Effect of different ratio and intercropping systems on forage yield and some components of Hungarian vetch (*Vicia pannonica* Crantz.) and grass combination under arid climate conditions

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Abstract

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Intercropping productivity under conventional farming system was carried out in the experimental field of The Trakya Agricultural Research Institute (TTAE) in Edirne province in 2012-2015 growing seasons with 3 replications on randomized complete block design. The experiment consisted of mainly 7 entries for yield components - i.e., three pure stands Hungarian vetch (HV), oat (O) and annual rye grass (ARG) and four different mixtures (66% HV+34% O, 34% HV+66% O, 66% HV+34% ARG, 34% HV+66% ARG) as follow. Seven traits including plant height (PH), stem diameter (SD), leaf/stem ratio (LSR), legume ratio in botanic composition (LRBC), legume fresh forage yield (LFFY), total fresh forage yield (TFFY), total dry forage yield (TDFY), plant height (PH), stem diameter (SD) and leaf/stem ratio (LSR) were measured on 10 random (vying plant) points per plot. Legume ratio in botanic composition (LRBC), legume fresh forage yield (LFFY), total fresh forage yield (TFFY), total dry forage yield (TDFY) were recorded at each plot. In mixtures of Hungarian vetch with annual rye grass, average forage yield (21.86 t ha^{-1}) was lower by 32% than (28.87 t ha^{-1}) that in mixtures of Hungarian vetch with oat average yield. Consequently all of the investigated parameters in the present study, 60% or 40% HV mixture with oat combination, can be recommended for high yield forage production.

Keywords: Hungarian vetch; rye grass; oat; intercropping productivity

INTRODUCTION

Mixed culture (or intercropping) of legumes and cereals is an old practice in agriculture that dates back to ancient civilization. The current trend in global agriculture is to search for highly productive, sustainable and environmentally friendly cropping systems (Crew and Peoples, 2004). When two crops are planted together, interspecific competition or facilitation between plants may occur (Zhang and Li, 2003). The main objective of intercropping has been to maximise use of resources such as space, light and nutrients (Li et al., 2003), as well as to improve crop quality and quantity (Mpairwe et al., 2002). Other benefits include water quality control through minimal use of inorganic nitrogen fertilisers that pollute the environment (Crew and Peoples, 2004).

For example, studies have shown that mixtures of cereals and legumes produce higher grain yields than either crop grown alone (Dapaah et al., 2003). In such crop mixtures, the yield increases were not only due to improved nitrogen nutrition of the cereal component, but also to other unknown causes (Connolly et al., 2001). In addition legume is a natural mini-nitrogen manufacturing factory in the field and the farmers by growing these crops can play a vital role in increasing indigenous nitrogen production. Legume help in solubilizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity, and restoring organic matter, and also has smothering effect on weed. The carryover of N derived from legume grown, either in crop sequence or in intercropping system for succeeding crops, is also important.

Vetches (*Vicia* sp.) are the most widely distributed annual leguminous crops throughout the Mediterranean basin, western Asia and in countries of the former Soviet Union (Martiniello and Ciola, 1995; Dhima et al., 2007; Yolcu et al., 2010). It can be used for pasture or as grain legume, showing high palatability at all growth stages. Because of its high feed value for animals it is often used as grain for livestock feed (mainly lambs) and also for production of silage and hay or as green manure (Açıkgöz, 1988).

Mixtures of legumes with cereals are expected to have advantages over pure stands in terms of forage yield and quality. In vetch-cereal intercroppings, cereals provide structural support for vetch growth, improving light absorption and allowing mechanical harvest (Lithourgidis et al., 2006). Many previous studies have reported that intercropping with legumes can achieve an enhance biomass and yield over corresponding monoculture (Zhang et al., 2011; Arshad and Ranamukhaarachchi, 2012; Huňady and Hochman, 2014; Zafaranieh, 2015).

Different small grain cereals and vetches have been successfully used in cereal-legume intercropping systems (Karagić et al., 2011). Although there is a large diversity of *Vicia* species in the Mediterranean Basin, including Turkey and Thrace region vetches, particularly common vetch (*Vicia sativa* L.) and Hungarian vetch (HV) (*Vicia pannonica* Crantz.) are the most common annual forage crops cultivated (Uzun et al., 2004). HV is a winter-hardy (-16°C) legume species, which is widely used in Thrace region with cool winter growing conditions. It has satisfactory forage yields with tiny plentiful and palatable leaves, and good quality hay with high crude protein (CP) (Tuna and Orak, 2007; Unal et al., 2011). Moreover, that is generally recommended in dry regions (Uzun et al., 2004). HV has a semi erect growth habitus with a leaning tendency in pure stands, especially during rainy years. Intensive early spring rains lead to the decay of plant parts close to the ground to, as a consequence of high humidity. This results in a decrease in the rate of forage yield and quality (Iptas, 2002). Cereals can provide support for climbing vetches, improve light interception, and thus facilitate mechanical harvesting (Nadeem et al., 2010). For instance, HV can be grown with forage grasses or cereals under Mediterranean conditions, during which the fallow+cereal system is performed.

The other one of the most important forage crops is annual ryegrass (ARG) (*Lolium multiflorum* Lam.), which is a cool-season grass that is suitable for quality herbage production on account of its rich protein, minerals, and water-soluble carbohydrate content (Kusvuran and Tansi, 2005, 2011). It is generally a highly nutritious grass that may be presented as forage for beef cattle through grazing, dried out and fed as hay, or ensiled and fed as silage (Durst et al., 2013) and desirably eaten by livestock, especially in milk production (Kusvuran, 2011). Cereal species, seeding ratios, and competition between mixture components may affect yield and quality of forage produced by mixtures (Papastylianou, 1990). Caballero and Goicoechea (1986) and Thomson et al. (1990), reported that the most suitable cereal for a mixture with common vetch is oat (*Avena sativa* L.), whereas Thomson et al. (1990) and Roberts et al. (1989) reported that barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.) are the most suitable cereals for mixtures. Other studies show, however, that spring barley is a better component for self-finishing cultivar of vetch compared to oats (Księżak, 1997).

Competition of different species can also have a significant impact on growth rate of the used in mixtures. The aim of the present study were to evaluate Hungarian vetch, oat and annual rye grass monocultures as well as mixtures of Hungarian vetch with oat and annual rye grass in two seeding ratios (66:34 and 34:66) for forage yield and its components.

MATERIAL AND METHODS

The evaluation of Hungarian vetch, cv "Budak" (HV) cereal oat, cv "Kahraman" (O) and annual rye grass, cv "Grass" (ARG) intercropping productivity under conventional farming system was carried out in the experimental field of The Trakya Agricultural Research Institute (TTAE) in Edirne province (41°65′ N, 59°68′ E). The experiments were conducted for three consecutive growing seasons

(2012-2013, 2013-2014 and 2014-2015). The soil of the study site has been classified as mainly clay. The experimental area has an arid climate with hardy winters and hot dry summers. In the experimental location, a total precipitation amounted to 615.1 mm, 486.0 mm and 674.0 mm during the growing season (October-July) of 2012, 2013 and 2015, respectively, while a 30-year average amounted to 547.7 mm. The precipitation distribution significantly differed over year, hence in February and March of 2015, the precipitation amounted to 615.1 mm and 674.1 mm, respectively, that was higher than the long-term average (547.7 mm). Long term temperature condition (11.6°C) was lower than in all years of investigation (14.6, 12.6 and 12.7°C). With regard to climatic requirements of these crops, it appeared that conditions were normal for the growth and development in experimental years 2012-2015.

Cultivars and their mixtures were grown in a randomized complete block design with three replications. The experiment consisted of mainly 7 entries for yield components - i.e., three pure stands Hungarian vetch (HV), oat (O) and annual rye grass (ARG) and four different mixtures (66% HV+34% O, 34% HV+66% O, 66% HV+34% ARG, 34% HV+66% ARG) as follow.

Seeds were planted at a depth of 3 cm in October of the first, second and third year, at rate of 100 kg ha^{-1} for HV, 180 kg ha^{-1} for O and 30 kg ha^{-1} for ARG in each plot. Each plot consisted of six rows spaced 0.25 m apart and 5 m long, occupying an area of 7.5 m^2. All plots in each replication were separated by a 0.5 m buffer zone, and replications were separated by a 2.5 m buffer zone. The crop seeding prior to the experimental area were applied appropriate cultural practices (deep summer field plow, disk harrowing, cultivation, hand weeding, etc). No agrochemicals were applied either on the previous crop (wheat) or on the mixture combinations.

The HV and its mixtures with O and ARG individual were sown in the same rows by hand. The size of each plot was 7.5 m^2 (1.5×5 m). During the first, second and third year, the experiments were carried out without supplementary irrigation. Four 2.5 m rows at the center of each plot were harvested with 4.0 m^2 area. Control by hand weeding was carried out twice when the weed density was high, in the pre-flowering and postflowering stages. Seven traits including plant height (PH), stem diameter (SD), leaf/stem ratio (LSR), legume ratio in botanic composition (LRBC), legume fresh forage yield (LFFY), total fresh forage yield (TFFY), total dry forage yield (TDFY), plant height (PH), stem diameter (SD) and leaf/stem ratio (LSR) were measured on 10 random (vying plant) points per plot. Legume ratio in botanic composition (LRBC), legume fresh forage yield (LFFY), total fresh forage yield (TFFY), total dry forage yield (TDFY) were recorded at each plot.

The harvest time was determined by taking the physiological periods of the HV into consideration. Hence, plots were harvested at the 50% flowering and initial pod-set stage for the HV and at the beginning of flowering for the ryegrasses (at the end of May) (Kusvuran and Tansi, 2005) at the same time for the forage yield. Following the harvest, the HV ratios in the mixtures were determined in the fresh material.

Analysis of variance of experimental results was calculated according to randomized complete block experimental design with three replications using MSTAT-C statistical software package (MSTAT-C, 1988). Significant differences among the mean values were compared by LSD test (P<0,05) (Duzgunes et al., 1987). Cluster analyses was performed with SPSS 22.0 (IBM, 2013) statistical software.

RESULTS AND DISCUSSION

Yielding of legume-cereal mixtures largely depends on the proper selection of species. Yield and yield characteristics averaged over-three year data of Hungarian vetch and its mixture combinations with oat and annual rye grass are presented in Table 1.

Mixture combinations showed significant effects on total fresh, total dry and legume fresh forage yield and all yield components. Plant height, stem diameter, leaf/stem ratio and legume ratio in botanic compositon were remarkable affected. All Hungarian vetch mixtures with oat and Italian rye grass combination had higher yields than pure Hungarian vetch during three production years. The yields of combinations varied based on species and ratio of oat and annual rye grass used in mixtures. High mixture rates of oat and Italian rye grass tended to produce higher forage yield in all individual (not shown) years as well as for the combined years (Table 1). Similar results were also reported by Cacan and Yilmaz (2015).

Plant height

Yield and yield components of Hungarian vetch (HV) with different rate combination of oat (O) and annual rye grass (ARG) are given in Table 1. There were significant differences between the mixture rates. The heighest planth height was detemined from pure oat (86.22 cm). The heighest planth height of HV (55.00 cm) was obtained from 34% HV+66% ARG which was followed by 66% HV+34% ARG (53.78 cm). The mixtures of Hungarian vetch with oat and annual rye grass showed similiar planth height when they grew in monoculture. Plant height of oat (86.22 cm) was found to be lower than Tuna and Orak (2007) findings (128.8 cm).

Stem diameter

With regard to the different mixture ratios, the highest stem diameter was obtained from pure oat (3.26 mm) which was followed by pure ARG (2.55 mm). Howerver pure and mixture combination of Hungarian vetch stem diameter measurements were found to be lower than of pure oat and annual rye grass.

Leaf/stem ratio

Leaf stem ratio represents the leaf weight divided by stem weight. In pure stand, mean maximum leaf stem ratio was recorded in ARG (2.86) followed by HV (1.75) and O (0.74) (Table 1). Leaf/stem ratio in crops decreased with the advancement of crop growth stage and increase in stem thickness. In mixtures and pure stand of HV, maximum leaf stem ratio (1.79, 1.78 and 1.78) was noted in 34% HV+66% ARG, 34% HV+66% O and 66% HV+34% ARG combinations respectively. Kilcher and Troelsen (1973) measured the leaf/stem ratio of two oat varieties at flowering and dough stages to be 1.4 and 0.6 respectively. Response of increasing competitiveness of oat based on an increase in its mixture rate was observed in leaf/stem ratio of Hungarian vetch. Thus the highest leaf/stem ratio (1.79) in 34:66 (HV+O) ratio was realized. The lowest ratio was found to be 1.75 in pure sowing of Hungarian vetch.

Legume ratio

The proportion of Hungarian vetch in dry forage was lower to the proportion of Hungarian vetch in the seed mixture at all sowing ratios. The proportion of vetch in vetch-oats hay was higher than vetch – annual rye grass sowing because oats was more competitive than annual rye grass.

According to the average value while the highest vetch rate in dry matter was determined from the mixture containing 66% Hungarian vetch and 34% annual rye grass (42.88%). The mixture containing 34% Hungarian vetch+66% oat had the lowest vetch rate in dry matter. There were differences between oat and annual rye grass with vetch. Our results showed the percentage of vetch in vetch+annual rye grass mixture (42.88% and 27.75%) were found to be higher than vetch+oat (32.38% and 16.63%) combination in both combination rates (66:34 and 34:66). According to previous studies, while Yolcu et al. (2010) found the average vetch rate as 34% in different HV-cereal mixtures, Orak and Nizam (2012) found rates of 42% in a 50% HV+50% cereal mixture. Our results were found to be similar to their findings. Separately, according to two years average results of Kusvuran et al. (2014) found a vetch rate of Hungarian vetch ratio in botanic composition 76.1 and 57,5% in HV+ARG mixture yield were found to be higher than sowing rate of Hungarian vetch ratio, 66% and 34% respectively. Vetch ratio decreased in mixture sowing with annual rye grass, because of more competitive habit of annual rye grass (ARG) in mixture and may originate from differences of region and climate conditions.

Forage yield

Our findings confirmed that the increased seeding rate of Hungarian vetch increased fresh forage yield in Hungarian vetch-oat intercropping (Table 1). Similar results have been reported in triticale-vetch intercropping (Albayrak et al., 2004). Our findings also suggested that when scaling the oat, Hungarian vetch were physically supported by oat plants, and this resulted in better establishment and development (Karagić et al., 2011; Atis et al., 2012).

Legume fresh forage yield

Legume fresh forage yield of mixtures were affected by seeding ratio of Hungarian vetch in all mixture combination. Proportions of Hungarian vetch decreased as the percentage of cereal seed increased in the mixtures (Table 1). The highest legume fresh forage yield (6.97 t ha^{-1}) was recorded from 66% HV+34% O mixture and 66% HV+34% ARG combination with 6.80 t ha^{-1} except pure Hungarian vetch sowing. Green herbage and hay yield values derived from the sole sowing of HV were reported as 6.2-17.0 t ha–1 and 1.7-4.0 t ha–1, respectively, in the previous studies (Karadag and Buyukburc, 2004; Balabanli and Turk, 2006; Unal et al., 2011; Albayrak et al., 2011; Orak and Nizam, 2012). Our findings were found to be similar to those from previous studies.

Total fresh forage yield

The greatest total fresh forage yield (29.41 t ha^{-1}) was obtained from 34% HV+66% O combination. In addition, forage yield was positive affected using of oat in mixture. In addition, forage yield was not affected by the increase of Hungarian vetch ratio in mixtures. Competition between component species in a mixture may affect the yield and quality of forage produced. However, forage yields of monocultures and annual rye grass mixtures with Hungarian vetch were lower than yields of oat mixtures with Hungarian vetch. Similarly Roberts et al. (1989) found that DM decreased with increasing common vetch ratios in mixtures with wheat. In contrast, Caballero et al. (1995) reported that mixtures of common vetch with oat produced 34% more forage yield than common vetch alone, but 57% less than monoculture oat. Lithourgidis et al. (2006) reported that forage yield was higher in cereals monocultures as well as in mixtures of common vetch with oat compared with mixtures of common vetch with triticale and monoculture common vetch. The other researchers have found that all Hungarian vetch-cereal intercropping systems had higher yields than pure Hungarian vetch during both and the yields of intercropping systems varied based on species and ratio of cereals used in mixtures (Acar et al., 2017).

Some previous findings showed that differences in yields of mixtures were mainly because of differences in tillering characteristics, climate and soil requirements in mixtures. In mixtures of Hungarian vetch with annual rye grass, average forage yield (21.86 t ha^{-1}) was lower by 32% than (28.87 t ha^{-1}) that in mixtures of Hungarian vetch with oat average yield. In addition, both mixtures of Hungarian vetch with ARG (21.86 t ha^{-1}) produced about 73% more forage yield than the monoculture Hungarian vetch (12.61 t ha^{-1}), in addition about 2% more than the monoculture ARG (21.41 t ha^{-1}). Both mixtures of Hungarian vetch with oat combinations (66:34 and 34:66 seeding ratios), however, produced total fresh forage yield about 124% and 133% respectively, more forage yield than the monoculture Hungarian vetch 12.61 t ha^{-1}, in addition about 14 and 19%, respectively, more than (24.83 t ha^{-1}) the monoculture oat (Table 1). Similarly, Glacomini et al. (2003) reported that yield of mixtures was similar to that of oat and greater than that of monoculture common vetch. Balabanli et al. (2010) reported that green forage yield of HV+O mixture was 17,75 t ha^{-1}, our findings was found to be higher than their

Table 1. Forage yield and yield components of Hungarian vetch and combine with oat and annual rye grass, data are the means of the 3 years

Mixture rates	Plant height (cm)		Stem diameter (mm)		Leaf/Stem ratio		HV ratio in botanic composition (%)	HV fresh forage yield (t ha^{-1})	Total fresh forage yield (t ha^{-1})	Total dry forage yield (t ha^{-1})
HV	53.44b	-	1.84	-	1.75b				12.61c	2.81d
O	-	86.22	-	3.26	-	0.74	-	-	24.82ab	7.70a
ARG	-	63.44	-	2.55	-	2.86	-	-	21.41b	5.55ab
66%HV+34%O	53.67ab	-	1.83	-	1.76ab	-	32.38b	6.97a	28.33a	7.37a
34%HV+66%O	51.67b	-	1.79	-	1.78a	-	16.63d	3.91c	29.41a	7.79a
66%HV+34%ARG	53.78ab	-	1.80	-	1.78a	-	42.88a	6.80a	20.56b	5.23c
34%HV+66%ARG	55.00a	-	1.83	-	1.79a	-	27.75c	4.33b	23.15b	5.93b
Average	59.60	-	1.87	-	1.78	-	30.04	4.53	22.90	6.05
LSD (%5)	1.48		ns		0.03	-	0.43	0.39	0.50	0.06

results (66:34 and 34:66 mixture; 28,33 and 29,41 t ha^{-1}, respectively. The other researchers findings (Palágyi et al., 2012) have been found higher (40,3 t ha^{-1}) than our results.

Total dry forage yield

According to Table 1, the heighest total dry forage yield was found to be 7.79 t ha^{-1} for 34% HV+66% O in combined analysis of the years. However, forage yields of all mixtures with oat were found to be statistically similiar to yield of oat (7.70 t ha^{-1}) in monoculture. In addition, pure ARG dry forage yield (5.55 t ha^{-1}) was lower than the monoculture oat and both mixture Hungarian vetch with oat combination (66:34 and 34:66 seeding ratios), respectively. The lowest total dry forage yield (2.81 t ha^{-1}) was obtained from pure Hungarian vetch. The results obtained by Palágyi et al. (2012) for pure HV, pure O and HV+O mixture (8.1, 14.5 and 13,6 t ha^{-1} respectively) are higher than our results (2.81, 7.70 and 7.79 t ha^{-1}, respectively). Some researchers have reported 5.17 t ha^{-1} of Hungarian vetch and oat mixture. Their results was found to be lower than our findings (7.70 t ha^{-1} and 7.79 t ha^{-1}). Different application, region and climatic condition may effect the results.

Correlation

Achieving the high yield through major yield attributes requires the knowledge of the magnitude of correlation among various yield components. Correlations between important characters for mixture and monocultures showed that total fresh forage yield had a highly significant correlation ($p \leq 0.01$ and $p \leq 0.05$) with total dry forage yield (r=0.994**), plant height (r=0.717**) and stem diameter (r=0.594**), while negative and significant (r=-0,569**) correlation was observed between total fresh forage yield and legume ratio in botanic composition (Table 2).

Acording to Table 2, in Hungarian vetch mixture with oat and annual rye grass, HV plant height (r=0.693**) showed the significant direct effect on total dry forage yield and moreover, forage yield also was positively associated with stem diameter (r=0.570**).

In mixture, stem diameter had significant positive direct effect on plant height (r=0.921**) and, moreover stem diameter was negative and insignificant correlated with leaf/stem ratio (r=-0.024). This relationship isn't a clear case of component compensation in determining stem dimeter of HV, and indicated a trend for leaf/stem ratio to decrease as stem diameter increased.

Cluster analysis

Cluster analysis is a tool for classifying objects into groups. Hierarchical cluster analysis was done using unweighted pair group method (UPGMA) (Sneath and Sokal, 1973). The dendrogram generated by Unweighted Pair Group Method using Average (UPGMA) based on SM (Simple Matching) correlation showed clustering of pure Hungarian vetch and addition oat and annual rye grass mixture with Hungrian vetch combination traits into three groups at a 45% similarity level (Figure 1). The first group consist of 3 mixture combinations 34% HV+66% ARG, 66% HV+34% ARG and 66% HV+34% O which are all high mixture fresh and dry forage yield, the highest plant height and leaf/stem ratio in mixture combinations and the second cluster consist of 34% HV+66% O, which is the highest mixture fresh and dry forage yield, the low-

Table 2. Correlation coefficients between different traits and total forage yield of mixtures and monoculture of Hungarian vetch

Traits	TFFY	TDFY	LFFY	PH	SD	LSR	BOTCOM
TFFY	1						
TDFY	0,994**	1					
LFFY	-0,147	-0,192					
PH	0.717**	0.693**	0,440**	1			
SD	0.594**	0.570**	0,517**	0.921**	1		
LSR	-0.094	-0,080	0,234	-0.015	-0.024	1	
BOTCOM	-0,569**	-0,616**	0,803**	-0,064	0,043	-0,204	1

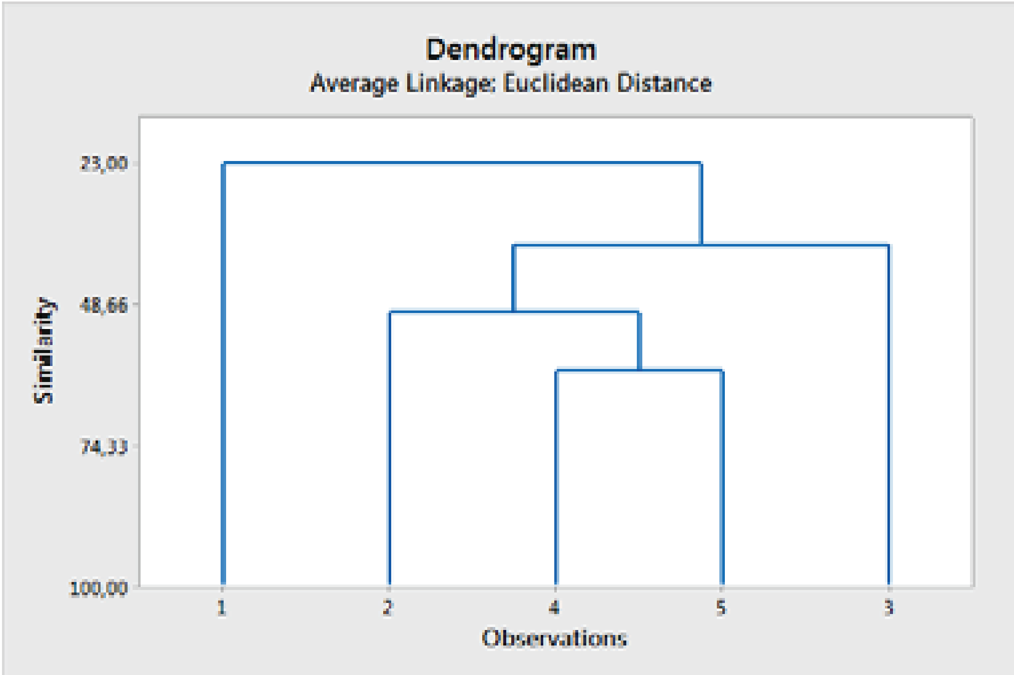

Figure 1. Dendogram of pure Hungarian vetch, oat, annual rye grass mixture with Hungarian vetch, based on yield and yield components

est stem diameter, second higher leaf/stem ratio and the last one pure Hungarian vetch sowing which is second lowest fresh and dry forage yield, the highest stem diameter, lower leaf/stem ratio and lower plant height, combinations. From these results it can be evaluate that using yield and five yield components, Hungarian vetch mixture with oat combination at both mixture rate can be successfully recognize from vetch mixture with annual rye grass and pure vetch sowing.

CONCLUSION

Forage yield is a quantitative trait that is strongly affected by environment. The present study was carried out over three year and used average values of pure and mixture combination of Hungarian vetch, oat and annual rye grass. Our results showed that total fresh and dry forage yield were mainly influenced by plant height and stem diameter. Thus in this mixture combinations, plant height and stem diameter played an important role in determining both total fresh and dry forage yield production.

In mixtures of Hungarian vetch with annual rye grass, average forage yield (21.86 t ha^{-1}) was lower by 32% than that in mixtures of Hungarian vetch with oat average yield (28.87 t ha^{-1}). Consequently all of the investigated parameters in the present study, 60% or 40% HV mixture with oat combination can be recommended for high yield forage production.

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