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Field bean for forage and grain in short-season rainfed Mediterranean conditions

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Abstract

The research was carried out to evaluate the growth rate, the evolution of the nutrient characteristics, and the best stage to obtain the highest yield of nutrients from field bean (*Vicia faba* var. *minor* Beck) sown in spring for forage and seed. The best models for quanti-qualitative parameter estimation were curvilinear, such as the one proposed by Hoerl with type $y = A\ x^{B}\ e^{Cx}$, and linear, using the sum of the growing degree days (GDD) as the climatic variable. The lengths of both the whole biological cycle and the individual phases of the field bean cycle were related to the amount of GDD of the growing environment and were not affected by the cultivation year. Forage dry matter and nutrient yield of the field bean followed a curvilinear model, while the main quality characteristics followed a linear model over the measured GDD. The highest nutrient and forage yields were not reached at the same time. The highest crude protein, total digestible nutrients and forage DM yields were obtained, at approximately 1230, 1290 and 1360 GDD respectively, when the plants were at stages from the pods being visible in the middle of inflorescence to the end of the pod development. The varieties used in this study presented a similar precocity but a very different productivity. Italian varieties, of which Scuro di Torrelama was the best, produced more than the French variety. With the most productive variety, almost 7 t/ha of forage DM, almost 1.2 t/ha of CP and more than 1.3 t/ha of TDN were obtained. At the GDD of maximum forage production, the CP concentration of the field bean varied from 16 to 18%, EE from 0.6 to 0.7%, NDF from 56 to 58%, RFV from 83 to 94%, TDN from 41 to 48%, and NEL from 1.0 to 1.2 Mcal kg^{-1}. The effects of advanced or delayed harvests, compared to those carried out at the maximum yield stage, are discussed. Grain yield, which reached a maximum of 1.9 t/ha DM, 0.56 t CP/ha and 1.5 t TDN/ha, was mainly limited by a reduced seed filling stage.

Introduction

Field bean (*Vicia faba* L. var. *minor* Beck) is grown worldwide as an alternative protein source to soybean for feed, (Jezierny *et al.*, 2010), but also for green forage, hay, silage, or green manure (Onofrii and Tomasoni, 1989; Fraser *et al.* 2001; Borreani *et al.* 2009). The role of field bean is becoming increasingly important in low-input cropping systems designed to reduce mineral fertilizer inputs (Sulas *et al.*, 2013) and associated N_2O emissions and fossil fuel consumption (Jensen *et al.*, 2012). This is because it has a greater ability to enrich the soil of nitrogen (through biological N_2 fixation) compared with other legume crops (Walley *et al.*, 2007). Field bean also facilitate diversification of the agroecosystem, i.e. planned biodiversity over time, via diversified crop rotations (Jensen *et al.*, 2010), and space, via intercropping (Mariotti *et al.*, 2011). This thus indirectly enhances soil fertility, productivity, and system stability, as well as the resilience of the entire agroecosystems (Kopke and Nemecek, 2010).

In the Mediterranean climate, the sowing date for the field bean generally falls in the autumn. However, the actual time of the autumn sowing is crucial: if done too early, the plants may die due to the following cold winter, and if late, the plants will start to grow in the following spring, negating the effects of advance sowing. Moreover, the excess autumn rains typical of many areas of the north and central Italy often prevent autumn sowing and the field bean has thus to be sown in the spring.

In Italy, research on the forage and seed production by field bean sown in spring is scarce. In Spain, Confalone *et al.* (2010) reported a reduction in growth cycles from 165 to 93 days and a reduction in grain yield of about 26%, between the autumn-winter and spring sowings.

Some authors (Caballero 1989; Fraser *et al.*, 2001) have reported that the optimal harvesting stage to obtain the highest forage yield is when the pods in the lower inflorescences are fully developed in size (stage 78 of Stülpnagel's scale - 1984). However it is not clear if the reduction in growth cycles caused by the delayed sowing from autumn to spring also modifies the optimal harvesting stage to obtain the highest forage yield. In addition, the maximum forage yield, the maximum nutrients yield and the maximum forage quality probably not coincide, as usually occur in other forage crops; however, to the best of our knowledge, no data are available for field bean to establish a precise relationship between these characteristics and the plant growth.

The objectives of the present work were: (i) to study the growth rate and the evolution of the nutrient characteristics of the field bean sown for forage and seed in spring; (ii) to determine the best stage to obtain the highest production of nutrients per unit area; and (iii) to evaluate the genotypic differences between varieties widely used in the Mediterranean area.

Materials and methods

The research was carried out in 2009 and 2010 at the experimental station of the Department of Agricultural, Food and Environmental Science of the University of Pisa, Italy, which is located at a distance of approximately 10 km from the sea (43° 41' N, 10° 23' E) and 1 m asl. The climate is hot, humid Mediterranean with mean annual maximum and minimum daily air temperatures of 20.2° and 9.5° C, respectively, and a precipitation of 971 mm, 37% of which fall in autumn (Moonen *et al*., 2001). During the experiment and the growth cycle of the field bean, the total rainfall was 319 mm in 2009 and 317 mm in 2010, with a mean temperature of 16.1 and 15.5 °C, respectively.

In both years, treatments were four field bean varieties, three of Italian origin, Chiaro di Torrelama (CH), Scuro di Torrelama (SC), Vesuvio (VE), and the fourth of French origin, Irena (IR). Harvests were carried out at five stages: at the first flower racemes in bloom (stage 61 of the Stulpnagel scale (1984)), at complete flowering (stage 69), when the pods are visible in the middle inflorescences (stage 74), when the first pods lose the green colour (stage 81), and when the seeds in the upper pods are completely hard (stage 92).

In both years, the experiment was arranged in a split-plot design with three replicates. Variety was the main plot factor, and harvest stage was the subplot factor. Sub-plot dimensions were 3 by 4 m, each separated by 2 m.

Plants were grown in rows spaced 30 cm apart. Sowing took place on 4 March 2009 and 26 February 2010 at densities equivalent to 40 viable seeds m^{-2}. Seeding rates used for field bean reflected rates used normally in the region. Field bean was fertilized with nitrogen, phosphorus, and potassium, applied pre-planting as urea, triple mineral phosphate, and potassium sulphate at a rate of 15 kg ha^{-1} of N, 50 kg ha^{-1} of P, and 60 kg ha^{-1} of K. Nitrogen was applied as a starter dose to prevent the nutritive deficiency that could occur under water and thermal stress condition (Jensen *et al*. 2010; Di Paolo *et al*., 2015). The research was carried under rainfed conditions. Weed control was achieved with a post-emergence application of Propaquizafop and Imazamox.

At each harvest, forage yield was determined by weighing crop biomass harvested from 1 m^2, cutting the plants at 5 cm above-ground level.

One half of the biomass harvested was used for chemical analysis and the rest was separated into leaves, stems, inflorescences (or pods), and, in stage 92, seeds. All samples were oven dried at 70°C to constant weight in order to determine the dry matter (DM) yield. Chemical analyses were performed on the entire biomass (leaves, stems and inflorescences) except for the final harvest, in which the chemical analyses were performed separately on the seeds and residues (leaves, stems and pod walls). The parameters analyzed were the concentrations of crude protein (CP), ash, ether extract (EE), neutral-detergent fiber (NDF), acid-detergent fiber (ADF) and acid-detergent lignin (ADL), according to Martillotti *et al*. (1987). Forage quality was estimated by the relative feed value (RFV), an index calculated by ADF (related to dry matter digestibility), and NDF (related to intake potential).

The following equations were used to estimate the RFV and total digestible nutrients

(TDN), as described by Aydin *et al.* (2010), while net energy for lactation (NEL) was estimated through the equation proposed by Horrocks and Vallentine (1999):

RFV = (88.9-(0.77xADF%)) x (120/NDF%) x 0.775,

TDN (%) = (1.291xADF%) + 101.35,

NEL (Mcal/kg) = (1.044-(0.0119xADF%)) x 2.205.

In the seeds, non-fibrous carbohydrate (NFC) was estimated as NFC=100 – (NDF% + CP% + EE% + Ash%).

The CP, NDF and TDN yields per unit area were calculated by multiplying the yield per hectare and the CP, NDF and TDN concentrations.

Results were subjected to analysis of variance using CoStat version 6.4 (CoHort Software, Berkeley, CA, USA). The effects of year, variety, harvest stage and their interaction were analyzed using a split-split-plot design with year designed as whole plot, variety as sub-plots, and harvest stage as sub-sub-plots. Significantly different means were separated at the 0.05 probability level by the least significant difference test (Steel *et al.* 1997). ANOVA revealed no significant differences between years or “Year x Variety x Harvest” interaction, “Year x Variety” interaction and “Year x Harvest” interaction for all the parameters measured. The results were thus averaged over the two years.

Changes in field bean and qualitative parameters were evaluated by calculating the relationship between yield and qualitative parameters against time and growing degree days

(GDD). GDD were calculated with the NOAA method, assuming 1.7°C as the base temperature (Iannucci *et al.* 2008). Linear, quadratic and Hoerl equations were tested to describe the relationship between parameters and time/GDD. The Hoerl function of type $y = A\,x^{B}\,e^{Cx}$ was used, where y is yield or qualitative parameter, *x* is accumulated GDD, and A, B, C are regression constants. This function, which combines a power and exponential relationship, has already been used in similar experiments and generally in plant science (Singh *et al.*, 1996; Paparozzi *et al.*, 2005). The equation with the highest determination coefficient (R^2) and the smallest standard error of estimate was selected as the most appropriate (Hair *et al.* 1995). All regression analyses were performed using ten pairs of x, y values (five sampling dates for each of the two years, and the mean sampling value over the two years are presented in graphs). For the curvilinear relationships, the first derivative was computed to define the maximum value reached by the curve and the time/GDD corresponding to the maximum value (Bullock and Bullock, 1994).

Results

The growth stages of field bean at harvest are reported in Table 1. About twenty days from sowing and 190 GDD were needed for the plant emergence (T_{base} 1.7 °C, Iannucci *et al.* 2008). Field bean completed the growth cycle three months after sowing and after about 1,800 GDD accumulated. No appreciable differences among varieties were detected regarding the GDD required to complete the phenological stages.

The code of the growth stage of field beans, as reported in the Stülpnagel scale (1984), was linearly related with the increase in the number of days and the accumulation of GDD from sowing. However, GDD were more appropriate than the number of days to represent the change in growth stage (i.e. the linear regression coefficient was higher for GDD than for days from sowing). Therefore, regardless of the variety, from the stage of first flower racemes in bloom (code 61) onwards, the code increased linearly by about three stages every 100 GDD accumulated (Figure 1).

Forage production

The increase by weight of the field bean forage, expressed as a function of the sum of GDDs, showed reduced differences between the two years, and thus can be represented by a single equation. This confirms that GDD provides a sufficiently precise index of all the climatic elements that affect the growth of field bean (Yoldas and Esiyok, 2009).

The yield variation of field bean forage, as a function of accumulated GGD, was best represented by the Hoerl equation (Figure 2), and the coefficient of determination was very high for all the varieties ($R^2 \geq 0.94$ **).

Forage yield increased to about 1300-1400 GDD, and thereafter decreased (Figure 2 and Table 2). The highest forage yield of field bean and the stage in which the maximum yield was reached varied between the varieties: SC presented the highest value (more than 6 t/ha) and IR, the lowest (just under 4 t/ha). IR and CH varieties were the earliest, because they reached the maximum yield when the pods were visible in the upper inflorescences (stage 77), after accumulating about 1320 GDD, while VE was the latest (end of pod development, stage 79, 1391 GDD).

The same model was the best to describe the relationship between the GDD and the dry matter forage concentration (Figure 2). The equation parameters did not differ significantly regarding the four varieties, thus a single equation was sufficient to represent them all. At the GDD of the maximum yield, the DM concentration was 20% in CH and IR, 22% in SC and 24% in VE.

During the growth cycle, the DM distribution in different plant parts of field bean (leaves, stems and inflorescences) changed appreciably (Figure 3). The leaves decreased from 50 to less than 10%, the inflorescences increased from less than 10 to about 40%, while the stems remained stable from 40% to 50% (data not shown). The SC variety always presented the lowest percentage of leaves and the highest percentage of inflorescences, while the opposite occurred in VE (Figure 3). At the stage of maximum yield for each variety, SC presented a 21% leaf proportion and a 38% inflorescence proportion, while IR and VE presented more leaves (26%) and fewer inflorescences (about 31%).

Quality characteristics

The CP concentration of forage decreased linearly with the increase in GDD accumulated by the field bean (Figure 4). The magnitude of the decrease (slope of regression) was almost the same in CH, IR and SC (about -1.5% for each 100 GDD accumulated) and substantially lower in VE (-0.9%). Accordingly, at about 800 GDD (stage 61), the CP forage concentration was the same in all varieties (about 25%), while from about 1400 GDD (stage 79) onwards, VE presented a higher CP concentration than the other varieties (Figure 4).

The EE and ash concentration decreased linearly as the GDD increased. The ANOVA indicated that there were no statistical differences among the varieties, thus the EE and ash concentrations of the forage can be represented for all the varieties by the following linear equations: EE = 1.54 – 0.00071x (R^2= 0.96**); Ash = 10.10 – 0.0017x (R^2 = 0.88**) (data not shown). The EE and ash concentrations showed a low variation throughout the increase in GDD: from 800 to 1800 GDD, values changed from 0.9 to 0.3% for the EE and from 10 to 8% for the ash concentration (data not shown).

NDF and ADF concentrations showed a linear increase with GDD accumulated by field bean ($0.89^{**} \leq R^2 \leq 0.99^{**}$). The SC variety showed the highest concentration in both parameters, while IR showed the lowest. The NDF and ADF rate increase ranged respectively from 1.5 to 1.9% and from 1.1 to 1.4% every 100 GDD accumulated (Figure 4).

The ADL concentration in the forage of field bean and between the varieties did not change appreciably with the increase in GDD, showing an average value of 12% (data not shown).

The relative feed value decreased linearly during the growth cycle from values higher than 100% at about 800 GDD (stage 61), to 65-75% at 1800 GDD (stage 92). SC always presented the lowest value (from 106 to 64%), while IR and CH presented the highest values (from about 116 to 73%).

The TDN concentration and the NEL showed a linear decrease with the increase in GDD. The average decrease in TDN ranged from 53% to about 35%, and the decrease in NEL from 1.32 to 0.96 Mcal/kg. Regarding varieties and for both parameters, IR showed the highest values, while SC and VE showed the lowest. The rate of decrease (regression slope) was appreciably lower for the IR than for the other varieties (Figure 4).

The main quality characteristics of the field bean forage were highly positively correlated with the leaf proportion, regardless of the variety or the cultivation year (Figure 5). With the increase in age of the plants, with every 10% decrease in leaf proportion, the CP, RFV and TDN decreased by 2.5, 8.4 and 3.1%, respectively.

Nutrient yield

The Hoerl model was the best at representing the relationship between GDD and production per unit area of CP, NDF and TDN by field bean (Figure 6).

The maximum CP yield was obtained at around 1200-1300 GDD, between the 73 (pods visible in the lower inflorescences) and 76 (pods visible in the upper inflorescences) growth stages (Figure 6). The most productive variety was SC (about 1170 kg CP ha^{-1}) and the lowest productive variety was IR, with a 49% difference between both (Table 2).

The NDF yield of field bean increased to about 1400 GDD and subsequently decreased (Figure 5). IR was found to be the earliest variety (maximum NDF yield at stage 78) and VE the latest variety (stage 80) (Table 2). The maximum yield was obtained by SC and the minimum by IR, with a 93% difference between both.

The TDN yield increased to about 1300 GDD (stages 75-77) with the highest values reached by SC (2.8 t/ha) and lowest by IR (1.8 t/ha) (Table 2).

Seed yield and quality

Grain yield and the main characteristics of grain production are reported in Table 3.

The highest grain yield was obtained by SC (192 g/m^2) and the lowest by IR (111 g/m^2). The highest yield shown by SC was due to the greater number of pods per plant and the higher 1000 seed weight than the other varieties.

The nutrient concentration of the seeds ranged between the varieties from 28 productive variety to 33% CP, from 30 to 36% of NDF, and from 26 to 37% of NFC, while TDN was about 78% for all (Table 3). VE presented the highest crude protein and NDF concentration, but a lower NFC concentration, while the opposite was found for CH.

The nutrient yield of grain was always highest in SC and lowest in IR. In terms of SC about 550 kg CP ha^{-1}, 670 kg NDF ha^{-1} and 1500 kg TDN ha^{-1} were obtained (Table 3).

Discussion and conclusions

From the beginning of the bloom onwards, the phenological stages of the field bean sown in spring, encoded with Stulpnagel (1984) scale digits, followed a linear positive trend with the accumulated GDD, with no differences between the two years and the four varieties. To complete the flowering stage (code stage 69), the field bean required little more than 1000 GDD, almost the same value recorded by Iannucci *et al.* (2008), although they sowed field bean in the autumn.

Forage dry matter and nutrient yield of the field bean followed a curvilinear model over the measured GDD as there was an increase from about 800 to 1200-1400 GDD, and a decrease thereafter. In contrast, the main bromatological characteristics followed a linear model over the measured GDD.

The highest forage yield was reached at the end of the pod development (code stage 78), after the accumulation of about 1360 GDD. The differences in the precocity among the varieties were very low, IR was slightly earlier than the others, and VE, slightly later. On the other hand, the choice of variety was a very important factor in maximizing the yield: from the end of the full blossom phase (about 1000 GDD, stage 67), the SC variety produced a significantly higher forage yield than the others. The yield obtained with the most productive variety exceeded 6 t ha^{-1}, which was similar to that obtained in the Mediterranean area sowing the field bean in autumn (Caballero, 1989; Colombari *et al.*, 2006; Borreani *et al.*, 2009).

In general, from the first flower to the maturity stages, the quality of the field bean forage declined linearly as the accumulated GDD increased. The CP concentration decreased from 25 to 12%, EE from 1 to 0.3%, RFV from 112 to 69%, TDN from 51 to 44% and NEL from 1.3 to 0.9 Mcal kg^{-1}. In the same period NDF increased from 49 to 66%, and ADF from 37 to 50%. The modifications in the forage quality during the growth cycle of field bean are in relation to the morphological plant changes, and especially with the fall and senescence of the leaves.

At the highest forage production (code stages 77-79), the CP concentration of the field bean varied from 16 to 18% among the four varieties: EE from 0.6 to 0.7%, NDF from 56 to 58%, RFV from 83 to 94%, TDN from 41 to 48%, and NEL from 1.0 to 1.2 Mcal kg^{-1}.

The highest nutrient yield was achieved earlier, while the maximum NDF yield occurred later than the maximum forage yield. With regard to crude protein, the maximum yield was obtained when the pods were visible in the middle inflorescences (stage 74, 1234 GDD). With the most productive variety (SC), a little less than 1.2 t/ha of CP was obtained, in line with findings in the Mediterranean area by Caballero (1989), and Dordas and Lithourgidis

(2011).

Considering the TDN, the maximum yield, corresponding to a little less than 3 t/ha for the SC variety, was obtained just before the maximum forage DM yield, i.e. when the pods were visible in the upper inflorescences (stage 76), after accumulating about 1285 GDD.

Our models can be used to estimate whether any production losses occur by harvesting the forage in stages other than those of maximum yield. Thus, if the forage was harvested with the highest CP production, the loss of forage DM would reach a maximum of 5% among the different varieties. In addition, if the forage was harvested with the maximum TDN production, the loss of forage DM would be at most 2%. On the other hand, if the forage was harvested at the time of the highest forage DM yield, there would be a lower CP production of 7% and TDN of 2%, compared to the maximum possible.

The forage of field bean can be ensiled. However, the high moisture content at cutting makes the crop unsuitable for direct ensiling and thus requires a wilting period, in order to prevent poor fermentation and the production of effluent (Borreani *et al.*, 2009). At the maximum forage yield of CP and DM, the dry matter concentration of the field bean was respectively 17 and 22% in all varieties. In both cases, wilting is necessary, but our equations can be used to estimate when the forage should be harvested to eliminate this. Considering a target value of 30% DM, such harvesting should be carried out at about 1480 GDD, thus when the first pods lose their green colour (stage 82). If the forage is harvested at this stage, the DM yield loss, compared to that obtained at the maximum forage yield, would be low (up to 6%). However, CP and TDN losses would be high both in terms of concentration (about -20% for CP and -8% for TDN) and yield (-30% CP and -15% TDN, respectively). Thus, abandoning the wilting by delaying the harvest would lead to low DM losses, but high quality losses.

The Italian varieties produced more than the French variety (IR), which was therefore the least suitable for spring sowing. However, IR was found to have a better quality than the others, in relation to the higher leafiness and the lower fibre accumulation.

In summary, the spring sowing of the field bean obtained a sufficiently high forage production and the optimal harvesting stage ranged from 74 to 78, depending on whether the highest nutrients or DM yield is preferred.

The seed yield of the field bean was in line with other studies carried out on field bean sown in the spring (Battini *et al.*, 2001; Moschini *et al.*, 2014). Among the production characteristics, the average weight of the seeds was rather low, probably because sowing delays may have exposed the plants to high temperatures and water stress (Flores *et al.*, 2013). As a result, the grain nutrient production was also considerably smaller than that obtained with the forage (about half) and smaller than that estimated by Annicchiarico (2017) to match the economic value of a relevant cereal benchmark crop. Consequently, the spring sowing of the field bean seems more suitable for forage than for seed production.

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Table 1. Main growth stages of field bean and corresponding number of days after sowing (DAS) and number of growing degree days (GDD).

Growth stage	Code stage*	DAS	GDD
Sowing (Dry seed)	01	0	0
Emergence	10	21	191
First flower racemes in bloom	61	71	820
Flowering complete	69	84	1056
Pods visible in the middle inflorescences	74	96	1280
First pod looses green color	81	106	1472
Ripeness complete	92	121	1791

*Stulpnagel's scale (1984).

Table 2. Maximum values and corresponding GDD plus code stage obtained by field bean varieties calculated with the quadratic equations between accumulated GDD and yields of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and total digestible nutrients (TDN).

Character	Parameter	Variety			
		CH	IR	SC	VE
DM (g m^{-2})	Max value	462.7 b*	370.5 a	659.6 c	516.7 b
	GDD (Stage°)	1328 (77)	1311 (77)	1359 (78)	1391 (79)
CP (kg ha^{-1})	Max value	947.0 b	781.9 a	1168.2 c	1005.3 b
	GDD (Stage)	1205 (73)	1186 (73)	1245 (75)	1298 (76)
NDF (kg ha^{-1})	Max value	2669.1 b	2123.2 a	4106.5 d	3053.8 c
	GDD (Stage)	1382 (79)	1354 (78)	1393 (79)	1435 (80)
TDN (kg ha^{-1})	Max value	2240.1 b	1792.3 a	2844.6 c	2170.4 b
	GDD (Stage)	1262 (75)	1261 (75)	1303 (76)	1312 (77)

CH, Chiaro di Torrelama; IR, Irena; SC, Scuro di Torrelama; VE, Vesuvio. *In a row, values followed by the same letter are not significantly different, for P≤0.05; °Stulpnagel's scale (1984).

Table 3. Grain yield and quality of the four field bean varieties. Values are the means of two years and three replicates.

Character	Variety			
	CH	IR	SC	VE
DM yield (g m^{-2})	135.7 b*	111.4 a	192.1 c	127.5 b
Pods (n $plant^{-1}$)	6.9 b	4.1 a	8.3 c	8.7 c
Seeds (n pod^{-1})	2.4 a	2.8 a	2.3 a	2.3 a
Mean seed w. (mg)	190.3 b	214.3 bc	231.0 c	146.3 a
PG (%)	27.8 a	29.0 ab	29.0 ab	32.5 b
EE (%)	0.71 a	0.72 a	0.69 a	0.86 b
Ash (%)	3.99 b	4.07 b	3.82 a	4.02 b
NDF (%)	30.4 a	35.4 b	35.1 b	36.2 b
ADF (%)	17.2 a	19.4 b	17.7 ab	18.0 ab
ADL (%)	2.06 a	2.54 ab	2.83 b	2.68 b
NFC (%)	37.1 c	30.8 ab	31.4 ab	26.4 a
TDN (%)	79.2 a	76.3 a	78.5 a	78.1 a
CP (kg ha^{-1})	377.2 b	323.1 a	557.1 c	414.4 b
NDF (kg ha^{-1})	412.5 ab	394.5 a	674.4 c	461.6 b
TDN (kg ha^{-1})	1074.7 b	850.3 a	1508.4 c	996.0 b

CH, Chiaro di Torrelama; IR, Irena; SC, Scuro di Torrelama; VE, Vesuvio. *In a row, values followed by the same letter are not significantly different, for $P \leq 0.05$.

Figure 1. Relationship between the code stage of field bean (Stulpnagel, 1984) and the accumulated GDD. CH = Chiaro di Torrelama; IR = Irena; SC = Scuro di Torrelama; VE = Vesuvio. Values are the means of two years and three replicates.

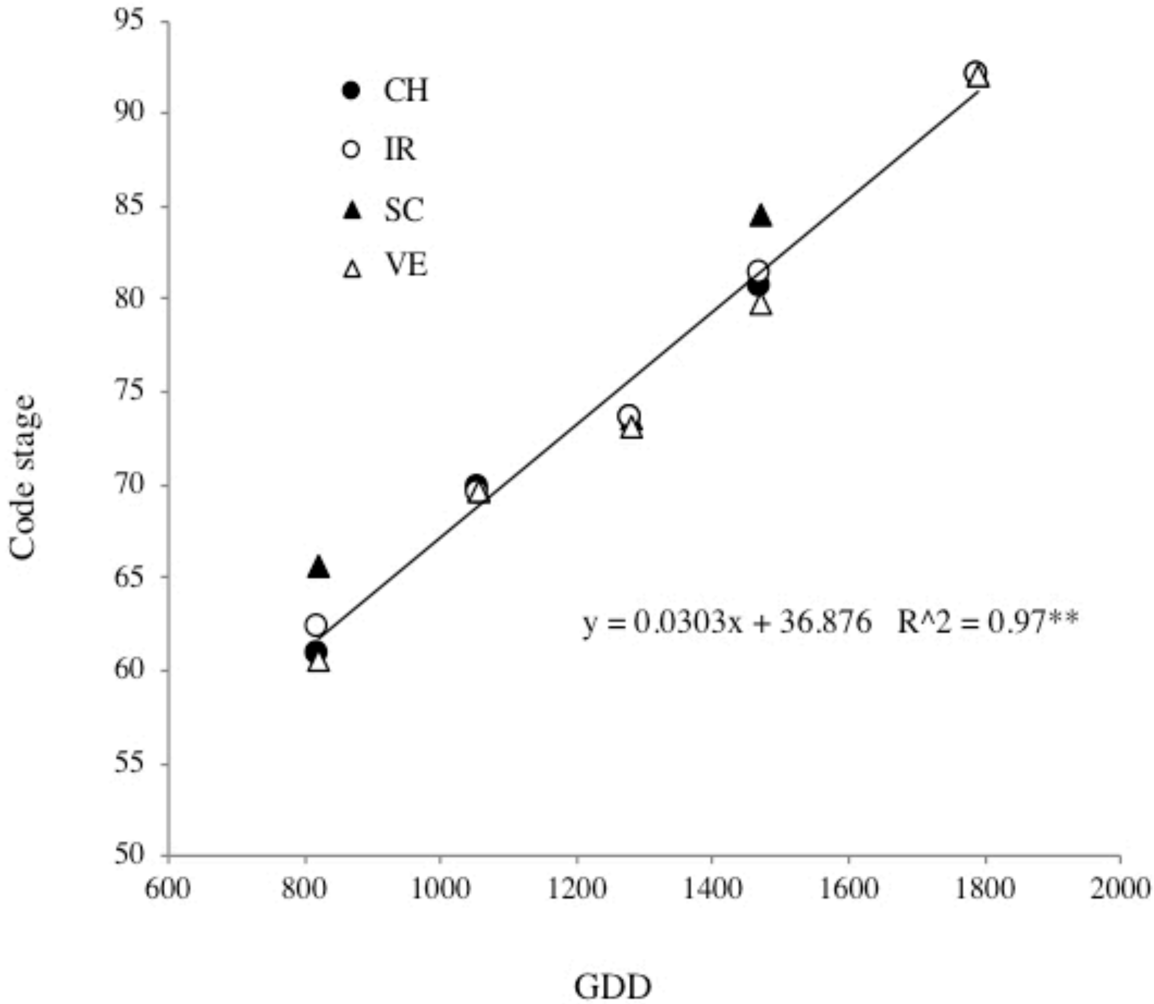

Figure 2. Relationship between the forage DM yield, the forage DM concentration and the accumulated GDD. CH = Chiaro di Torrelama; IR = Irena; SC = Scuro di Torrelama; VE = Vesuvio. Values are the means of two years and three replicates.

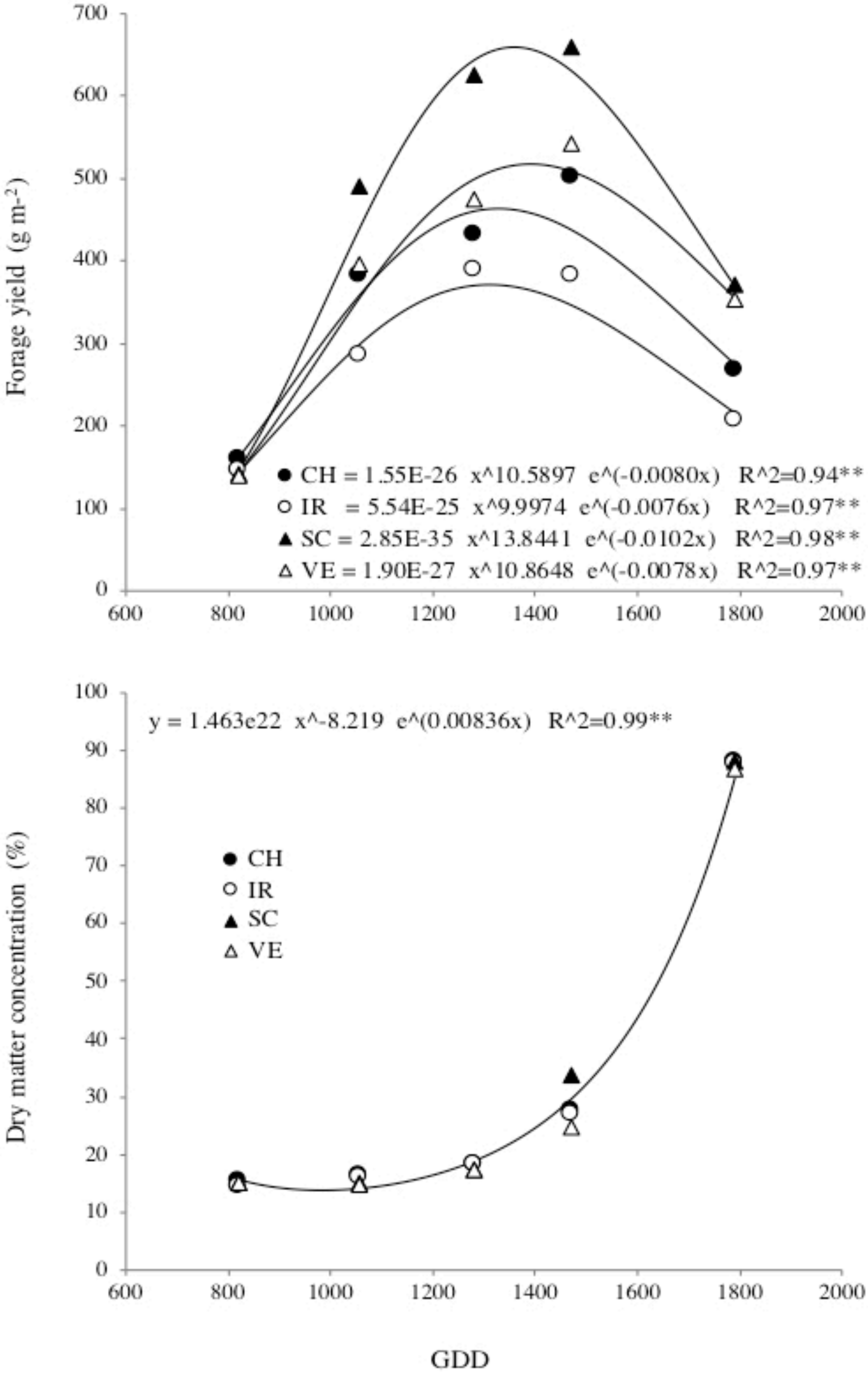

Figure 3. Relationship between the leaf and inflorescence proportion (as % of the total DM) and the accumulated GDD. CH = Chiaro di Torrelama; IR = Irena; SC = Scuro di Torrelama; VE = Vesuvio. Values are the means of two years and three replicates.

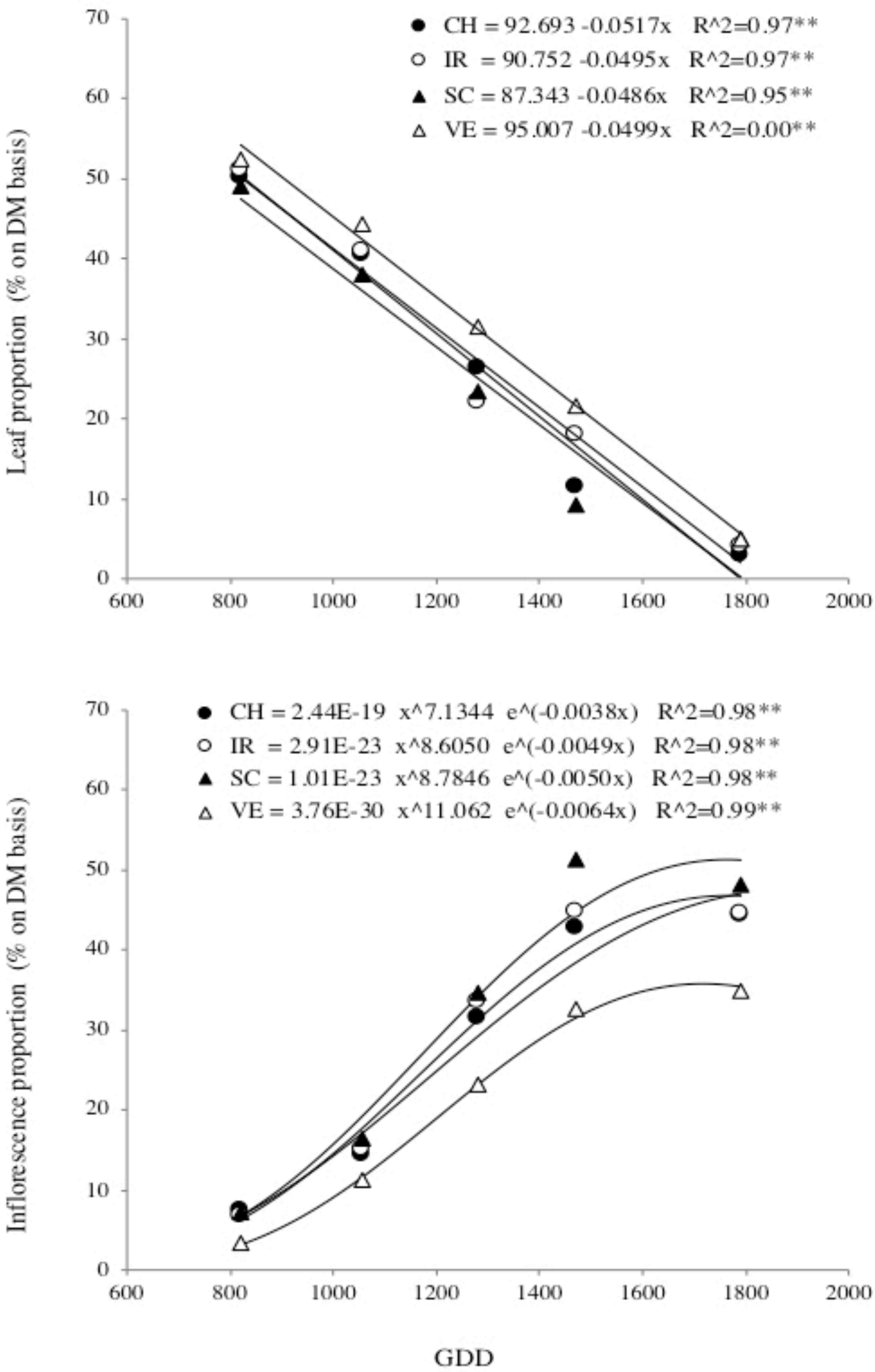

Figure 4. Relationship between the concentrations of CP, NDF, ADF, RFV, TDN, NEL and the accumulated GDD. CH = Chiaro di Torrelama; IR = Irena; SC = Scuro di Torrelama; VE = Vesuvio. Values are the means of two years and three replicates.

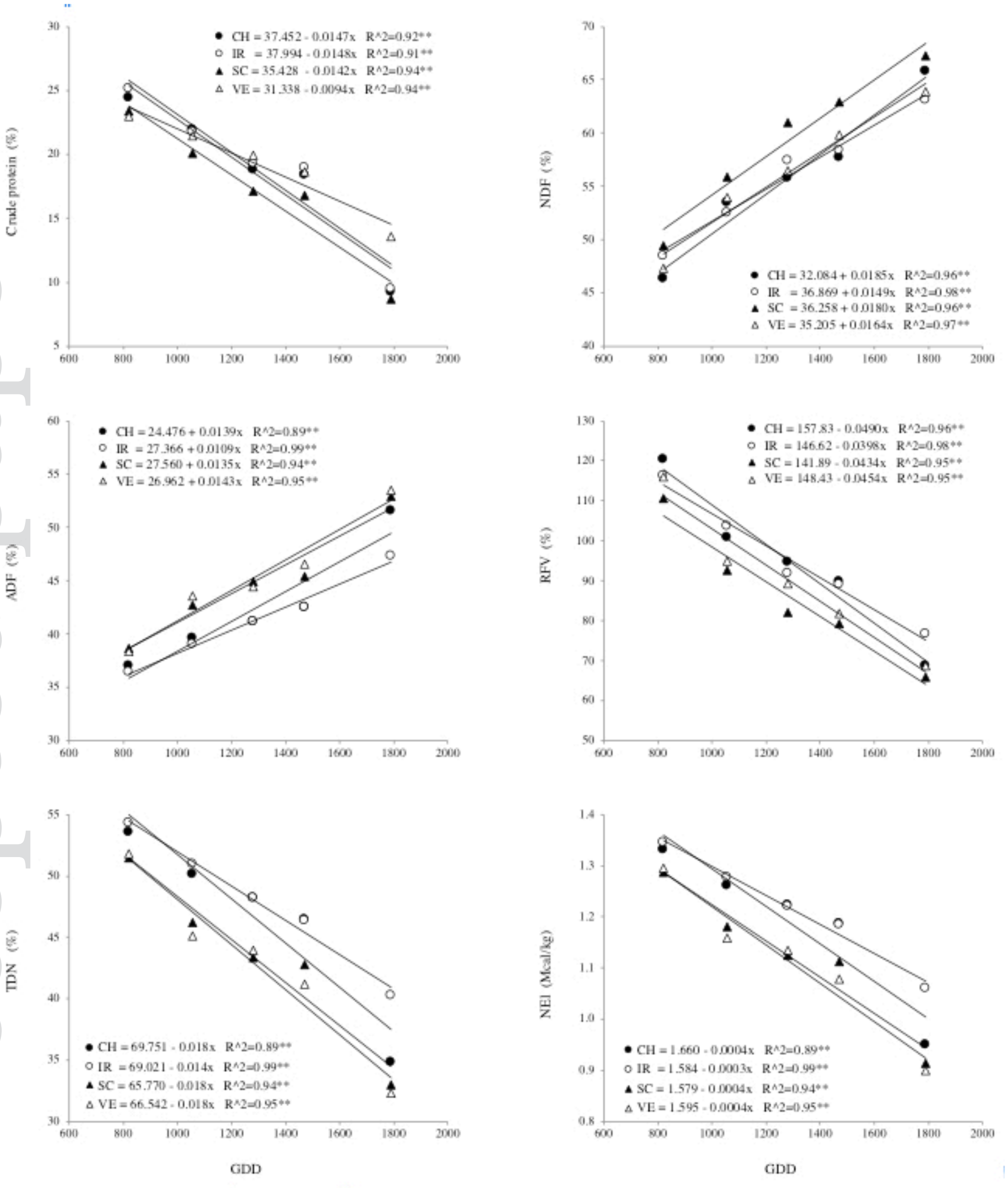

Figure 5. Correlation between CP, RFV, TDN and the leaf proportion (as % of the total DM).

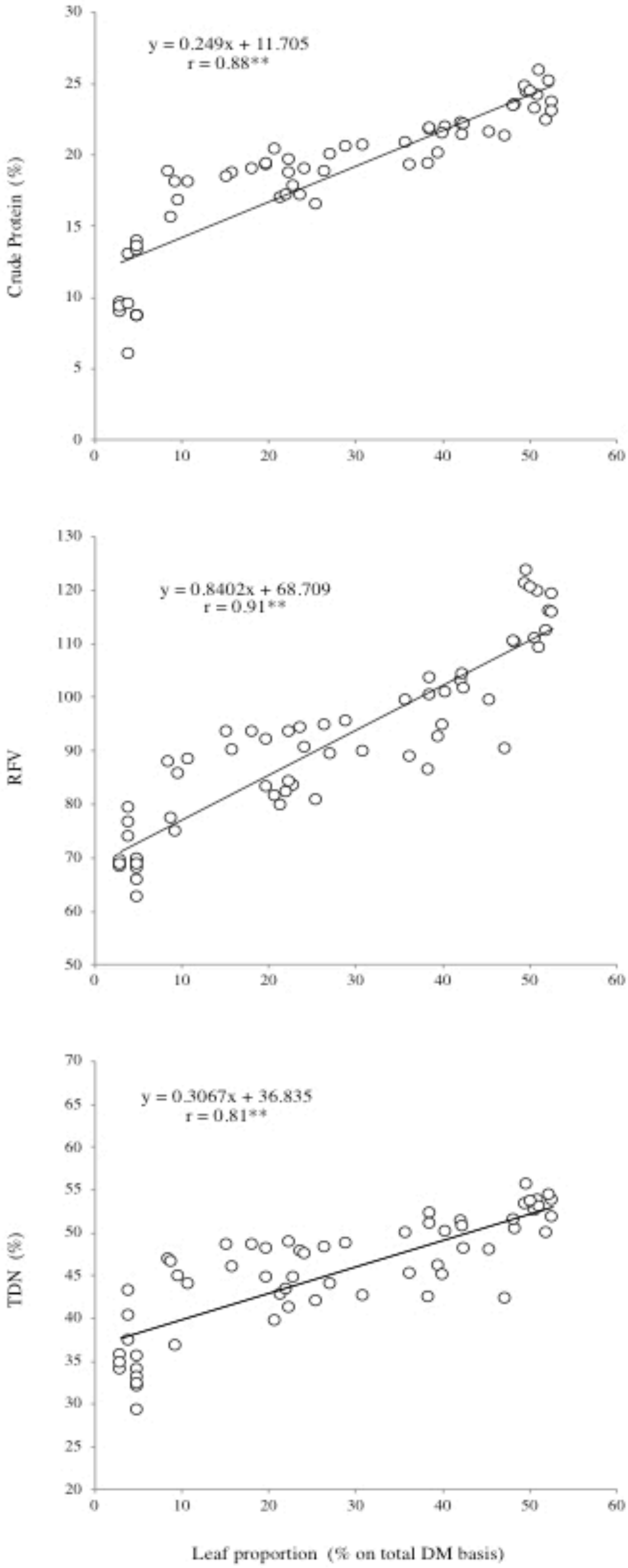

Figure 6. Relationship between the yields of CP, NDF, TDN and the accumulated GDD. CH = Chiaro di Torrelama; IR = Irena; SC = Scuro di Torrelama; VE = Vesuvio. Values are the means of two years and three replicates.