8.2 a</td>
</tr>
<tr>
<td>Model-II</td>
<td>21.5 c</td>
<td>507 c</td>
<td>8.0 c</td>
<td>Model-II</td>
<td>21.7 b</td>
<td>507 c</td>
<td>8.0 c</td>
</tr>
<tr>
<td>Model-III</td>
<td>23.0 b</td>
<td>507 c</td>
<td>8.0 c</td>
<td>Model-III</td>
<td>23.0 b</td>
<td>507 c</td>
<td>8.0 c</td>
</tr>
<tr>
<td>Model-IV</td>
<td>22.5 c</td>
<td>421 e</td>
<td>8.0 c</td>
<td>Model-IV</td>
<td>22.5 c</td>
<td>421 e</td>
<td>8.0 c</td>
</tr>
<tr>
<td>Mean models</td>
<td>22.3 a</td>
<td>471 b</td>
<td>8.1 a</td>
<td>Mean models</td>
<td>22.3 a</td>
<td>471 b</td>
<td>8.1 a</td>
</tr>
</tbody>
</table>
Figure 1. Meteorological characteristics (mean of monthly temperature, solar radiation, rainfall and evapotranspiration) and their standard deviation over the three years of crops experiments (2006, 2007, 2008).

Means with the same letters are not significant at Duncan’s Multiple-Range Test at P>0.05 level of probability. ns, not significant. The effect of water supply on genotype of cropping system models in winter (barley) and spring sown (grain sorghum), increased SY and seed weight (18.2% and 3.9% in model III of winter and 73.7% and 64.9% in model IV of spring sown, respectively) while others traits (HI and MFU) were less influenced by irrigation treatment (Table 4). The number of MFU ha⁻¹ was related to the modality of forage utilization of the winter-spring sown models (silage-silage, silage-grain and grain-grain). The MFU ha⁻¹ mean over models of silage-silage utilization was higher 34.6% and 62.3% under rainfed and 8.4% and 37.37% under irrigated than silage-seed and seed-seed utilization, respectively (Table 5). Comparison of MFU ha⁻¹ among forage consumption of model IV, silage-silage utilization was higher 13.6% and 16.6% under irrigated and 8.4% and 62.3% under rainfed than silage-seed and seed-seed models, respectively (Table 5).
Figure 2. Mean over years of DM production (a), moisture at harvest (b) and milk forage unit in winter (W) and spring (S) sowing forage crop models (model I, model II, model III and model IV) under rainfed and irrigated condition.

Model means trait of the same genotype under rainfed and irrigated treatments with the same letter are not significant at Duncan's Multiple-Range Test at $P>0.05$ level of probability.
Figure 3. Mean over years of plant height (a) and stems density (b) of the crops in winter (W) and spring (S) sowing forage crop models (model I, model II, model III and model IV) under rainfed and irrigated condition of growing.

Model means trait of the same genotype under rainfed and irrigated treatments with the same letter are not significant at Duncan's Multiple-Range Test at P>0.05 level of probability.

Furthermore, the MFU ha\(^{-1}\) of model II, under irrigated treatment in silage-silage utilization, was 45.0%, 1.5% and 41.3% higher than model I, model III and model IV, respectively while the variation, among models under rainfed was reduced in model III and model IV and increased in model I (24.7% 36.5% and 19.9%, respectively). The highest MFU ha\(^{-1}\) of silage-seed utilization was obtained in the model III under irrigated (16.7% and 43.4% higher than models II and IV) and model IV under rainfed treatments (21.0% higher than model I) (Table 5). The gap (difference between highest and lowest value of models) of trait MFU ha\(^{-1}\) under irrigated and rainfed of the silage-silage utilization in comparison to those of silage-seed was reduced among irrigated and rainfed models (13853 vs 11989 under irrigated and 6767 vs 2261 under rainfed) (Table 5).

The trait OM content at the beginning and those at end of experiments, under irrigated was higher reduced in grasses winter-spring sown models (3.1 g kg\(^{-1}\), model II and model III) than those sown in winter with legume and spring with grass (1.4 g kg\(^{-1}\), model I and model IV). By contrast under irrigated treatment, the gap among the content of OM at beginning and those at end of experiment, except perennial legume (increased 2.6 g kg\(^{-1}\) in model I made perennial legume), was reduced by 2.2 g kg\(^{-1}\) in the models made by annual legumes in winter and grasses in spring sown (model IV) and 4.3 g kg\(^{-1}\) in winter-spring sown models made by grasses (mean model II and III) (Tables 5, 6).

The N content at the beginning of experiment was reduced (mean over models) in all models of irrigated (0.08 g kg\(^{-1}\)) and irrigated treatments (0.17 g kg\(^{-1}\)).
low content of N in topsoil of the models under irrigated in comparison to those of rainfed, was consequences of high requirements of nutrients need for supporting the high DM and SY production recorded under water supply condition (Fig. 2a, Table 4). The C/N ratio increase of the beginning experiment in models made by annual legume-grass under rainfed and irrigated treatment (mean of model I and model IV: 1.15 and 0.1 respectively) and reduction by 0.7 in grass-grass models (mean of model II and model III) of both irrigated treatments, was due to wider rhizobia activity in legume-grass than grass-grass models (Table 6).

The content of P and K in all models showed opposite trend across irrigation treatment. The mean of P and K content in models, in comparison to those present at the beginning of experiment was reduced by 5.2 mg kg⁻¹ and 887 mg kg⁻¹ under irrigated and 3.5 mg kg⁻¹ and 917 mg kg⁻¹ under rainfed, respectively (Table 6). The mean value of P across the model I, model II, model III and model IV under rainfed was 6.0%, 1.9%, 7.0% and 8.9% higher and 11.1%, 3.1%, 2.7% and 8.1% lower in K than models under irrigated treatment, respectively (Table 6). However, the variation of P and K elements among models may support the role in cycling nutrient elements for crop growing.

The pH value was statistically significant under irrigated treatment across the legume-grass rather than grass-grass models (Table 6). The variation of pH trait observed in models with winter sown legume-grass rotation under irrigated rather than rainfed, were due to higher effect of rhizobia activity in topsoil.

**DISCUSSION**

The significant effect of the main factors (year, irrigation, seedling and cropping system models) in all DM, SY and biochemical soil traits evidenced wide opportunity to provide forage requirement for buffalo breeding under irrigated and rainfed condition in UAA land of EU Mediterranean environments with reduced impact of cropping system on biochemical soil parameters (Tables 2, 3, 6) (Borghese, 2005; Barile et al., 2007; Martiniello et al., 2007a).

The higher magnitude of mean square values of agronomic treatment and their two-, three- and four-way interaction factors in herbage than grain yield traits of cropping systems were due to the effect of agronomic management on plant development of winter and spring sown crops (Tables 2, 3). The reduced effect of irrigation on winter crops rather than spring sown (0.93 t ha⁻¹ under rainfed vs 1.087 t ha⁻¹ under irrigated and 1.49 t ha⁻¹ vs 2.38 t ha⁻¹ irrigated) was a consequences of better vegetative performance of plants to grow in months with available water supply than natural weather condition (Fig. 1) (Pala et al., 2007, Martiniello, 2009; Martiniello and Texeira da Silva, 2011). The reduced effect of the weather impact on plant development by irrigation weakened the discrepancy and standard error among traits (DM, moisture and MFU in model I, II, III and IV) in cropping models in comparison to those of rainfed (Figs 2a, 2b, 2c). However, instead the stress of weather effect on plant development, the winter-spring sown cropping system models under rainfed favours forage production in environment with harsh environmental condition allowing the opportunity to extend the buffalo breeding husbandry dairy farms in the UAA land of EU Mediterranean environments.

According to Pierce and Rice (1988), Garcia et al. (2007) and Martiniello (2009), the rainfed winter and spring sown models, in comparison to those of irrigated, influences the physiological process of plant growth and relocation of photosynthesized compounds in the organs of plant with reduction of moisture at harvest and MFU (Figs 2b, 2c) and plant height and plant density (Figs 3a, 3b) (3.2%, 0.06, 13.6 cm and 38 stem m⁻², respectively). Thus, the effect of irrigation feeble the physiological stress on plant development favouring higher water use efficiency of biochemical compounds in the organs of plant than rainfed (Figs 2a, 2c, Table 4) (Stanhill, 1986; Pierce and Rice, 1988; Pala et al., 2007). Soever, the yearly mean decrease observed in herbage production, between rainfed and irrigated treatment of DM silage sorghum in model III (12.59 t ha⁻¹ rainfed vs 20.75 t ha⁻¹ irrigated) and SY of sorghum in model IV (2.63 t ha⁻¹ rainfed vs 9.22 t ha⁻¹ irrigated), was due to reduction of physiological efficiency of the crops under drought conditions of environment (Fig. 2a, Table 4). The reduction of MFU ha⁻¹ from silage-silage to silage-seed and seed-seed utilization was due to the delay of harvests in winter and spring sown cropping system models used for SY production (Table 5). In agreement to Hudson (1994) and Martiniello and Texeira da Silva (2011), the lack of weather natural resource, spoiled by plant during the time from DM harvest to SY harvest for sustain
physiological process of respiration, reduced the relocation of stored compounds in the sink organ with a consequent reduction of DM of plant for SY consumption (Fig. 2a, Table 4). Therefore, the effect of irrigation on MFU ha\(^{-1}\) seed-seed utilization, in comparison to those for silage-silage, was reduced by 20.8% in winter sown (3903 rainfed vs 4930 irrigated) and by 76.4% in spring sown (6504 under rainfed and 27595 under irrigated condition) (Figs 2a, 2c, Table 4). According to results found in other experiments by Gerber and Hoffmann (1998), Stockdale et al. (2001) and Martiniello (2011), the discrepancies existing among content of OM, N and chemical elements of the topsoil of beginning and end of experiment are related to the agronomic exploitation of weather resources and management techniques adopted for crop growing. The effect of three years continuous growth of models influenced the beginning content of chemical parameters of topsoil (Table 6). The higher value of OM, N and C/N traits under rainfed and irrigated treatments of winter sown legumes models (model I and model IV) rather than those of grasses (model II and model III), was due to the effect left by legume cropping system on rhizosphere of topsoil (Table 6).

In agreement to Kumar and Goh (2000) and Martiniello (2011), the higher reduction of OM and N traits in the soil of winter and spring sown models based on grasses (Italian ryegrass, barley, corn and sorghum) in comparison to content present at the beginning of experiments, was a consequences of their utilization in mineralization process for providing nutrient needed for sustaining crops production. By contrast the cropping system models based on winter legume and spring grass sown models (model I and model IV), showed lower differences among value of soil chemical parameters at end of experiment than those with winter and spring grass sown (Table 6).

In agreement with Silgram and Shepherd (1999), Follet (2001) and Martiniello (2011), the reduction of OM and N content of the beginning experiment through the three years of continuous growing under rainfed and irrigated conditions (Table 6), was due to the microbial activity for providing nutrient inputs able to sustaining plant development for DM (Figs 2a, 3a) and SY production (Table 4). Thus, the higher content of OM of winter legume than grass sown under rainfed and irrigated treatment may support the soil OM content for sustaining the MFU ha\(^{-1}\) production.

According to Hudson (1994), Perucci et al. (1997), Reeves (1997), Pagliai et al. (2004), Martiniello (2007) and Goulding et al. (2008) the advantages derived by legumes forage crop model over grasses increased the sources of OM and C/N in topsoil for sustaining the turnover of biochemical soil characteristics (7.1% and 6.2% under rainfed and 17.6% and 14.8% under irrigated, respectively) (Table 6). The higher reduction of C/N ratio observed in the models under irrigated than those under rainfed was a consequences of microbial activity which promote reduction of OM content for provide nutrients required for DM and SY production (Fig. 2a, Table 4) (Ladha et al., 1996; Murphy et al., 1999; Kumar and Goh, 2008).

Winter legume and spring grass sown in cropping systems in comparison to winter-spring grasses sown favoured sustainable effect on soil OM and quality of feeding nutritive forage production. Particularly, considering the C/N values of model IV under rainfed (10.6) and irrigated (9.9) treatment, the winter sown legume in comparison to those of grass models, favoured better dynamics of biochemical activity in topsoil rendering forage production for buffalo breeding a sustainable cropping systems of OM in topsoil of rainfed and irrigated treatment (Table 6).

The difference in N content between rainfed and irrigated treatment models (higher in rainfed than irrigated) was a consequence of the higher uptake of element under favourable irrigated weather than unfavourable harsh environment. Thus the lower content of nitrogen in topsoil of the models under irrigated than those of rainfed, was consequences of high requirements of nutrients need for supporting the high DM and SY production recorded under water supply condition (Figs 2a, 3a, 3b, Table 4).

In line with the results found by Watson (1963) in subterranean clover (Trifolium subterraneum L.), Graham and Vance (2003) in lentil (Lens esculenta L.), bean (Phaseolus vulgaris L.) and soybean (Glycine max L.) and Martiniello (2007) in berseem clover (Trifolium alexandrinum L.) and lucerne, the reduction of P in the legumes models of rainfed and irrigated treatment in comparison to those of grasses may be due to the use of element by Rhizobium spp for providing nitrogen requirement for the aerial development of the crops. The reduction in the content of P in topsoil of legume-grass of irrigated cropping system models was...
consequences of microbial activity for cycling nutrients for sustain the MFU ha\(^{-1}\) production. The reduction of pH values in the winter sown legume and spring sown grass models during the period of experiment were due to the effect of rhizobia activity in the topsoil (Pokorny and Stralkova, 1999; Mohammod, 2009; Phillips, 2010). The discrepancy of P and K content in the models made by legumes (model I and model IV) and grasses (model II and model III) (20.3 and 21.4 mg kg\(^{-1}\) for P and 461 and 522 mg kg\(^{-1}\) for K under irrigated; and 21.9 and 22.3 mg kg\(^{-1}\) for P and 435 and 507 mg kg\(^{-1}\) for K under rainfed) was a consequence of their role played in the biochemical pathways of cropping systems under irrigated and rainfed treatments. Thus, it is possible to retain that the elements are mutually involved in the role in the process of mineralization of OM in topsoil (Table 6).

In line with Halvorson et al. (1987), Pokorny and Stralkova (1999) Errebhi et al. (2004) and Mohammod (2009), the reduction of P and K content present at the beginning and those at end of experiment in the cropping system models under rainfed and irrigation treatment was a consequence of their function in microbial activity for cycling nutrient elements from crop residues mineralization for sustain crop productivity. Furthermore, the higher reduction of the K content present in soil at beginning experiment under rainfed than irrigated treatment may evidence a higher effect of element in mineralization process for sustaining the impact of weather condition on physiological activity of plant development under natural condition of growing (Table 6). The agronomic practices based on the introduction of winter and spring sown forage legume species in intensive forage production cropping systems for buffalo farming activity, reduce the impact of double crops per year on plant development and sustain the OM turnover in the soil of UAA land of Mediterranean-type environments (Barile et al., 2007; Borghese et al., 2010; Martiniello, 2011).

**CONCLUSIONS**
The agronomic management based on legume grass crop with winter and spring sown reduce the DM production of cropping system and increase the sustainability and turnover of chemical characteristics of topsoil.

The forage cropping systems based on winter legume and spring grass instead those based on winter and spring grass acquire: reduction of MFU ha\(^{-1}\) and DM traits (8.0% and 7.1% under irrigated and 7.9 and 2.7% under rainfed, respectively), increase OM (7.0% under rainfed and 17% under irrigated) and favour the turnover of chemical characteristics of topsoil.

The effect of irrigation over rainfed increase MFU ha\(^{-1}\) (30.1% in winter and 41.4% in spring sown cropping models) allowing the opportunity to expand the buffalo breeding activity in UAA irrigated land of the Mediterranean-type environments.

Water supply reduced the impact of environmental factor on physiological process of plant developments increasing the mean of silage production of MFU and DM (35.0% and 33.1% higher than the amount of the traits under rainfed condition, respectively).

The effect of irrigation was more evident in spring sown than winter models cropping systems (MFU ha\(^{-1}\) and DM under rainfed condition was lower 28.1% and 30.0% in winter and 41.0% and 37.0% in spring sown models than irrigated, respectively).

The agronomic management of models with winter and spring sown grasses in comparison to winter sown legumes and spring sown grasses, after three years of continuous crops, reduced the beginning cont of OM in topsoil (4.3 and 2.2 g kg\(^{-1}\) under irrigated and 3.2 and 1.4 g kg\(^{-1}\) under rainfed, respectively).

The use of annual and perennial legume in cropping system models in winter and spring sown for buffalo breeding, represents a management practice able to support agronomic production for dairy farming activity and sustain the turnover of OM in environments with a Mediterranean climate.

Buffalo breeding activity based on rainfed and irrigated legume cropping system achieves benefit which may represent the agronomic approaches able to expand and provide forage MFU ha\(^{-1}\) production, to recover the OM in topsoil and to sustain the husbandry dairy activity in UAA land of EU Mediterranean environments.

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REFERENCES


Burtlett, M. S. 1937. Some examples of statistical methods of research in agriculture and applied biology. Supplement to the J. Royal Stat. Soc. 4, 137-183.


UNICHIM. 1985. Determinazione potassio, magnesio, calcio e sodio scambiabile per terreni con pH>7.0), Parte I, Metodi manuali: Metodo UNICHIM No 679, Manuale No 145, 55-60.

matter and proposed modification of the chromic acid titration method. Soil Sci. 37, 29-38.
