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Biomass Yield of Faba Bean (*Vicia faba* L.) and its mixture with Some Grasses (*Poaceae*)

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Abstract

This study was conducted at the experimental area of the Field Crops Department of Cukurova University in the 2003-2004 and 2004-2005 growing seasons. The objective of this study was to determine of biomass production capacities of sole faba bean (*Vicia faba* L.), triticale (*Triticosecale* Witt.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), annual ryegrass (*Lolium multiflorum* Lam.) and mixture of these plants with faba bean at the rate of 75% faba bean+25% grasses. The field experiment was arranged in a randomized complete block design with 3 replications. The results show that the highest values of fresh biomass yields were obtained in sole faba bean (96.4 t ha^{-1}), 75% faba bean+25% triticale mixture (81.8 t ha^{-1}) and sole barley (72.5 t ha^{-1}), whereas the lowest values were observed in sole triticale (52.9 t ha^{-1}) and wheat (55.9 t ha^{-1}). The superior nitrogen rates in hay (3.04%) and dry root (1.09%) were obtained in sole faba bean, while sole wheat (1.34%) and sole barley (0.79%) gave the lowest nitrogen rates. Besides, 75% faba bean+25% annual ryegrass (1.97% and 0.89%) and 75% faba bean+25% triticale (1.89% and 0.99%) followed sole faba bean. In addition, the highest green herbage yield (67.7 t ha^{-1}) and hay yield (22.5 t ha^{-1}) were observed in faba bean, as well. However, the lowest nitrogen ratios in hay were obtained from the sole wheat (1.34%) and barley (1.45%). In terms of biomass yield, the most suitable results were observed in the sole faba bean and the faba bean+triticale mixture.

Key words: *Fabaceae*, forage, green manure, *Poaceae*, soil productivity

Bakla (*Vicia faba* L.)'nın Bazı Buğdaygiller ile Karışımında Biyomas Verimi

Özet

Bu araştırma Çukurova Üniversitesi Tarla Bitkileri Bölümü uygulama alanında 2003-2004 ve 2004-2005 yetiştirme sezonlarında yürütülmüştür. Araştırmada, bakla (*Vicia faba* L.), tritikale (*Triticosecale* Witt.), buğday (*Triticum aestivum* L.), arpa (*Hordeum vulgare* L.) ve tek yıllık çim (*Lolium multiflorum* Lam.)'in yalın ekimleri ile bu türlerin %75 bakla+%25 buğdaygil oranında karışımlarındaki biyomas üretim kapasitelerinin belirlenmesi amaçlanmıştır. Arazi çalışması tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak düzenlenmiştir. Araştırma sonuçlarına göre, en yüksek yeşil biyomas verimi sırasıyla, baklanın yalın ekiminden (96.4 t ha^{-1}), %75 bakla+%25 tritikale karışımından (81.8 t ha^{-1}) ve arpanın yalın ekiminden (72.5 t ha^{-1}) elde edilirken, en düşük değerler yalın tritikale (52.9 t ha^{-1}) ve buğday (55.9 t ha^{-1})'da saptanmıştır. En yüksek kuru otta (%3.04) ve kuru kökte (%1.09) azot oranı baklanın yalın ekiminden elde edilirken, yalın buğday (%1.34) ve arpa (%0.79) ekimlerinde en düşük değerler saptanmıştır. Ayrıca, %75 bakla+%25 tek yıllık çim (%1.97 ve %0.89) ve %75 bakla+%25 tritikale (%1.89 ve %0.99) karışımları baklanın yalın ekimini izlemişlerdir. Bununla birlikte, en yüksek yeşil ot (67.7 t ha^{-1}) ve kuru ot (22.5 t ha^{-1}) verimleri de yine yalın bakla ekiminde tespit edilmiştir. En düşük kuru otta azot oranları ise buğday (%1.34) ve arpa (%1.45)'nın yalın ekimlerinde belirlenmiştir. Biyomas verimi bakımından en uygun değerler baklanın yalın ekimi ve tritikale ile karışımından elde edilmiştir.

Anahtar kelimeler: baklagiller, buğdaygiller, toprak verimliliği, yem bitkileri, yeşil gübreleme

Introduction

One of the major problems is brought on by the use of excessive fertilizers and pesticides to obtain higher productivity. Both fertilizers and pesticides increase productivity of agricultural production but the chemical residue influences human health (Demirkol et al., 2012). In addition to biologically derived food, as well as fruits and vegetables consumed directly by humans, the application of organic farming should also be considered within the scope of livestock health and animal products.

Biomass is defined as the sum total of the plant component above and below the soil line and is an important concept, which directly affects soil productivity. The integration of cover crops into cropping systems brings costs and benefits, both internal and external to the farm (Snapp et al., 2005). Soil productivity is the ability, under the effect of specific chemical, physical and biological factors, to provide the required nutrients and water to the plant cover, and especially to the higher plants, found within the composition of the soil (Eldor, 2007). Green manure, which is the incorporation of crop biomass to soil, is a topic of high interest for biological farming and its approaches to crop production might improve economic viability, while reducing the environmental impacts of agriculture. Because the application of green manure minimizes, and in fact removes, the use of synthetic fertilizers, it plays a vital role in the production of biological nutrients and reduction of costs (Cher et al., 2006). When the use of green manure is supported with farming fertilizers, biological nutrients may be produced for cheaper than when using synthetic chemicals and nutrients that are harmful to health. Besides, major benefits of increasing the soil organic N levels through green manure is an increase in the mid growing season N mineralization, which in most cases translates into a higher grain N content (Olesen et al., 2009).

In organic farming, in which mineral fertilizers are prohibited and yields are predominantly limited by nitrogen availability (Clark et al., 1999), diversified crop rotations with legumes are a key element in enriching the plant-soil-system with atmospheric nitrogen. Besides biological nitrogen fixation by the symbiosis with rhizobia bacteria, legumes such as faba bean (*Vicia faba* L.) supply protein-rich forage as feed for livestock (Baumgartner et al., 2008; Schroder and Kopke, 2012). Before using a legume as green manure, including crop residue, the ability of the legume to supply its own N by N_2 fixation associated with rhizobia should be estimated, because N input by a legume to the cropping system has considerable importance in the management of soil fertility (Yamawaki et al., 2014). Each year, at global level, in the agroecosystems, about 50 million t of nitrogen are fixed (Herridge et al., 2008). Accordingly, Unkovich et al. (2008) consider that legume species fix between 15 and 25 kg nitrogen t^{-1} of dry matter. Mixtures of annual forage legumes with annual grasses for forage and green manure were practiced traditionally in the Mediterranean conditions due to their ability to increase the herbage yield and produce forage with more balanced nutrition for livestock feeding (Giambalvo et al., 2011; Koc et al., 2013). The cultivation of annual legumes in mixtures may also have many advantages in comparison to pure stands, especially in a more efficient exploitation of environmental resources (Cupina et al., 2011). One of these plants that faba bean (*Vicia faba* L.) is a cool season legume used as a source of protein in human diets, as a forage crop for animals, and for boosting nitrogen in the biosphere (Duc et al., 2010). Faba beans are often introduced into crop rotation as forage and green-manure legume, and several researchers have referred to the beneficial role of their belowground parts in nutrient cycling in several cropping systems, including cereals (Jensen et al., 2010; Munoz-Romero et al., 2011). When crops are grown in the Mediterranean climate conditions, cultivated for green manure, they can be harvested 25 to 30 days prior to the harvesting of the main crop during grain formation at the start of the spring season, and directly incorporated into the soil. Also these plants can be grown for forage, and then residues of roots incorporate into the soil (Saglamtimur et al., 1998). Therefore, cultivation of legumes as mixtures with cereals or grasses and their use within crop rotation will not only enrich the soil in terms of organic matter, but will also help in physical and chemical fortification of the soil.

The objective of this study was to determine the biomass production capacities of both sole faba bean and its mixtures with grasses, as well as to determine the levels of beneficial effects they have on soil productivity.

Materials and Methods

In this study, local variety of faba bean (*Vicia faba* L.), Tacettin bey cultivar of triticale (*Triticosecale* Witt.), Balatilla variety of wheat (*Triticum aestivum* L.), Sahin-91 cultivar of barley (*Hordeum vulgare* L.) and caramba variety of annual ryegrass (*Lolium multiflorum* L.) were used as the plant materials. This study was carried out (37°57´N and 35°30´E, altitude 24 m) at the research and implementation area of Field Crops Department of Cukurova University, during the 2003-2004 and 2004-2005 growing seasons, using a randomized complete block design with 3 replications. Sole cultivation of faba bean and grasses, and their mixtures with faba bean (75% faba bean+25% grasses) were used in the study.

The size of each plot was 8.80 m^2 (2.20 x 4.0 m), and sowing rate was used as 200 kg ha^{-1} for the faba bean, triticale, wheat and barley, and 45 kg ha^{-1} for the annual ryegrass. Seeds were planted in last week of October of both the first and second years. Before seeding, 100 kg ha^{-1} nitrogen and phosphorus were applied as a starter fertilizer in sole triticale, wheat, barley, and annual ryegrass, while 50 kg ha^{-1} nitrogen and phosphorus were used for sole faba bean and the mixtures of its with grasses. The harvest time was concluded by taking the physiological stage of the faba bean into consideration. Namely, at the fruit development stage of the faba bean, at milk ripening stage of the grasses, and the beginning of flowering for the annual ryegrass (in April), the plants were ready to be harvested. Green herbage and fresh root samples were collected from 10 randomly selected separate locations in each plot using an Albrecht Bohrer auger drill with a 16 cm diameter and a 30 cm length. Then, these samples, 500 g in weight, were dried at 70 ºC for a period of 48 hours. Afterwards, dried samples were ground in a hand mill with a 1-mm sieve, and the Kjeldahl method was used to determine the N contents of the dry samples (Kacar and Inal, 2008).

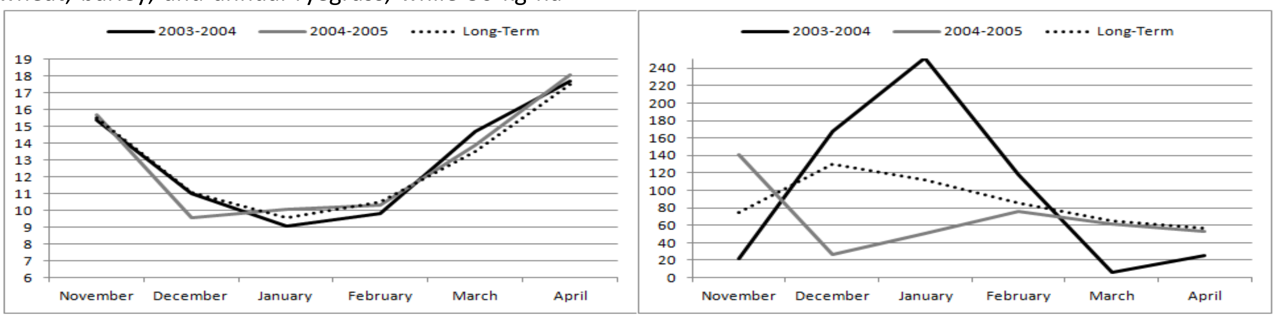

Figure 1. Mean temperature (°C) and total rainfall (mm) values of the location in 2003-2004 and 2004-2005 years, and long-term average (1954-2013) at Adana, Turkey.

Table 1. Initial chemical and physical properties of the soil.

Property	Depth (0-30 Cm)	Depth (30-60 cm)
Sand (%)	18	14
Silt (%)	27	28
Clay (%)	55	58
Organic matter (%)	1.1	0.6
CEC (cmol kg^{-1})	47	37
Soil Texture	Clay	Clay
pH (1:2.5)	7.47	7.63
Salt (%)	0.065	0.060
$CaCO_3$ (%)	24	27
P_2O_5 (kg ha^{-1})	40.8	-

The region is under Mediterranean climate conditions. During the growing seasons, mean temperature values followed a course parallel to average values for long years. However, the rainfall was irregular in consideration of both the averages of the trial years and of long years. The total precipitation was 589.5 mm, 408.8 mm and 524.3 mm during the 2003-2004, 2004-2005 growing seasons and long-term years, respectively (Figure 1). As is seen, while the total rainfall of the first growing season was higher than the long-term value, it was considerable lower to this value in second growing season. Beyond that, irregular rainfall was calculated in months compared to long-term values. Soils where the study was conducted are entisols brought by Seyhan River, formed of very young alluvial deposits. They have in almost flat and near-flat topographies. There are only A-horizons well-decomposed by external influences and rich in organic matters and humus and C-horizons formed of large pieces and located over the main rock. Major soil characteristics are given in Table 1 for experimental area, which has a clay texture and organic matter level is highly low.

Analysis of variance of the experimental results was performed using MSTAT-C statistical software (Freed, 1991) and means were compared using Duncan’s multiple range tests at a significance of $P < 0.05$.

Table 2. Green herbage yield, hay yield, fresh root yield and dry root yield values of sole sowings and mixtures, statistical groups, and error mean squares.

Plants and Mixtures	**GHY (t ha^{-1})**	**HY (t ha^{-1})**	**FRY (t ha^{-1})**	**DRY (t ha^{-1})**
Faba bean	**67.7 ^{a}**	**22.5 ^{a}**	**28.7 ^{a}**	**6.48 ^{a}**
Triticale	**39.7 ^{f}**	17.6 ^{b}	22.3 ^{c}	3.39 ^{d}
Wheat	**39.8 ^{f}**	14.4 ^{e}	16.1 ^{f}	2.81 ^{ef}
Barley	60.0 ^{b}	**10.9 ^{g}**	**12.5 ^{g}**	**2.03 ^{g}**
Annual ryegrass	50.2 ^{d}	13.1 ^{f}	19.3 ^{d}	2.82 ^{ef}
75% Faba bean+25% Triticale	55.9 ^{c}	15.5 ^{d}	25.9 ^{b}	3.77 ^{b}
75% Faba bean+25% Wheat	51.1 ^{d}	16.4 ^{c}	15.6 ^{f}	2.70 ^{f}
75% Faba bean+25% Barley	44.9 ^{e}	14.1 ^{e}	17.8 ^{e}	2.88 ^{e}
75% Faba bean+25% Annual ryegrass	45.3 ^{e}	**11.0 ^{g}**	22.3 ^{c}	3.63 ^{c}
Mean	**50.5**	**15.1**	**20.1**	**3.39**
CV (%)	4.02	4.18	3.53	3.13
Year (Y)	8646.4**	2358.6**	4073.0^{ns}	114.9**
Plant and mixtures (PM)	10457.3**	3969.0**	5033.3**	112.5**

Data are the means of the 2 years. Numbers followed by the same letters within a column do not differ at the 0.05 level of significance, *P<0.05, **P<0.01, ns: not significant, GHY: Green herbage yield, HY: Hay yield, FRY: Fresh root yield, DRY: Dry root yield

Results and Discussion

As shown in Tables 2 and 3, statistical significance was determined among the all studied properties. Upon analyzing Table 2, green herbage yield ranged from 39.7 to 67.7 t ha^{-1} and hay yield ranged from 10.9 to 22.5 t ha^{-1}. The highest green herbage and hay yields were observed in sole faba bean while the lowest yields were obtained in sole triticale and sole barley, respectively. Fresh root yield was attained between 12.5 and 28.7 t ha^{-1} and dry root yield was calculated between 2.03 and 6.48 t ha^{-1}. Similarly, the maximum fresh and dry root yields were obtained from the sole faba bean while the minimum values were observed in sole barley, as well.

Short-season crops, such as field pea (*Pisum sativum* L.), vetches (*Vicia* spp.), and faba bean (*Vicia faba* L.) produced a plenty of vegetative components and significantly increased forage yield and quality (Cupina et al., 2011). Moreover, these plants have played an important role in obtaining high yields of green herbage as both sole and mixture with grasses. In this study, the values of green herbage and hay were obtained higher compared to the other studies performed earlier (Cecen et al., 2005; Nykanen et al., 2009; Jensen et al., 2010). These differences were probably because of the plant species and various soil and climate conditions at the experiment sites. In addition, the competition of cover and undersown crops for light directly affects the morphological and physiological parameters and their dynamics in the latter. Such results have also been demonstrated recently on durum wheat-winter pea annual intercrops (Bedoussac and Justes, 2010). In our study, sole barley was produced higher green herbage yield (60.0 t ha^{-1}) than triticale (39.7 t ha^{-1}) and wheat (39.8 t ha^{-1}), and their mixtures with faba bean (55.9 t ha^{-1} and 51.1 t ha^{-1}, respectively). However, the lowest fresh (12.5 t ha^{-1}) and dry root yields (2.03 t ha^{-1}) were observed in the barley. Despite the barley has high vegetative matter as sole, but the same findings were not obtained for the root yields of it. It can be explained of the does not stronger development displayed by these two species because of weaker competitive ability (Dhima et al. 2007) when grown as a mixture with legume grasses. Indeed, some researchers (Ross et al., 2004; Anwar et al., 2010; Nadeem et al., 2010; Lithourgidis et al., 2011) have reported that as the grass ratio decreased in the mixture, both green herbage and hay yields decreased. Furthermore, some researchers reported that intercropping increased herbage yield compared with the sole species and the increase was higher than for cereals and legume intercropping systems, and cereal-legume intercropping can be used as a suitable management strategy for producing high quality and quantity biomass (Mariotti et al., 2009; Eskandari et al., 2009).

According to the results given in Table 3, nitrogen ratio in hay ranged from 1.34 to 3.04% and nitrogen ratio in dry root ranged from 0.79 to 1.09%. While the highest nitrogen ratio in hay and dry root was determined in sole faba bean (3.04% and 1.09%, respectively), the lowest value was observed from wheat in hay (1.34%) and from barley in dry root (0.79%). Fresh biomass yield ranged from 52.9 to

96.4 t ha^{-1} and dry biomass yield ranged from 12.9 to 28.9 t ha^{-1}. The highest fresh biomass yield was observed in sole faba bean (96.4 t ha^{-1}), the lowest values were observed from triticale in fresh biomass yield (52.9 t ha^{-1}) and from barley in dry biomass yield (12.9 t ha^{-1}).

Table 3. Nitrogen ratio in hay, nitrogen ratio in dry root, fresh biomass yield and dry biomass yield of sole sowings and mixtures, statistical groups, and error mean squares.

Plants and Mixtures	HNR (%)	DRNR (%)	FBY (t ha^{-1})	DBY (t ha^{-1})
Faba bean	**3.04** ^{a}	**1.09** ^{a}	**96.4** ^{a}	**28.9** ^{a}
Triticale	1.79 ^{cd}	0.90 ^{cd}	**52.9** ^{f}	21.0 ^{b}
Wheat	**1.34** ^{f}	0.91 ^{cd}	55.9 ^{ef}	17.2 ^{d}
Barley	1.45 ^{e}	**0.79** ^{f}	72.5 ^{c}	12.9 ^{g}
Annual ryegrass	1.53 ^{e}	0.94 ^{bc}	69.6 ^{cd}	16.0 ^{e}
75% Faba bean+25% Triticale	1.89 ^{bc}	0.99 ^{b}	81.8 ^{b}	19.3 ^{c}
75% Faba bean+25% Wheat	1.86 ^{cd}	0.86 ^{de}	66.6 ^{cd}	19.2 ^{c}
75% Faba bean+25% Barley	1.78 ^{d}	0.81 ^{ef}	62.7 ^{de}	16.9 ^{d}
75% Faba bean+25% Annual ryegrass	1.97 ^{b}	0.89 ^{cd}	67.7 ^{cd}	14.7 ^{f}
Mean	**1.85**	**0.91**	**69.5**	**18.4**
CV (%)	4.08	5.67	10.67	3.36
Year (Y)	0.008^{ns}	0.005^{ns}	512792.3^{ns}	2313.0**
Plant and mixtures (PM)	0.006**	0.003**	550746.2**	3834.3**

Data are the means of the 2 years. Numbers followed by the same letters within a column do not differ at the 0.05 level of significance, *P<0.05, **P<0.01, ns: not significant, HNR: Nitrogen ratio in hay, DRNR: Nitrogen ratio in dry root, FBY: Fresh biomass yield, DBY: Dry biomass yield

There are studies assessing the amount of fixed nitrogen, particularly of symbiotic nitrogen from the relation of nitrogen-fixing bacteria and species of the legumes, depending on the ecological area and on the cultivation technology (Ghiocel et al., 2012). Therefore it must be concluded that the rate of nitrogen obtained from faba bean being higher compared to that of the grasses, is the result of this characteristic. In fact, researchers informed that (Sparrow and Masiak, 2004; Budak, 2005; Turgut et al., 2006; Javanmard et al., 2009), in addition to higher levels of nitrogen detected in legumes compared to that in grasses, the rate of nitrogen obtained from mixtures decreased in relation to the increasing grass ratios. Also, legumes accumulate the free nitrogen from the air in various organs of the plant, while using the roots for supplementary storage of nutrients. The effects of legumes were usually considered to be a direct result of higher N availability (Nyfeler et al., 2011). In temperate regions, faba bean is grown as a food crop. The crop residues of such winter legumes should also be used as an organic matter. Several studies have shown the N2 fixation of faba bean (Lopez-Bellido et al., 2011) and its potential contribution to the sustainability of cropping systems, including wheat (Melero et al., 2011; Munoz-Romero et al., 2011). As a result of this situation, the amount of nitrogen accumulated in roots of faba bean (1.09%) was observed higher compared to the other species. Moreover, the lower levels of nitrogen obtained from the mixture of faba bean with grasses, might be explained by the higher numbers of roots formed by grasses due to their dominance over legumes in the mixtures. Considerable amounts of fixed nitrogen might be added by residue input in this experiment, and these residues could be used as the N source. Soils with a higher nutrient supply capacity require reduced fertilizer inputs. If fertilizer costs are reduced while yield is maintained, profitability over the long-term may more than compensate the immediate costs of cover crop establishment (Snapp et al., 2005). Some researchers (Nykanen et al., 2009; Lithourgidis et al., 2011; Nyfeler et al., 2011) have been determined that both legumes, and mixtures containing legumes, dispose varying levels of nitrogen in the soil based on the plant species, mixture ratios, as well as the yields obtained. In this study, high ratio of nitrogen was obtained from sole faba bean (3.04%), as well as from its mixtures with various grasses compared to the sole grasses.

In conclusion, in terms of biomass production capacity, the most suitable results were observed in the sole faba bean (96.4 t ha^{-1}) and the faba bean+triticale mixture (81.8 t ha^{-1}). The sole faba bean and its mixtures with grasses should be suggested with priority due to the high amounts of biomass production, while at the same time providing the soil with nitrogen, and that it would make for a suitable application to grow legumes in sole stands or as mixtures and incorporate them into the soil as green manure. Additionally, while it may be seem to be a positive outcome for annual ryegrass and triticale to deposit generous amounts of root residue, due to having fibrous root structures, it is recommended that their mixture with faba bean should be preferred.

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