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Mixture cropping of berseem clover with cereals to improve forage yield and quality under irrigated conditions of the Mediterranean basin

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ABSTRACT

Mixture cropping of annual forage legumes and grasses is a common strategy to support sustainable forage supply in low input agricultural systems, especially in the Mediterranean basin. In a two-year field study, conducted in Northern Egypt, productivity and nutritive value of four cuts of berseem clover, triticale, and oat, cultivated as monocultures as well as legume-grass binary mixtures, with variable mixing rates, were investigated using a split plot design in three replicates. The tested mixing rates were: 1. 0% Grass (G) + 100% Berseem clover (BC), 2. 25% G + 75% BC, 3. 50% G + 50% BC, 4. 75% G + 25% BC, and 5. 100% G + 0% BC. Berseem clover mixtures with triticale produced the highest significant 3rd cut fresh yield, while BC mixtures with oat were superior at the 1st and 2nd cut's fresh yield. Crude protein (CP) content was highest in BC monocultures and clover-triticale mixture (75%:25%). Grasses, in general, improved the dry matter accumulation and carbohydrate components in the forage mixtures, with triticale being superior to oat. The significantly highest digestible organic matter (DOM) was a character of the pure BC stands, and mixtures with 75% BC. Noticeably, the tested grasses did not regrow after being cut for the third time; thus, the fourth cut was composed only of BC. Variations in DOM were most dependent on variations in CP content. Results revealed that mixtures of BC with triticale at 75%:25% mixing rate produced high forage yield with improved quality than the other mixtures.

1. Introduction

Mixture cropping is a common strategy adopted in the forage production sector to support sustainable forage supply in low input agricultural systems. Especially in the Mediterranean region, mixture cropping of annual winter legumes and grasses is widely applied (Lithourgidis et al., 2006). Crops in a mixture respond differently to pests, soil and weather conditions and thus reduces the risks associated with the cropping system (Lithourgidis et al., 2011). In addition, mixture crops possess different abilities in utilizing soil water and nutrients which lead to high resource use efficiency and, thus, increase the productivity and maximize the overall benefit from the agricultural practice (Atis et al., 2012). In an arid region like Egypt, with a negligible amount of precipitation, resulting in agriculture mainly dependent on irrigation, mixture cropping would increase water use efficiency over sole cropping.

The benefit from any species mixture in the forage sector is achieved when legumes and grasses are included in the mixture. Legume-grass binary mixtures combine the benefits of both worlds; they provide high yield, high quality, and a reduced need for nitrogen fertilization due to nitrogen fixation by the legume crop. Thus, they are expected to provide an end product of highest nutritional value than monocultures of both crop species (Rakeih et al., 2008), driven by the high protein content of legumes and high dietary fiber content of grasses. In addition, it is evident that intake of fodder is low when fed as pure species, either of legumes or grasses compared to their mixtures (Ansar et al., 2010). For a successful mixture, crop components should have compatible growth habit and harvesting schedule, complement each other in growth requirements and resources utilization, with minimal competition for the different life requirements (Al-Khateeb et al., 2001). In Egypt, and some of the world's countries, particularly those having long winter season with cold-moderate temperature, berseem clover (*Trifolium alexandrinum* L.) is the most important annual forage legume. It showed particular adaptation and superiority in the Mediterranean areas (Iannucci et al., 1996). Despite that the yield and protein content of BC are high, its cultivation in Egypt is currently facing several challenges, among them is its relatively high water requirements, low dry matter content especially in the first cut (Salama, 2015), and high sensitivity to climate change, especially rising temperatures associated with global warming (Bakheit et al., 2012; Dost et al., 2014). Moreover, feeding only BC results in bloating hazards and bone abnormalities due to the unbalanced ratios of P and Ca (Hall et al., 1991). On the other hand, grass monocultures provide a level of quality that is insufficient for many categories of livestock (Lithourgidis et al., 2006). Thus, mixture cropping of BC with forage grasses is a proposed low input technology

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that might solve these problems (Muhammad et al., 2014). In mixtures, companion forage grasses will provide structural support for BC growth, correct P and Ca values, improve water and nutrient uptake and light interception, and, thus, result in a better dry matter accumulation, whereas BC will increase the quality of the produced forage. This may allow small-holder livestock producers, who are the main suppliers for milk and meat, to substitute part of the grain component in the cattle diet with appropriate forage mixtures from their farms.

The choice of the grass species greatly affects the performance of the legume-grass mixtures, as different grass species possess variable competitiveness to the legume crop which would influence the productivity and quality of the end product (Ross et al., 2004). While, Yucel et al. (2018) proposed annual ryegrass (*Lolium multiflorum* Lam.) as a suitable forage grass for mixing with BC, Vasilakoglou and Dhima (2008), and El Karamany et al. (2014) reported barley (*Hordeum vulgare* L.) to be the best cereal for the mixture. Nonetheless, triticale (*X Triticosecale* Wittmack) and oat (*Avena sativa* L.) are among the promising cereals currently occupying a considerable agricultural area in Egypt, however, mostly for grain production, whereas their full potential as annual winter forage crops is not yet exploited.

In addition to the grass species, the success of the legume-grass forage mixture is highly dependent on the mixing rate of mixture components (Gill and Omokanye, 2018). As legumes are usually less competitive than grasses (Ross et al., 2004), the seeding rate is the main driver of the crops' growth rates and, thus, of the competition between them (Lithourgidis et al., 2006).

The specific objective of the current study was to investigate the productivity and nutritive value of several cuts of berseem clover, triticale and oat when grown as monocultures, as well as binary mixtures with varying mixing rates.

2. Materials and methods

2.1. Site description

A two-year field trial was conducted at the experimental station of the Faculty of Agriculture, Alexandria University, Alexandria, Egypt, during two successive winter seasons (2017/2018 and 2018/2019). The experimental site was characterized by its arid climate, with a negligible amount of precipitation throughout the growing season; therefore, it was completely dependent on irrigation. The average monthly temperature was 23.73, and 23.26 °C, for the two respective growing seasons. Soil of the experimental site was sandy loam in texture (51.50% sand, 28.00% silt, and 20.50% clay), with pH of 8.27, electrical conductivity of 1.30 dS m^{-1}. The organic matter content of the top layer of the soil reached 1.70%, while available nitrogen, phosphorous, and potassium were 100, 75, 450 ppm, respectively.

2.2. Experimental design and treatments

A split plot experimental design with three replicates was used to evaluate four successive cuts of two forage grass species, triticale (*X Triticosecale* Wittmack) and oat (*Avena sativa* L.), sown in monocultures and binary mixtures with berseem clover (*Trifolium alexandrinum* L.), cultivar "Helaly", with the following mixing rates: 1. 0% Grass (G) + 100% Berseem clover (BC), 2. 25% G + 75% BC, 3. 50% G + 50% BC, 4. 75% G + 25% BC, and 5. 100% G + 0% BC.

Cuts were allocated to the main plots, while the combinations between, grass species and mixing rates were tested in the subplots.

2.3. Agricultural practices

After ploughing and levelling, the land was divided into experimental plots; each was 9 m^2. During the two successive growing seasons, trials were sown on 15th October. Optimum seeding rate for the three investigated crops was 48 kg ha^{-1} from which the tested mixing rates were calculated. Seeds/seed mixtures were broadcasted on the flat experimental plots and then covered with a light soil layer. To encourage biological N_2 fixation, berseem clover seeds were inoculated with *Rhizobium trifolii* directly before sowing. The bacterial inoculum was prepared and provided by the Microorganisms Unit, Agricultural Research Center (ARC), Giza, Egypt. Fertilization, irrigation and weed management practices were homogeneous for all experimental plots. With seedbed preparation, an amount of 150 kg ha^{-1} calcium monophosphate (15.5% P_2O_5) was added. Ammonium nitrate (33.5% N), was applied at the rate of 80 kg N ha^{-1}, split into four equal doses that were applied, as a top dressing to the experimental plots, with sowing, directly after the first, second, and third cuts.

2.4. Sampling and measurements

Four cuts were taken from the experimental plots, first cut at 55 DAS (days after sowing), with 35 days interval before the 2nd, 3rd, and 4th cuts. At cutting, plants were manually clipped with a garden cheers at a 7 cm stubble height and fresh yield was directly weighed for each plot. For quality analyses, a representative sample of approximately 1 kg from each plot was dried at 60 °C until constant weight was reached, from which the dry matter (DM) content of the herbage was determined, followed by grounding the dried samples to 1-mm particle size. Crude protein (CP = N × 6.25), crude ash (CA) and crude fat (CF) were determined as described in the AOAC (2012). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were sequentially determined as described by Van Soest et al. (1991) using the semiautomatic ANKOM^{220} Fiber Analyzer (ANKOM Technology, Macedon, NY, USA). Non-fiber carbohydrates (NFC) were then calculated as follows:

$$NFC = 1000 - (CP + CF + NDF + CA)$$

Digestibility was determined using the in vitro cellulase technique developed by De Boever et al. (1988). The percentage of digestible organic matter (DOM) was then calculated by applying the following equation of Weissbach et al. (1999):

$$DOM\,(\%) = 100 * \frac{\left(940 - CA - 0.62 \times EULOS - 0.000221 \times EULOS^2\right)}{1000 - CA}$$

EULOS = enzyme insoluble organic matter; CA and EULOS were expressed as g kg^{-1} DM.

2.5. Statistical analyses

In the current experiment, tested grasses did not survive till the fourth cut, i.e. they didn't regrow after being cut for the third time. Thus, in the fourth cut there was only BC in all plots, with a complete absence of triticale and oat. This resulted in only four forage treatments instead of five in the fourth cut, because of the absence of the 100% grass treatment. Due to the smaller number of treatments of the fourth cut, than the first three cuts, it was analyzed separately and not incorporated in the same model with the first three cuts.

Yield and quality data (D) were subjected to ANOVA using PROC Glimmix of SAS 9.4 (SAS Institute Inc., 2012). Data of the two experimental years were separately analyzed, then test of homogeneity of variance's error (Hartley, 1950), was applied, and revealed that the variance's error of the two experimental years was homogeneous. Therefore, another combined analysis of variance was run, where "Year" and "Year × Treatment(s)" effects were declared non-significant. Thus, results were presented and discussed combined over the two experimental years.

The first three cuts were analyzed according to the following model, with cuts and replicates considered random, and grass species (GS) and mixing rates (MR) considered fixed:

$$Dijkl = \mu + Bi + Cj + eij + GSk + MRl + eijkl + Cj \times GSk + Cj \times MRl + GSk \times MRl + Cj \times GSk \times MRl$$

where μ is the overall mean, B_i is the block's effect ($i = 1,2,3$), C_j is the cut effect ($j = 1,2,3$), e_{ij} is the experimental error "a", GS_k is the grass species effect ($k = 1,2$), MR_l is the mixing rate effect ($l = 1,2,3,4,5$), and e_{ijkl} is the experimental error "b".

The fourth cut was subjected to a separate analysis of variance, where only replicates were considered random. Grass species and mixing rates and their interaction were tested against the experimental error, according to the following model:

$$Dijk = \mu + Bi + GSj + MRk + GSj \times MRk + eijk$$

where μ is the overall mean, B_i is the block's effect ($i = 1,2,3$), GS_j is the grass species effect ($_j = 1,2$), MR_k is the mixing rate effect ($k = 1,2,3,4$), and e_{ijk} is the experimental error.

Upon the analysis of variances, significances were declared at $P < 0.05$ and means were compared with the least significant difference (L.S.D) procedure.

To test how much the variable "DOM" was dependent on the other quality variables (CP, NFC, NDF, ADF and ADL), a stepwise regression analysis with a forward selection procedure was applied (Gomez and Gomez, 1984). Significance was declared at 0.2000 significance level, and non-significant variables were automatically removed from the model.

Table 1
Means of yield (t ha^{-1}), dry matter (DM), crude protein (CP), non-fiber carbohydrates (NFC), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents (g kg^{-1} DM), ±standard deviation (SD), as affected by the cut × grass species interaction, combined over the two growing seasons.

Cut	Yield		DM	
	Triticale	Oat	Triticale	Oat
1	$19.8^{bB} \pm 3.78$	$30.1^{aA} \pm 5.05$	$142.0^{aA} \pm 13.6$	$132.9^{bA} \pm 18.3$
2	$23.6^{bB} \pm 5.62$	$32.1^{aA} \pm 5.18$	$118.2^{aB} \pm 7.42$	$113.8^{bB} \pm 4.10$
3	$32.7^{aA} \pm 7.79$	$10.2^{bB} \pm 3.53$	$111.0^{aC} \pm 4.79$	$108.2^{bC} \pm 6.14$
L.S.D.$_{0.05\ Row}$	1.70		1.12	
L.S.D.$_{0.05\ Column}$	5.90		4.90	

Cut	CP		NFC	
	Triticale	Oat	Triticale	Oat
1	$139.6^{aA} \pm 12.7$	$131.0^{bA} \pm 18.7$	$205.1^{bC} \pm 29.0$	$238.8^{aB} \pm 20.0$
2	$137.5^{aA} \pm 12.0$	$127.4^{bA} \pm 18.4$	$286.6^{aA} \pm 21.6$	$269.7^{bA} \pm 21.5$
3	$136.0^{aA} \pm 9.07$	$121.5^{bB} \pm 16.4$	$246.4^{bB} \pm 20.4$	$280.2^{aA} \pm 24.4$
L.S.D.$_{0.05\ Row}$	1.58		2.51	
L.S.D.$_{0.05\ Column}$	4.65		15.1	

Cut	NDF		ADF	
	Triticale	Oat	Triticale	Oat
1	$532.2^{aA} \pm 32.3$	$490.8^{bA} \pm 43.2$	$313.0^{aA} \pm 39.7$	$275.0^{bB} \pm 34.5$
2	$452.7^{aC} \pm 28.2$	$463.5^{aB} \pm 46.5$	$271.1^{aB} \pm 38.7$	$263.7^{bC} \pm 36.4$
3	$494.4^{aB} \pm 16.3$	$458.9^{bB} \pm 24.6$	$310.4^{aA} \pm 16.6$	$300.9^{bA} \pm 17.0$
L.S.D.$_{0.05\ Row}$	2.41		1.98	
L.S.D.$_{0.05\ Column}$	14.9		3.15	

Means followed by different small letter(s) within the same row, and different capital letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

3. Results

Significant interactions between the studied factors are presented and discussed, while main effects are presented and discussed only when the interactions involving them are not significant.

Analysis of variance of the first three cuts revealed that all the studied parameters significantly varied as affected by the two-way interaction between the three tested factors, i.e. cut, grass species incorporated in mixtures with BC, and mixing rate ($P < 0.01$). In addition, ADL and DOM contents were significantly affected by the three-way interaction ($P < 0.01$).

3.1. Influence of cut × grass species interaction

Clover mixtures with triticale produced the maximum amount of fresh yield with the 3rd cut, representing an increase of around 65 and 38% over the yield produced from the 1st and 2nd cuts, respectively (Table 1). Mixtures with oat, however, followed an opposite descending trend in yield production among cuts, where the significantly highest yields were produced from 1st and 2nd cuts, amounting to 30.1 and 32.1 t ha^{-1}, respectively, then drastically dropped by the 3rd cut to 10.2 t ha^{-1}. Thus, regarding the yield of the three cuts, the 3rd cut was superior to the other two cuts with triticale incorporation in the mixture, while the 1st and 2nd cuts were superior with oat incorporation in the mixture. Among the three cuts, BC mixtures with triticale were advantaged by the accumulation of significantly higher amounts of DM than its mixtures with oat. In addition, both species accumulated the highest amount of DM with the 1st cut, which tended to significantly decrease with further cuts. Crude protein content was significantly highest in mixtures with triticale, with no significant variation among its three cuts (137.7 g kg^{-1} in an average of the three cuts), while CP content of mixtures with oat significantly decreased with advanced cuts from 131.0 to 121.5 g kg^{-1} for the 1st and 3rd cuts, respectively. Non-fiber carbohydrate values were significantly highest for the 3rd cut with oat mixture, and for the 2nd cut with triticale mixture. Clover mixtures with triticale were characterized by significantly highest amounts of NDF and ADF than mixtures with oat. Noticeably, the 2nd cut was always characterized with the least significant amounts of the two fiber components across all types of mixtures.

3.2. Influence of cut × mixing rate interaction

The variable direction of effect of the tested mixing rates among the three cuts was the main cause of their significant interaction. Observing the means in Table 2, revealed that pure BC stands produced the significantly highest amount of fresh yield for the 3rd cut (48.3 t ha^{-1}), while for the 1st and 2nd cuts, the mixture of 25% G + 75% BC was similarly superior in the amount of fresh yield. Increasing the grass percentage in the mixture was always accompanied by reducing the resulting fresh yield. Moreover, the significantly highest amount of fresh yield was produced from the 3rd cut among all mixing rates. Unlike the fresh yield, increasing the grass percentage in the mixture led to significantly increasing the DM content. Generally, the 1st cut of all mixing rates (except 100% BC), was characterized by the significantly highest DM accumulation than the 2nd and 3rd cuts. An opposite trend was observed for the CP content, where the 100% BC produced the significantly highest CP contents for the three cuts. Obviously, the CP content decreased with decreasing the BC percentage in the mixture. The NFC increased with increasing the grass percentage in the forage mixture. While, 100% G produced the significantly highest NFC content for the 3rd cut, 50 and 75% G were superior for the 2nd cut, and the three grass percentages, 25, 50 and 75% produced significantly highest NFC contents for the 1st cut. Regarding the fiber components, 1st cut was characterized with the significantly highest NDF, except for 100% BC. Meanwhile, the ADF content was significantly highest for the 3rd cut, except for 100% G. Nonetheless, the 100% G always produced the significantly highest contents of the two fiber components, which tended to decrease with decreasing the percentage of grass in the mixture.

Table 2
Means of herbage yield (t ha^{-1}), dry matter (DM), crude protein (CP), non-fiber carbohydrates (NFC), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents (g kg^{-1} DM), ±standard deviation (SD), as affected by the cut × mixing rate interaction, combined over the two growing seasons.

Mixing rate		Yield			DM		
Grass %	Berseem clover %	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2	Cut 3
0	100	$28.6^{cAB} \pm 1.66$	$35.5^{bA} \pm 1.78$	$48.3^{aA} \pm 2.12$	$100.4^{cE} \pm 1.53$	$114.9^{aBC} \pm 2.45$	$106.7^{bCD} \pm 2.11$
25	75	$31.5^{bA} \pm 5.21$	$31.3^{bAB} \pm 4.02$	$41.9^{aB} \pm 5.04$	$133.7^{aD} \pm 3.32$	$110.1^{bC} \pm 2.53$	$102.9^{cD} \pm 4.70$
50	50	$24.9^{cBC} \pm 6.01$	$29.7^{bB} \pm 4.94$	$36.7^{aBC} \pm 4.97$	$145.3^{aC} \pm 5.33$	$113.7^{bBC} \pm 4.30$	$108.7^{cBC} \pm 2.07$
75	25	$21.0^{cCD} \pm 5.83$	$23.4^{bC} \pm 4.33$	$31.1^{aC} \pm 4.06$	$150.4^{aB} \pm 7.45$	$116.1^{bB} \pm 4.89$	$112.7^{cAB} \pm 2.27$
100	0	$18.6^{bD} \pm 4.58$	$19.5^{bC} \pm 2.85$	$24.0^{aD} \pm 4.70$	$157.7^{aA} \pm 9.57$	$125.1^{bA} \pm 5.09$	$116.9^{cA} \pm 2.33$
L.S.D.$_{0.05\ \text{Row}}$		1.11			1.77		
L.S.D.$_{0.05\ \text{Column}}$		5.90			4.90		

Mixing rate		CP			NFC		
Grass %	Berseem clover %	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2	Cut 3
0	100	$144.2^{bA} \pm 4.23$	$149.7^{aA} \pm 2.11$	$139.3^{cA} \pm 2.11$	$217.0^{cB} \pm 4.17$	$262.4^{aC} \pm 2.13$	$224.3^{bD} \pm 2.11$
25	75	$136.4^{bB} \pm 1.45$	$146.0^{aB} \pm 4.47$	$135.3^{bB} \pm 5.83$	$244.9^{cA} \pm 5.48$	$288.4^{aB} \pm 12.3$	$264.6^{bC} \pm 13.1$
50	50	$133.6^{aBC} \pm 3.54$	$132.0^{bC} \pm 6.30$	$133.4^{aBC} \pm 6.77$	$246.9^{cA} \pm 10.9$	$299.1^{aAB} \pm 10.9$	$253.5^{bC} \pm 9.71$
75	25	$130.2^{aC} \pm 1.91$	$124.9^{bD} \pm 5.57$	$130.3^{aC} \pm 8.65$	$245.7^{cA} \pm 7.99$	$313.0^{aA} \pm 7.31$	$283.6^{bB} \pm 15.2$
100	0	$112.1^{aD} \pm 1.09$	$109.8^{bE} \pm 2.05$	$105.7^{cD} \pm 4.65$	$155.3^{cC} \pm 8.61$	$228.0^{bD} \pm 9.79$	$290.4^{aA} \pm 15.6$
L.S.D.$_{0.05\ \text{Row}}$		1.91			3.97		
L.S.D.$_{0.05\ \text{Column}}$		4.65			15.1		

Mixing rate		NDF			ADF		
Grass %	Berseem clover %	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2	Cut 3
0	100	$464.8^{bD} \pm 15.4$	$426.0^{cC} \pm 2.11$	$474.6^{aBC} \pm 2.12$	$285.1^{aB} \pm 1.63$	$251.2^{bB} \pm 2.11$	$285.5^{aD} \pm 2.03$
25	75	$470.9^{aD} \pm 20.0$	$425.6^{cC} \pm 15.4$	$460.1^{bD} \pm 18.6$	$259.6^{bD} \pm 20.0$	$251.1^{cB} \pm 6.76$	$303.3^{aC} \pm 12.9$
50	50	$489.5^{aC} \pm 15.6$	$438.7^{cBC} \pm 11.0$	$483.1^{bB} \pm 12.1$	$263.2^{bC} \pm 22.1$	$247.4^{cC} \pm 5.12$	$306.3^{aB} \pm 10.5$
75	25	$504.1^{aB} \pm 17.1$	$442.2^{cB} \pm 11.6$	$466.1^{bCD} \pm 15.7$	$282.1^{bB} \pm 9.42$	$248.6^{cC} \pm 14.6$	$308.3^{aB} \pm 13.4$
100	0	$628.1^{aA} \pm 15.0$	$557.7^{bA} \pm 7.29$	$499.4^{cA} \pm 20.4$	$380.2^{aA} \pm 12.5$	$338.7^{bA} \pm 7.25$	$324.8^{cA} \pm 2.11$
L.S.D.$_{0.05\ \text{Row}}$		3.82			1.55		
L.S.D.$_{0.05\ \text{Column}}$		13.9			3.15		

Means followed by different small letter(s) within the same row, and different capital letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

Table 3
Means of yield (t ha^{-1}), dry matter (DM), crude protein (CP), non-fiber carbohydrates (NFC), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents (g kg^{-1} DM), ±standard deviation (SD), as affected by the grass species × mixing rate interaction, combined over the two growing seasons.

Mixing rate		Yield		DM	
Grass %	Berseem clover %	Triticale	Oat	Triticale	Oat
0	100	$38.1^{aA} \pm 6.87$	$36.8^{aA} \pm 6.87$	$108.0^{aE} \pm 6.57$	$106.7^{aD} \pm 6.57$
25	75	$29.6^{bB} \pm 4.27$	$40.3^{aA} \pm 2.70$	$117.0^{aD} \pm 14.5$	$114.1^{bC} \pm 14.1$
50	50	$24.6^{bC} \pm 4.64$	$36.3^{aA} \pm 2.22$	$125.4^{aC} \pm 18.6$	$119.7^{bB} \pm 16.0$
75	25	$18.6^{bD} \pm 2.57$	$31.8^{aB} \pm 3.10$	$130.4^{aB} \pm 12.2$	$122.4^{bB} \pm 16.1$
100	0	$16.0^{bD} \pm 1.66$	$25.4^{aC} \pm 2.36$	$137.9^{aA} \pm 21.9$	$128.6^{bA} \pm 15.8$
L.S.D.$_{0.05\ \text{Row}}$		1.90		1.45	
L.S.D.$_{0.05\ \text{Column}}$		4.56		4.35	

Mixing rate		CP		NFC	
Grass %	Berseem clover %	Triticale	Oat	Triticale	Oat
0	100	$149.1^{aA} \pm 7.66$	$147.8^{aA} \pm 7.66$	$235.2^{aC} \pm 21.3$	$233.9^{aD} \pm 21.3$
25	75	$146.6^{aA} \pm 5.01$	$137.2^{bB} \pm 5.58$	$255.1^{bB} \pm 20.4$	$276.9^{aAB} \pm 20.8$
50	50	$138.4^{aB} \pm 2.88$	$127.6^{bC} \pm 2.90$	$267.1^{aAB} \pm 25.6$	$266.0^{aBC} \pm 15.8$
75	25	$133.3^{aB} \pm 5.14$	$123.5^{bC} \pm 4.99$	$279.8^{aA} \pm 28.8$	$281.8^{aA} \pm 23.9$
100	0	$121.2^{aC} \pm 2.89$	$97.2^{bD} \pm 3.96$	$193.2^{bD} \pm 28.0$	$256.0^{aC} \pm 24.5$
L.S.D.$_{0.05\ \text{Row}}$		1.74		3.25	
L.S.D.$_{0.05\ \text{Column}}$		5.16		16.6	

Mixing rate		NDF		ADF	
Grass %	Berseem clover %	Triticale	Oat	Triticale	Oat
0	100	$455.8^{aC} \pm 22.5$	$454.5^{aB} \pm 22.5$	$287.7^{aC} \pm 22.0$	$286.4^{aB} \pm 22.0$
25	75	$468.4^{aBC} \pm 23.1$	$436.0^{bC} \pm 16.4$	$282.0^{aC} \pm 24.0$	$260.6^{bD} \pm 18.5$
50	50	$474.6^{aB} \pm 24.8$	$466.5^{bB} \pm 14.3$	$277.3^{aD} \pm 20.2$	$267.3^{bC} \pm 26.4$
75	25	$477.0^{aB} \pm 24.8$	$464.7^{bB} \pm 19.3$	$290.9^{aB} \pm 25.5$	$268.4^{bC} \pm 26.7$
100	0	$589.7^{aA} \pm 25.7$	$533.8^{bA} \pm 20.9$	$353.0^{aA} \pm 21.9$	$316.6^{bA} \pm 23.7$
L.S.D.$_{0.05\ \text{Row}}$		3.12		1.27	
L.S.D.$_{0.05\ \text{Column}}$		16.3		6.45	

Means followed by different small letter(s) within the same row, and different capital letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

3.3. Influence of grass species × mixing rate interaction

It was clear from Table 3 that mixtures of BC with oat resulted in significantly higher fresh yield production than mixtures with triticale, across all tested mixing rates. Pure BC stands produced the highest significant yield (37.5 t ha^{-1}). Decreasing the BC percentage in mixtures with both grass species significantly reduced the amount of fresh yield. Hence, the significantly lowest yield was produced from the pure triticale and oat stands, amounting to 16.0 and 25.4 t ha^{-1}, respectively. On the contrary to fresh yield, DM content of mixtures with triticale was significantly highest than mixtures with oat. In addition, BC was characterized by significantly lowest DM content and, thus, its increased percentage in the mixture contributed to decreasing DM of the whole mixture. Similar to the DM content, pure triticale had significantly higher CP content (121.2 g kg^{-1}) than pure oat (97.2 g kg^{-1}). Therefore, mixtures with triticale were significantly higher in CP content than mixtures with oat, while, increasing the BC percentage in mixtures with both grass crops significantly increased CP content. A mixture of 75% BC + 25% triticale produced 146.6 g CP kg^{-1}, which was significantly similar to the 100% BC. Pure oat stands were richer in NFC content than pure triticale stands, while in mixtures with BC, both grasses resulted in similar amounts of NFC, except for 25% G + 75% BC, where the oat in the mixture gave significantly higher NFC content than triticale in the mixture. Noticeably, berseem clover-grass mixtures produced significantly higher NFC contents than pure stands of BC and both grass species. Opposite to NFC, triticale, either as a pure stand or in the mixtures with BC was significantly higher in the fiber components than oat. Nonetheless, pure grass was rich in NDF and ADF than pure BC stands, therefore, the fiber content increased as the grass percentage in the mixture increased.

3.4. Influence of cut × grass species × mixing rate interaction

Only ADL and DOM were significantly affected by the three-way interaction between the three tested factors. Means presented in Table 4 showed that BC and its contribution in the forage mixture with 75% were characterized with the significantly highest lignin content, which decreased with decreasing the BC percentage in the forage mixture, and reached its minimal values with 100% G. In general, the lignin content of the 3rd cut was significantly higher than that of the 1st and 2nd cuts. It was observed that pure oat had higher lignin content than pure triticale among the three cuts; however, mixtures of both crops with BC were similar in the lignin content. Noticeably, pure BC stands produced up to two-fold lignin content than that of grasses among all cuts. Similar to the lignin content, the significantly highest DOM was a character of the pure BC stands, and mixtures with 75% BC. Meanwhile, DOM significantly decreased with increasing grass percentage in the mixture, where triticale was more digestible than oat, with 594.2 against 549.8 g DOM kg^{-1}, in average for the three cuts.

Table 5
Means of herbage yield (t ha^{-1}), dry matter (DM), crude protein (CP), non-fiber carbohydrates (NFC), acid detergent lignin (ADL), and digestible organic matter (DOM) contents (g kg^{-1} DM), for the fourth cut as affected by the mixing rate, combined over the two growing seasons.

Mixing rate		Yield	CP	NFC	ADL	DOM
Grass %	Berseem clover %					
0	100	35.1^{a}	134.4^{a}	286.5^{ab}	65.7^{a}	655.9^{a}
25	75	19.6^{b}	135.5^{a}	243.5^{c}	62.5^{b}	648.9^{ab}
50	50	12.7^{c}	127.4^{b}	284.6^{b}	47.2^{c}	643.5^{ab}
75	25	10.7^{c}	128.3^{b}	287.9^{a}	41.5^{d}	639.8^{b}
L.S.D.$_{0.05}$		4.23	6.54	3.23	3.03	14.7

Means followed by different small letter(s) within the same column are significantly different according to the L.S.D. test at 0.05 level of probability.

3.5. Variations in yield and quality attributes of the fourth cut

Analysis of variance of the fourth cut revealed that all the studied parameters, except DM, were variable among the forage mixing rates ($P < 0.01$), while significant variations between the two tested grass species ($P < 0.01$), as well as significant grass species × mixing rate interaction, were detected only for NDF and ADF ($P < 0.01$). In this cut, only BC was present in the experimental plots, while triticale and oat were completely absent. Therefore, obviously, the significantly highest amount of fresh yield was produced from 100% BC stands, and was gradually reduced with reducing the BC seeding rate (Table 5). Despite the complete absence of grasses from the experimental plots, differences in quality existed between the BC cut from the pure stands and BC cut from plots where grasses were previously present. Significantly highest CP content was produced from 100% and 75% BC stands. However, the reduction in CP content with reducing BC sowing rate was minimal (0.81%). Similarly, the variations in NFC, ADL and DOM between BC sowing rates were negligible, and amounted to 4.44, 2.42, and 1.61%, respectively. Observably, BC regrowth in plots where grasses where previously present, was characterized by less lignin and DOM, which were characteristics of grasses, rather than BC pure stands. As for the

Table 4
Means of acid detergent lignin (ADL), and digestible organic matter (DOM) contents (g kg^{-1} DM), ±standard deviation (SD), as affected by the cut × grass species × mixing rate interaction, combined over the two growing seasons.

Mixing rate		ADL					
Grass %	Berseem clover %	Cut 1		Cut 2		Cut 3	
		Triticale	Oat	Triticale	Oat	Triticale	Oat
0	100	48.5 ± 1.29	47.2 ± 1.29	42.7 ± 2.23	41.5 ± 2.98	55.2 ± 1.25	54.0 ± 1.48
25	75	56.6 ± 1.15	43.7 ± 3.12	50.0 ± 1.52	46.6 ± 1.45	55.9 ± 1.74	59.3 ± 1.84
50	50	47.5 ± 1.36	42.6 ± 1.92	42.2 ± 1.89	42.6 ± 1.84	49.8 ± 1.68	55.3 ± 1.23
75	25	43.8 ± 1.99	39.0 ± 0.97	39.5 ± 2.23	42.2 ± 2.78	48.3 ± 0.98	53.0 ± 1.59
100	0	28.5 ± 2.45	29.7 ± 0.55	23.0 ± 2.65	29.7 ± 0.96	25.5 ± 2.03	29.0 ± 1.55
L.S.D.$_{0.05}$		5.57					
Mixing rate		**DOM**					
Grass %	Berseem clover %	Cut 1		Cut 2		Cut 3	
		Triticale	Oat	Triticale	Oat	Triticale	Oat
0	100	671.0 ± 8.56	669.7 ± 7.68	656.6 ± 7.48	655.3 ± 9.45	669.4 ± 9.62	668.1 ± 8.45
25	75	659.1 ± 10.5	640.7 ± 9.62	640.1 ± 8.59	639.9 ± 8.57	649.9 ± 10.5	647.8 ± 11.7
50	50	649.8 ± 12.7	625.0 ± 14.6	625.4 ± 12.5	604.5 ± 11.4	640.1 ± 10.5	614.9 ± 16.0
75	25	610.4 ± 11.1	591.5 ± 11.2	584.2 ± 10.7	576.3 ± 13.5	609.8 ± 13.7	590.3 ± 8.55
100	0	591.8 ± 9.58	551.3 ± 8.94	589.5 ± 9.85	540.1 ± 9.62	601.3 ± 8.74	557.9 ± 10.5
L.S.D.$_{0.05}$		52.1					

Table 6
Means of neutral detergent fiber (NDF), acid detergent fiber (ADF), contents (g kg^{-1} DM), ±standard deviation (SD), for the fourth cut as affected by the grass species × mixing rate interaction, combined over the two growing seasons.

Mixing rate		NDF		ADF	
Grass %	Berseem clover %	Triticale	Oat	Triticale	Oat
0	100	$417.9^{aD} \pm 20.6$	$416.6^{aC} \pm 12.4$	$273.0^{aD} \pm 6.23$	$271.7^{aB} \pm 16.0$
25	75	$457.1^{bA} \pm 15.5$	$469.4^{aA} \pm 7.95$	$327.4^{bA} \pm 7.15$	$343.3^{aA} \pm 4.27$
50	50	$426.4^{aC} \pm 10.9$	$429.7^{aB} \pm 8.15$	$284.8^{aB} \pm 5.85$	$266.0^{bC} \pm 6.95$
75	25	$434.8^{aB} \pm 13.7$	$398.5^{bD} \pm 10.7$	$279.0^{aC} \pm 6.14$	$228.7^{bD} \pm 12.7$
$L.S.D._{0.05\ Row}$		4.62		15.6	
$L.S.D._{0.05\ Column}$		7.96		5.23	

Means followed by different small letter(s) within the same row, and different capital letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

two-way interaction (Table 6), BC cut from plots where triticale and oat were previously present was characterized by significantly higher NDF and ADF than pure BC stands.

3.6. Stepwise regression analysis

Results of the forward selection of the stepwise regression analysis revealed that the variations in the DOM was most dependent on the variations in CP content ($r^2 = 0.8082$), followed by the variations in ADL and NDF contents, with r^2 values equal 0.0325 and 0.0288, respectively (Table 7). The contribution of NFC content in determining the DOM values was non-significant ($P < 0.1840$). No other variable met the 0.2000 significance level for entry into the model, therefore, ADF was excluded.

4. Discussion

A famous, widely grown BC cultivar "Helaly", with well-known productivity potential and nutritive value, was used in the present study, to ensure that investigation was relevant to a cultivar likely to be widely used in the Egyptian farming system. This would guarantee widespread of the results and encourage farmers to apply the research recommendations in their forage production fields.

4.1. Variations in herbage yield and dry matter accumulation

One of the challenges associated with BC cultivation is the low fresh yield and dry matter accumulation characterizing the 1st cut, and making it unprofitable, to the extent that sometimes farmers in Egypt tend to plough it in the soil as green manure rather than harvesting it as green forage. While the yield of BC was low for the 1st cut, it surpassed the other forage treatments for the 2nd and 3rd cuts. It was, therefore, observed that increasing the BC percentage in the clover-grass mixture uplifted the fresh yield for the 2nd and 3rd cuts, which could be mainly attributed to the higher branching ability and denser canopy structure of BC in comparison to forage grasses (El Kramany et al., 2012). On the other hand, forage grasses were characterized by their high DM content and, therefore, increasing the grass component in the forage mixture was responsible for improving its DM content. Thus, the current results confirmed that mixing BC with forage grasses improved the overall productivity and DM content, especially for the 1st cut. Similar results were reported for mixtures of BC with oat, barley, triticale, and ryegrass (Al-Khateeb et al., 2001; El Kramany et al., 2012; El Karamany et al., 2014; Salama and Badry, 2015). Several reasons stand behind the improved productivity of the legume-grass mixtures, especially the better utilization of the legume-fixed atmospheric nitrogen and improved light interception, which may have contributed to creating a more favorable micro-environment for better yield production than legume or grass pure stands (Sengul, 2003).

The current results revealed that oat out-yielded triticale in the 1st and 2nd cuts, while the situation was reversed in the 3rd cut, with triticale superiority to oat. This was clearly reflected on the mixtures of BC with both crops, which followed the same trend, where mixtures with triticale were highly productive in the 3rd cut, opposite to mixtures with oat which were highly productive in the 1st and 2nd cuts. Mixtures with oat out-yielded mixtures with triticale by around 24%. In a similar study, Lithourgidis et al. (2006) concluded that mixing common vetch with oat resulted in 18% more forage yield than mixtures of common vetch with triticale. A deep look into the growth dynamics of triticale and oat would clarify their variable productivity among the three cuts, when sown in monocultures and binary mixtures with BC. In their investigation, Sullivan et al. (1982) reported higher forage yield for oat early in the season, while triticale was more productive, with faster growth in mid-season. It is evident that oat plants are leafier than triticale plants, especially after cutting/grazing, oat regrowth will be characterized with higher dry matter and green leaf yields than triticale. Another reason for the increased yield of oat at the beginning of the growing season might be its higher plant density even when using the same seeding rate for triticale and oat. Similar to the current study, Berkenkamp and Meeres (1987) and Baron et al. (1992), reported yield advantage for oat over barley and triticale when seeded with similar rates based on seed weight or count, while, when McCartney and Vaage (1994), seeded oat at lower rates by weight to other cereal crops, its potential yield advantage was offset. This is because, triticale seeds are larger in size than oat seeds, therefore, to maintain equal plant densities from both crops, higher seeding rate in case of triticale should be used (Sullivan et al., 1982).

Generally, BC mixtures with triticale were less productive than pure BC stands, while mixtures of BC with oat produced similar yields to pure

Table 7
F-values and levels of significance of the forward selection of the stepwise regression procedure between the digestible organic matter (DOM) as dependent variable and the other tested variables. Significance was declared at 0.2000 significance level.

Step	Variable	Partial R-square	Model R-square	*F*-value	*Pr* > F
1	CP	0.8082	0.8082	118.00**	<0.0001
2	ADL	0.0325	0.8407	5.52*	0.0264
4	NDF	0.0288	0.8802	6.01*	0.0216
3	NFC	0.0106	0.8514	1.86ns	0.1840

ns: Non-significant - No other variable met the 0.2000 significance level for entry into the model.
* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

stands of BC. Berkenkamp and Meeres (1987) reported that Welsh spring triticale was less competitive in a legume-grass mixture than oat, to the extent that mixtures of triticale with field pea and faba bean yielded less than either monocrop. Noticeably, forage DM content of triticale was higher than that of oat, which was in line with the findings of McCartney and Vaage (1994), who compared the two crops at different growth stages.

In order for the forage mixture to be beneficial, Baron et al. (2015) suggested that the total yield of the mixture should be equal to or higher than the average yield of the two mixture components, which was the case in the current study. The total yield of the three cuts amounted to 112.37 and 62.13 t ha^{-1}, for pure BC and pure G stands, respectively. While their average was 87.25 t ha^{-1}, the total 3-cut yield of the 50% BC: 50% G treatment was 91.30 t ha^{-1}.

4.2. Variations in herbage nutritive value

Berseem clover was responsible for increasing the CP content in the mixtures with forage grasses. It was observed that all the tested legume-grass mixing rates produced CP content higher than that of the pure grass stands, but lower than that of pure BC stands. This result highlighted the potential protein benefit from including BC in mixtures with low-protein forage grasses. Similar findings were reported for various legume-grass mixtures (Barsila, 2018; Haq et al., 2018; Salama and Zeid, 2016).

While pure oat stands had very low CP content (9.72%), pure triticale stands were characterized by moderate CP content (12.12%) for a forage grass. This was reflected on the higher CP content of mixtures with triticale than with oat. Similar results were reported by Gill and Omokanye (2018) for mixtures of peas with oat and triticale. The improved CP content of the legume-grass forage mixtures in the current study, offers the beef cattle producers an on-farm green protein source that can partially substitute the grain component in cattle diet. According to the NRC (2000) model for beef cattle diet, 7%, 9% and 11–13% CP are recommended for mid pregnancy, late pregnancy, lactating dairy cows and young calves, respectively. In the current study, triticale pure stands and in binary mixtures with BC met the requirements of lactating dairy cows and young calves (approximately 12–14% CP). Meanwhile, oat pure stands (with only 9.72% CP) were only adequate for mid- and late-pregnancy cows, however, when grown in mixtures with BC, even with the least amount of clover contribution to the mixture (25%), the CP content of the mixture was much improved to meet the requirements of lactating dairy cows and young calves. Although 1st cut is usually characterized with higher CP content than subsequent cuts (Salama and Zeid, 2016), this was the case only with oat in the forage mixtures, while including triticale in the mixtures resulted in similar CP content for the three cuts, this might be attributed to the relatively high initial CP content of triticale.

Grasses, generally, contain higher amounts of the cell wall components than legumes. The NDF content, especially, is a direct determinant to forage intake, with NDF concentrations >550 g kg^{-1} DM severely reducing voluntary intake (Baron et al., 1992), which was the case with pure grass stands in the current study, while, mixing BC with grasses reduced the NDF content to below that critical limit. In dairy studies, the performance of grasses and legumes is always confounded by the differences in NDF between both species. With grasses containing more NDF than legumes, when diets contain equal amounts of dry matter, diets containing grasses will be characterized by higher NDF amounts than legumes. Similar findings were reported for mixtures of common vetch with oat and triticale by Lithourgidis et al. (2006). Similarly, ADF was decreased as a result of mixing BC with forage grasses (Salama and Zeid, 2016). In case of lignin content, pure BC stands and mixtures with the highest contribution of clover had significantly higher values than the other forage treatments (Laidlaw and Teuber, 2001; Salama and Zeid, 2016), and that was mainly because of the low lignin proportion in the cell wall of monocots than the cell wall of dicots (Buchanan et al., 2015; Carpita and McCann, 2015). Opposite to the current study, Gill and Omokanye (2018) reported no variations in the fiber fractions between pure stands of forage grasses and their mixtures with peas. They added that oat had higher NDF and ADF contents than triticale. In the current study triticale, in general, had higher NDF and ADF contents than oat, meanwhile, triticale supplied the legume-grass mixtures with higher contents of fiber components than oat. The higher CP and fiber components of triticale than oat, in the current study, might be attributed to its higher DM content.

Forage grasses were expected to have higher amounts of non-fiber carbohydrates than BC; however, this was true for the 3rd cut, while in the 1st and 2nd cuts, increasing the grass percentage in the mixture was accompanied with an increase in the NFC contents over the pure stands of either crops. Similarly, El Kramany et al. (2012), reported an ascending increase in carbohydrate content of berseem clover-triticale mixture with increasing the proportion of triticale in the mixture. In line with the current study, Keles et al. (2016) reported that oat had higher NFC content than triticale when compared at the tillering and stem elongation growth stages. This was obviously reflected on a higher NFC content of BC mixtures with oat, than with triticale in the current study. Keles et al. (2016) added, however, that triticale had more lignin content than oat, which did not fully concur with the current results, where oat had higher ADL content than triticale. This contradiction might be due to the different varieties of triticale and oat tested in both studies.

Forage grasses in the current experiment were characterized with higher amounts of structural cell-wall components which have low digestibility than other cell contents. Therefore, increasing the grass proportion in the mixture reduced its digestibility and the highest DOM was reported for the pure BC stands, and 25% G + 75% BC mixtures. Despite its higher NDF and ADF contents, triticale was more digestible than oat, probably because of its higher CP and lower lignin contents. Therefore, mixtures of BC with triticale possessed higher digestibility than mixtures with oat. Similarly, Sullivan et al. (1982) reported higher nutritive value of triticale than oat, in terms of higher intake and digestibility that was reflected on the better performance of cattle fed triticale. They, thus, recommended triticale as an alternative forage crop for fattening cattle.

4.3. Variations in yield and quality attributes of the fourth cut

After the 3rd cut, BC regrowth did not suffer from any competition for light, space and soil nutrients, due to the complete absence of oat and triticale, thus, all the experimental plots turned to be pure BC stands, cultivated with different seeding rates (25 to 100%). Obviously, the amount of forage yield was directly proportional to the seeding rate, and thus the highest yield was achieved with 100% seeding rate. That the NDF and ADF increased in plots where oat and triticale were previously present, was probably due to the increased spacing, accompanied with the low BC density that promoted the growth of thicker and more vigorous stems, which were characterized by higher fiber content than the leaves. For the same reason, CP content of the crop decreased with decreasing the seeding rate, due to the decrease in leaf: stem ratio, where leaves are characterized by higher CP content than stems.

4.4. Stepwise regression analysis

Forage digestibility is among the most important determinants to its quality, which is highly variable as affected by the forage's chemical composition. Organic matter digestibility represents digestibility of the cell components (100% digestible), as well as, digestibility of the cell wall components (variably digestible). Among the most practical and reliable measures proposed for determining the suitable maturity stage at which forages should be cut for high digestibility, were NDF (Givens and Deaville, 2001), and ADF (Castillo et al., 2009) contents. However, both fiber fractions are negatively correlated to digestibility (Bruinenberg et al., 2002). Aided by the stepwise regression analysis, the current study aimed at analyzing the amount of contribution of each of the studied quality parameters in determining the DOM of the investigated forage treatments. Results showed that the CP content had the highest significant contribution in determining DOM of the forage treatments. The positive correlation between CP content and digestibility suggests that the bundle of treatments that would increase the CP content of a forage, would meanwhile contribute to improving its digestibility (Salama, 2019). Therefore, it was reported in the current study that berseem clover mixtures with triticale were highly digestible, compared to mixtures with oat, probably because of the higher CP content of triticale, that proved to have the strongest influence on the forage digestibility. After CP content, NDF and ADL contents significantly affected the DOM. The NFC content proved to have no contribution in determining DOM of the forage treatments; therefore, it was excluded from the analysis.

5. Conclusion

Mixing BC with annual winter forage grasses provide the smallholder livestock producers (main suppliers for meat and milk) with a high amount of forage with balanced nutritional value to support the forage-based feeding systems. Results of the current study clearly indicated that mixing rate significantly influenced the yield and quality performances of the legume-grass mixtures. Forage yield was higher for BC monocultures followed by mixtures with oat for the 1st and 2nd cuts and mixtures with triticale for the 3rd cut. Crude protein content was highest in BC monocultures and berseem clover-triticale mixture (75%:25%). Grasses, in general, improved the dry matter accumulation and carbohydrate components (NFC, NDF and ADF) in the forage mixtures, with triticale being superior to oat. The significantly highest DOM was a character of the pure BC stands, and forage mixtures with 75% BC. The complete absence of the tested forage grasses in the 4th cut questions the feasibility of taking this cut against taking only three cuts and then clearing the land to allow for early subsequent summer cultivation. The variations in DOM were most dependent on the variations in CP content, followed by the variations in NDF and ADL contents. Under similar Mediterranean conditions, mixing BC with triticale at 75%:25% mixing rate would produce high fresh forage yield with balanced nutritional options.

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Declaration of competing interest

The author declares no conflict of interest for this research work.

References

Al-Khateeb, S.A., Leilah, A.A., Al-Thabet, S.S., Al-Barak, K.M., 2001. Study on mixed sowing of Egyptian clover (*Trifolium alexandrinum* L.) with ryegrass (*Lolium multiflorum* Lam.), barley (*Hordeum vulgare* L.) and oat (*Avena fatua* L.) on fodder yield and quality. Egypt. J. Appl. Sci. 16, 159–171.

Ansar, M., Ahmed, Z.I., Malik, M.A., Nadeem, M., Majeed, A., Rischkowsky, B.A., 2010. Forage yield and quality potential of winter cereal-vetch mixtures under rainfed conditions. Emir. J. Food Agr. 22, 25–36.

AOAC International, 2012. Official Methods of Analysis. 19th ed. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Atis, I., Kokten, K., Hatipoglu, R., Yilmaz, S., Atak, M., Can, E., 2012. Plant density and mixture ratio effects on the competition between common vetch and wheat. Aust. J. Crop. Sci. 6, 498–505.

Bakheit, B.R., Ali, M.A., Helmy, A.A., 2012. The influence of temperature, genotype and genotype x temperature interaction on seed yield of berseem clover (*Trifolium alexandrinum* L.). Asian J. Crop Sci. 4, 63–71.

Baron, V.S., Dick, A.C., Najda, H.G., Salmon, D.F., 1992. Post-flowering forage potential of spring and winter cereal mixtures. Can. J. Plant Sci. 72, 137–145.

Baron, V.S., Juskiw, P.E., Aljarrah, M., 2015. Triticale as forage. In: Eudes, F. (Ed.), Triticale. Springer.

Barsila, S.R., 2018. The fodder oat (*Avena sativa*) mixed legume forages farming: nutritional and ecological benefits. J. Agric. Natur. Resour. 1, 206–222.

Berkenkamp, B., Meeres, J., 1987. Mixtures of annual crops for forage in central Alberta. Can. J. Plant Sci. 67, 175–183.

Bruinenberg, M.H., Valk, H., Korevaar, H., Struik, P.C., 2002. Factors affecting digestibility of temperate forages from seminatural grasslands: a review. Grass Forage Sci. 57, 292–301.

Buchanan, B.B., Gruissem, W., Jones, R.L. (Eds.), 2015. Biochemistry and Molecular Biology of Plants. John Wiley & Sons.

Carpita, N., McCann, M., 2015. The cell wall. In: Buchanan, B.B., Gruissem, W., Jones, R.L. (Eds.), Biochemistry and Molecular Biology of Plants. American Society of Plant Biologists, Maryland, USA, pp. 52–108.

Castillo, J., Rojas-Bourrillón, A., WingChing-Jones, R., 2009. Nutritional value of silage made with a mixture of corn and mung bean (*Vigna radiata*). Agronomía Costarricense 33, 133–146.

De Boever, J.L., Cottyn, B.L., Andries, J.I., Buysse, F.X., Vanacker, J.M., 1988. The use of cellulose technique to predict digestibility, metabolizable and net energy of forages. Anim. Feed Sci. Technol. 19, 247–260.

Dost, M., Misri, B., El-Nahrawy, M., Khan, S., Serkan, A., 2014. Egyptian Clover (*Trifolium alexandrinum*); King of Forage Crops. Regional Office for the Near East and North Africa. Food and Agriculture Organization of the United Nations, Cairo.

El Karamany, M.F., Bakry, B.A., Elewa, T.A.E.F., 2014. Integrated action of mixture rates and nitrogen levels on quantity and quality of forage mixture from Egyptian clover and barley in sandy soil. Agric. Sci. 5 (14), 1539. https://doi.org/10.4236/as.2014.514165.

El Kramany, M.F., Elewa, T.A., Bakry, A.B., 2012. Effect of mixture rates on forage mixture of Egyptian clover (*Trifolium alexandrinum* L.) with triticale (×*Triticosecale Wittmack*) under newly reclaimed sandy soil. Aust. J. Basic Appl. Sci. 6, 40–44.

Gill, K.S., Omokanye, A.T., 2018. Potential of spring barley, oat and triticale intercrops with field peas for forage production, nutrition quality and beef cattle diet. J. Agric. Sci. 10, 1–17. https://doi.org/10.5539/jas.v10n4p1.

Givens, D.I., Deaville, E.R., 2001. Comparison of major carbohydrate fractions and cell wall digestibility in silages made from older and newer maize genotypes grown in the UK. Anim. Feed Sci. Technol. 89, 69–82.

Gomez, K.A., Gomez, A.A., 1984. Statistical Procedures for Agricultural Research. 2 ed. John Wiley and Sons, New York.

Hall, D.D., Cromwell, G.L., Stahly, T.S., 1991. Effects of dietary calcium, phosphorus, calcium: phosphorus ratio and vitamin K on performance, bone strength and blood clotting status of pigs. J. Anim. Sci. 69, 646–655.

Haq, S.A., Korieng, K.J., Sheikh, T.A., Bahar, F.A., Dar, K.A., Raja, W., Khuroo, N.S., 2018. Yield and quality of winter cereal-legume fodder mixtures and their pure stand under temperate conditions of Kashmir Valley. India. Int. J. Curr. Microbiol. App. Sci 7, 3626–3631.

Hartley, H.O., 1950. The maximum F-ratio as a short-cut test for heterogeneity of variance. Biometrika 37, 308–312.

Iannucci, A., Fonzo, N.D., Martiniello, P., 1996. Effects of the developmental stage at harvest on dry matter and chemical component partitioning in berseem. J. Agron. Crop Sci. 176, 165–172.

Keles, G., Ates, S., Coskun, B., Alatas, M.S., Isik, S., 2016. Forage yields and feeding value of small grain winter cereals for lambs. J. Sci. Food Agric. 96, 4168–4177.

Laidlaw, A.S., Teuber, N., 2001. Temperate forage grass-legume mixtures: advances and perspectives. Proc. XIX International Grassland Congress, 11–21 February 2001. Sao Paulo, Brazil, 85–92.

Lithourgidis, A.S., Vasilakoglou, I.B., Dhima, K.V., Dordas, C.A., Yiakoulaki, M.D., 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crop Res. 99, 106–113.

Lithourgidis, A.S., Dordas, C.A., Damalas, C.A., Vlachostergios, D., 2011. Annual intercrops: an alternative pathway for sustainable agriculture. Aust. J. Crop. Sci. 5, 396–410.

McCartney, D.H., Vaage, A.S., 1994. Comparative yield and feeding value of barley, oat and triticale silages. Can. J. Anim. Sci. 74, 91–96.

Muhammad, D., Misri, B., EL-Nahrawy, M., Khan, S., Serkan, A., 2014. Egyptian clover (*Trifolium alexandrinum*) king of forage crops. FAO, Regional Office for the Near East and North Africa. Egypt, Cairo.

NRC, 2000. Nutrient Requirements of Beef Cattle. 7th Revised Ed., Update 2000. National Academy Press, Washington, DC.

Rakeih, N., Kayyal, H., Larbi, A., Habib, N., 2008. Forage potential of triticale in mixtures with forage legumes in rainfed regions (second and third stability zones) in Syria. Tishreen University Journal for Research and Scientific Studies - Biological Sciences Series 30, 203–216.

Ross, S.M., King, J.R., O'Donovan, J.T., Spaner, D., 2004. Forage potential of intercropping berseem clover with barley, oat, or triticale. Agron. J. 96, 1013–1020.

Salama, H.S.A., 2015. Interactive effect of forage mixing rates and organic fertilizers on the yield and nutritive value of berseem clover (*Trifolium alexandrinum* L.) and annual ryegrass (*Lolium multiflorum* Lam.). Agric. Sci. 6 (04), 415. https://doi.org/10.4236/as.2015.64041.

Salama, H.S.A., 2019. Yield and nutritive value of maize (*Zea mays* L.) forage as affected by plant density, sowing date and age at harvest. Italian J. Agron. 14, 114–122.

Salama, H.S.A., Badry, H.H., 2015. Influence of variable mixing rates and nitrogen fertilization levels on the fodder quality of Egyptian clover (*Trifolium alexandrinum* L.) and annual ryegrass (*Lolium multiflorum* Lam.). Afr. J. Agric. Res. 10, 4858–4864.

Salama, H.S.A., Zeid, M.M.K., 2016. Hay quality evaluation of summer grass and legume forage monocultures and mixtures grown under irrigated conditions. Aust. J. Crop. Sci. 11, 1543.

Sengul, S., 2003. Performance of some forage grasses or legumes and their mixtures under dry land conditions. Eur. J. Agron. 19, 401–409.
Statistical Analysis System, 2012. SAS PC Windows Version 9.4 SAS Institute Inc. Cary, NC, USA.
Sullivan, M.T., Hales, J.W., Norton, B.W., 1982. A comparison of triticale and oats as forages for fattening cattle in south-east Queensland. Proceedings of the Australian Society of Animal Production. 14, pp. 289–392.
Van Soest, P.V., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597.
Vasilakoglou, I., Dhima, K., 2008. Forage yield and competition indices of berseem clover intercropped with barley. Agron. J. 100, 1749–1756.
Weißbach, F., Kuhla, S., Schmidt, L., Henkels, A., 1999. Estimation of the digestibility and the metabolizable energy of grass and grass products. Proceedings of the Society of Nutrition Physiology (Germany).
Yucel, C., Inal, I., Yucel, D., Hatipoglu, R., 2018. Effects of mixture ratio and cutting time on forage yield and silage quality of intercropped berseem clover and Italian ryegrass. Legum. Res. 41, 846–853.