

YIELD, QUALITY AND PROFITABILITY OF HUNGARIAN VETCH (*Vicia pannonica* Crantz) UNDER DIFFERENT TILLAGE SYSTEMS AND SEED RATIOS

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ABSTRACT

In this study, Hungarian vetch (*Vicia pannonica* Crantz) 'HV' production, under different tillage systems (zero 'ZT', reduce 'RT' and conventional 'CT') and seed ratios (80, 100, 120, 140, 160 kg ha⁻¹) was evaluated in yield, protein content and profitability for forage and seed. This two-year study was conducted in Yozgat-Turkey conditions in 2014-2015 and 2015-2016 seasons. The experiments were arranged in split-plot, with the tillage systems as main plots and seed ratios as split-plots. Previous crop was wheat in both years. According to the two-year averages, the tillage systems were ordered statistically as follows: CT=RT=ZT for hay yield, ZT > RT for protein content of hay, RT=ZT=CT for seed yield and ZT>RT=CT for protein content of seed. However the effect of year was significant for the treatments and, although not significant, seed ratio exhibited different effects changing depend on forage or seed harvest. Namely, seed yield was relatively more at the low seed ratios (80-100 kg ha⁻¹) while hay yield was more at the high seed ratios (140-160 kg ha⁻¹). Yield performances and low costs made ZT and RT economically superior than CT in both productions. Considering the yield and economy, ZT has seen as a more suitable system in HV cultivation with the seed ratio of 100 kg ha⁻¹ for seed and 140 kg ha⁻¹ for forage purposes. All these results have showed that HV cultivated with conservation tillage systems, especially with ZT can be competitive by conventional tillage regarding yield, moreover is much better for economically.

Kew words: Conservational tillage, hay yield, Hungarian vetch, profitability, seed yield.

INTRODUCTION

Today, sustainability is main concern in Agricultural due to series of threats that occur either man-made or naturally. As a matter of fact some management strategies that conserving the soil, air and water resources are being implemented to combat all these threats or reduce their negative effects. In this context, interest in conservation tillage systems that are reduced tillage and no-till systems have gained interest in worldwide due to their economic and environmental benefits for farmers, environment and society (Neugschwandtner et al., 2014). These systems may provide many economic and biological benefits arose from conserving soil water content, less labor and fuel requirement, time saving, reducing carbon emission and soil erosion and also improving physical, chemical and biological structure of the soil (Huang et al., 2008; Kabiri et al., 2015).

In Turkey, the studies for conservation tillage have a history of about 50 years. But these studies have been performed mostly by universities and research institutes, and the findings were not been adequately applied in the farm conditions. Therefore, there is limited data about the performance of certain crops grown with the conservation

tillage systems in Turkey. There are many studies on the no-till cultivation of high-income plants such as maize, soybean, sunflower, soybean and wheat, however, it is seen that the studies on fodder crops are very limited in Turkey (Altikat et al., 2018; Ileri et al., 2018).

Vetches (*Vicia* sp.), annual legumes, are among the most cultivated forage crops with about 0.39 mil hectare in Turkish agricultural systems (Tuik, 2019). It is mostly used for pasture, silage, hay or as green manure. Vetches shows high palatability at all growth stages and also grains with high protein content are used for livestock feed (Acikgoz, 1988). Among the vetch species, the cultivation of Hungarian vetch (*Vicia pannonica* Crantz), which is winter-resistant, has been increasing in recent years. Hungarian vetch is one of the most important components of the cereal-legume rotation in the Turkey (Unal et al., 2011), especially in the inner regions with cold winter conditions (Acikgoz, 1988). For Hungarian vetch, it is critical to early sown in autumn and enter to the winter with strong seedlings. However, in some years, dry autumns or late heavy rainfall not allow to soil tillage and delayed the sowing and, the desired performance cannot be obtained from the Hungarian vetch (Bingol et al.,

2007). Sowing with no-till or reduced tillage can make an important contribution to alleviate this problem by providing flexibility for sowing time, conserving soil moisture and encourage early germination. In addition to soil conditions and sowing time, seed rate is also a determining factor in the production of Hungarian vetch, as in all cultivated plants, and directly affects plant growth and yield (Uzun et al., 2004).

Therefore, the objectives of the study were to investigate the effect of different tillage systems and seed ratios on the yield, quality and profitability of Hungarian vetch grown for forage and seed purposes in the Inner Anatolian conditions of Turkey.

MATERIALS AND METHODS

Plant material

As plant material “Beta” variety of Hungarian vetch (*Vicia pannonica* Crantz) was used.

Experimental site.

This study was conducted in Yozgat province characterized with hot dry summer and cold winter, located inner region of Turkey (Figure 1) in 2015-2016 and 2014-2015 growing seasons.

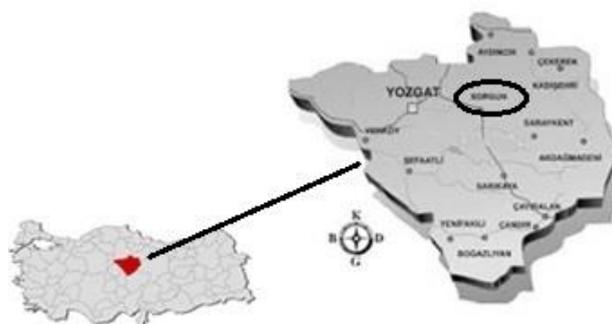


Figure 1. Experimental site.

Climatic conditions and soil

Monthly average temperature and total precipitation in the growing seasons and long-term were given in Figure 2. Higher temperatures were noted in the season of 2015-2016 than was in 2014-2015 especially on February and April. Long-term total precipitation in the experimental site is 540 mm during the growing season and, higher total precipitation was recorded in the 2014-2015 (688.6 mm) than 2015-2016 (502mm).

The soil taken from 0-30 cm was characterized with high pH (8.68), low organic matter (1.77%), loamy (36.30%), low salty (0.008%), medium CaCO₃ (3.02%), low P₂O₅ (3.16%) and high K₂O (64.75%).

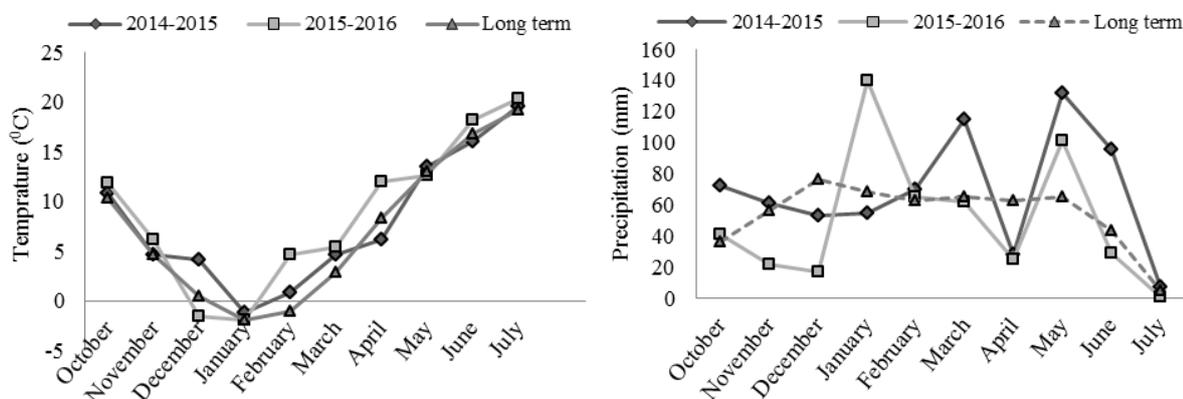


Figure 2. Temperature (left) and precipitation (right) diagrams of the experiment site for the study years and the long-term (limited by the growing season).

Method

The experiments were sown on 16 and 14 October in 2014 and 2015 respectively. Five seed rates (80, 100, 120, 140, 160 kg ha⁻¹) and three soil tillage (conventional, reduced and zero) (Table 1) were used as a treatment. Previous crop was wheat in both years. Experimental design was a split-plot, with the three tillage systems as main plots, five seed ratio as split-plots. Each plot size was 27 m² (2.7x10) with 30cm line distance, in three

replications. Fertilization was done in equal amount to each plot and with 100 kg ha⁻¹ DAP (18% NH₄ - 46% P₂O₅) with sowing.

Each split plot was divided into two equal pieces and harvested for forage and seed separately. Forage harvest was performed when plants Hungarian vetch was at the 50% flowering stage and seed harvest was at the full maturity stage.

Table 1. Soil tillage systems

Treatment	Tillage practices and sowing
Zero-tillage (ZT)	Direct sowing with special zero-till drill seeder.
Reduced tillage (RT)	Chisel-plowing to 15 cm + sowing with same drill seeder.
Conventional tillage (CT)	Plowing with bottom plow to 30 cm + harrowing + sowing with same drill seeder.

Yield and crude protein content were determined in both hay and seed samples. All the treatments were evaluated economically for hay and seed production as well. Crude protein was determined by using near infrared reflectance spectroscopy (Foss 6500, Foss NIR Systems, Inc. Silver Spring MD USA) with "IC0904FE" software (Basaran et al., 2011; 2019) Profitability in combined years was determined using certain cost and product prices in 2019 (Table 2) and converted to US Dollars, and treatments were compared according to net economic gain.

Table 2. Input costs for tillage, seed, fertilizer and harvest and, hay price in 2019*.

Inputs**	Cost, \$***
Plowing, \$/ha	50.17
Chisel-plowing, \$/ha	21.51
Sowing, \$/ha	19.71
Fertilizer, \$/kg	0.53
Seed, \$/kg	0.31
Harvest, \$/ha	71.68
Hay, \$/kg	0.12

*:Other production costs, such as land rent, management and labor, etc., were fixed and eliminated.

** : Obtained from Yozgat Chamber of Agriculture Presidency.

***USD/TRY=5.68 (Mean Exchange Rate of 2019,

<https://www.tcmb.gov.tr>).

Statistical analysis

Data was analyzed according to a split plot design with the SPSS 20.0 software program for separate and combined years. Means were compared by the Duncan's multiple tests and statistical significance was determined at 5% level (Steel and Torrie, 1980).

RESULTS

For forage production

The effect of tillage system, seed ratio and year on the hay yield of Hungarian vetch (*HV*) was given in Table 3. Tillage system and seed ratio were not significant on the hay yield of *HV* both separate and combined years. However mean forage yield was significantly ($p<0.01$) different between the years and was higher in 2015 (8.78 t ha⁻¹). Additionally, partial differences have been determined between the treatments in terms of hay yield in separate and combined years. Hay yield of zero-tillage (ZT) was above the conventional tillage (CT) and reduced tillage (RT) at 140 kg ha⁻¹ in all years. In the 2014-2015 seasons, reduced tillage (RT) produced mean yield (9.02 t ha⁻¹) above the other treatments, especially at 80 kg ha⁻¹ (10.53 t ha⁻¹). However, regarding mean hay yield, CT was above ZT and RT in 2015-2016 (5.74 t ha⁻¹) and combined years (7.36 t ha⁻¹). Also, results released that to obtain high hay yield, seed ratio at 80 kg ha⁻¹ can be option for RT and CT but higher seed ratios up to 140 kg ha⁻¹ may be chosen for ZT.

Table 3. The effect of tillage system and seed ratio on hay yield of Hungarian vetch (t ha⁻¹)

Season**	Tillage system	Seed ratio (kg ha ⁻¹)					Mean
		80	100	120	140	160	
2014-2015	ZT	7.86	7.69	7.83	9.53	8.78	8.34
	RT	10.53	9.22	7.55	9.10	8.69	9.02
	CT	8.74	8.66	9.99	8.86	8.70	8.99
	Mean	9.04	8.52	8.45	9.17	8.72	8.78 A
2015-2016	ZT	4.95	4.91	5.09	5.93	5.91	5.36
	RT	5.42	4.20	4.90	5.89	5.49	5.18
	CT	5.82	6.03	5.26	5.56	6.01	5.74
	Mean	5.40	5.05	5.08	5.79	5.80	5.43 B
Mean	ZT	6.41	6.3	6.79	7.73	7.34	6.92
	RT	7.98	6.71	6.22	7.49	7.09	7.10
	CT	7.28	7.35	7.62	7.21	7.35	7.36
	Mean	7.22	6.79	6.88	7.48	7.26	7.13

** : $p<0.01$. There is no difference between the means, showing by the same letter in the same row and column ($p<0.05$). ZT: Zero-tillage, RT: Reduced tillage, CT: Conventional tillage.

Crude protein content significantly affected by tillage system ($p<0.01$) seed ratio ($p<0.01$), year ($p<0.01$) and tillage system x seed ratio interaction ($p<0.05$, $p<0.01$)

(Table 4). Over the tillage systems and seed ratio, mean protein content was higher in the first season (17.84%) than second season (16.60%). In the first season, crude

protein content of the *HV*'s hay as an average of the seed ratios was not different amongst tillage systems, however, in the second and combined years, ZT and CT were in the same group and higher than RT. For crude protein, the differences amongst the seed ratios were significant in

separate years but not in combined years. These results indicated that climatic conditions were more determinative on the protein content of hay compared to tillage system or seed ratio, moreover, affected the performance of these treatments.

Table 4. The effect of tillage system and seed ratio on crude protein content of Hungarian vetch hay (%)

Season**	Tillage system	Seed ratio (kg ha ⁻¹)					Mean
		80	100	120	140	160	
2014-2015 **	ZT	18.27 abc	18.52 abc	18.39 abc	18.59 abc	15.97 c	17.95
	RT	20.27 a	17.11 c	16.03 c	18.33 abc	20.04 ab	18.36
	CT	17.2 c	17.33 bc	15.93 c	17.21 c	18.39 abc	17.21
	Mean*	18.58 a	17.65 ab	16.78 b	18.04 ab	18.13 ab	17.84 A
2015-2016 **	ZT	18.27 abc	18.26 abc	17.07 b-e	19.22 ab	14.28 efg	17.42 a**
	RT	14.74 d-g	12.26 g	18.04 abc	12.66 fg	15.37 c-f	14.61 b
	CT	17.53 bcd	15.36 c-f	20.71 a	19.14 ab	16.12 b-e	17.77 a
	Mean**	16.85 ab	15.29 b	18.60 a	17.01 ab	15.26 b	16.60 B
Mean**	ZT	18.27 ab	18.39 ab	17.73 ab	18.90 a	15.13 de	17.68 a**
	RT	17.51 abc	14.68 e	17.04 a-d	15.49 cde	17.71 ab	16.48 b
	CT	17.37 abc	16.35 b-e	18.32 ab	18.18 ab	17.25 abc	17.49 a
	Mean	17.71	16.47	17.69	17.52	16.69	17.22

**: $p < 0.01$, *: $p < 0.05$. There is no difference between the means, showing by the same letter in the same row and column ($p < 0.05$). ZT: Zero-tillage, RT: Reduced tillage, CT: Conventional tillage.

For seed production

Tillage system and seed ratio were not significant on seed yield of *HV* in the separate and combined years (Table 5). As in hay yield, ZT and RT showed promising results for seed yield. Moreover, both ZT and RT had over mean seed yield than CT in combined years as an average

of the seed ratios. With some exceptions, lower seed ratios especially at 100 and 120 kg ha⁻¹ produced well seed yield in all the tillage systems. Although not significant, seed yield in tillage systems, seed ratio and interactions changed between years (about 6.25%). This reveals that the efficiency of the treatments in terms of seed yield was moderately changed by the climatic conditions.

Table 5. The effect of tillage system and seed ratio on seed yield of Hungarian vetch (t ha⁻¹)

Season	Tillage system	Seed ratio (kg ha ⁻¹)					Mean
		80	100	120	140	160	
2014-2015	ZT	1.87	1.74	1.73	1.76	1.51	1.72
	RT	1.28	1.89	1.53	1.47	1.90	1.61
	CT	1.82	1.77	1.35	1.13	1.24	1.46
	Mean	1.66	1.80	1.54	1.46	1.55	1.60
2015-2016	ZT	1.47	1.94	1.54	1.70	1.55	1.64
	RT	1.86	1.61	1.96	1.77	1.65	1.77
	CT	2.03	1.63	1.78	1.57	1.47	1.70
	Mean	1.79	1.73	1.76	1.68	1.56	1.70
Mean	ZT	1.67	1.84	1.64	1.73	1.53	1.68
	RT	1.57	1.75	1.74	1.62	1.77	1.69
	CT	1.92	1.70	1.57	1.35	1.36	1.58
	Mean	1.72	1.76	1.65	1.57	1.55	1.65

ZT: Zero-tillage, RT: Reduced tillage, CT: Conventional tillage

Crude protein content in *HV* seeds was significantly ($p < 0.01$) affected by all the treatments and years (Table 6). Over the seed ratio, both separate and combined year significantly higher protein content was detected in ZT (22.17%, 24.26% and 23.21%, respectively) compared to RT and CT. All the tillage systems exhibited higher

protein content at 140 and 160 kg ha⁻¹ seed ratios. Also mean protein content in the *HV* seed was significantly different between the years and higher in second year (23.05%) than first year (20.96%). Two-year results showed that ZT was superior to CT and RT in almost all the seed ratios in terms of seed protein content.

Table 6. The effects of tillage system and seed ratio on seed crude protein content of Hungarian vetch (%).

Season**	Tillage system	Seed ratio (kg ha ⁻¹)					Mean
		80	100	120	140	160	
2014-2015**	ZT	21.50 abc	22.17 ab	22.26 ab	22.69 a	22.24 ab	22.17 a**
	RT	20.29 cde	19.36 de	17.05 f	21.74 abc	22.34 ab	20.16 b
	CT	21.14 abc	19.25 e	20.93 bcd	21.37 abc	20.12 cde	20.56 b
	Mean**	20.97 bc	20.26 dc	20.08 d	21.93 a	21.57 ab	20.96 B
2015-2016**	ZT	23.59 abc	24.26 ab	24.35 ab	24.78 a	24.33 ab	24.26 a**
	RT	22.38 cde	21.45 de	19.14 f	23.83 abc	24.43 ab	22.25 b
	CT	23.23 abc	21.34 e	23.02 bcd	23.46 abc	22.21 cde	22.65 b
	Mean**	23.06 bc	22.35 dc	22.17 d	24.02 a	23.66 ab	23.05 A
Mean**	ZT	22.54 bcd	23.21 abc	23.30 abc	23.73 a	23.29 abc	23.21 a**
	RT	21.33 efg	20.41 g	18.10 h	22.78 a-d	23.38 ab	21.20 b
	CT	22.18 c-f	20.29 g	21.97 def	22.42 b-e	21.17 fg	21.61 b
	Mean**	22.02 b	21.30 c	21.13 c	22.98 a	22.61 a	22.01

**p<0.01. There is no difference between the means, showing by the same letter in the same row and column (p<0.05). ZT: Zero-tillage, RT: Reduced tillage, CT: Conventional tillage.

Economic analysis for forage and seed production.

HV production in different tillage systems and seed ratios were compared economically using the prices given in Table 2, separately for forage and seed harvest. The net gain from each treatment was as seen in Figure 3. Concerning the forage production, the highest net gain per

hectare in HV (809.59 \$ ha⁻¹) was obtained from RT with the seed rate of 80 kg ha⁻¹. This was followed by the ZT with seed rates of 140 kg ha⁻¹ (781.54 \$/ha). CT was more economic up to 120 kg ha⁻¹ with the exception of RT in 80 kg ha⁻¹. However conservation tillage systems (ZT and RT) were more economic at 140 and 160 kg ha⁻¹.

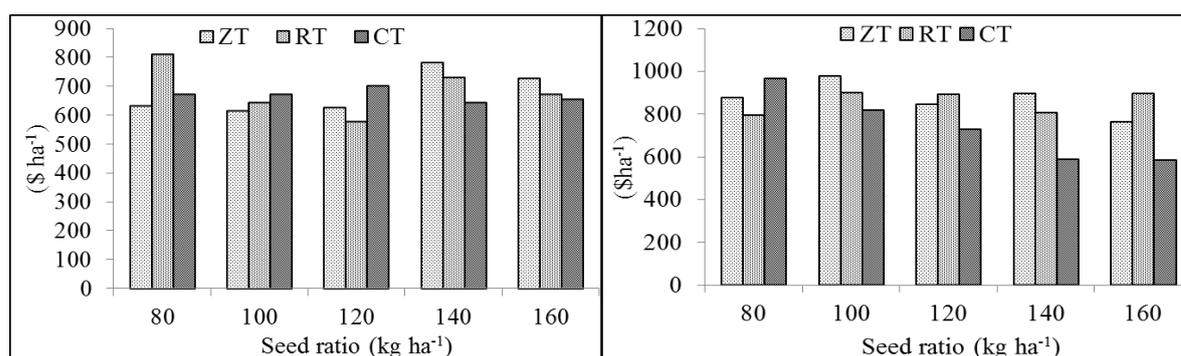


Figure 3. The net economic gain in Hungarian vetch as forage (left) and seed (right) production under different tillage systems and seed ratios.

In seed production, ZT at 100 kg ha⁻¹ seed rate was the most economical treatment with 978.49 \$ gain per hectare. Except 80 kg ha⁻¹, conservation tillage systems were more economic compare to CT in seed production. CT was more economic at 80 kg ha⁻¹ seed rate but, increasing seed rate caused a decrease in net gain in this system. This trend made conservation systems more advantageous, especially at high seed rates such as 140 and 160 kg ha⁻¹. Because, the increase in seed rate did not have a negative effect on the net gain of ZT and RT as was in CT. Accordingly, when appropriate seed ratios were selected, HV production under conservation tillage systems given higher net gain than that grown under conventional tillage. Moreover, this situation occurred in both seed and forage production.

DISCUSSION

When it comes to the concept of conservation tillage, most people usually thinks plants such as corn, soybean,

cotton, sunflower and wheat (FAO, 2012; Altikat et al., 2018; Ileri et al., 2018), and forage crops are mostly overlooked. Technically all crops even root and tuberous can be grown sufficiently in this system (Derpsch and Friedrich, 2009). Jones (2000) expressed risk about vetch establishment with conservation tillage in dry areas. However, our results indicated that both ZT and RT are well-suited to be used in HV establishment.

In the present study, tillage systems and seed ratios were not significant on both hay and seed yield of HV in separate and combined years. Year was significant but only on the hay yield, with the higher value in the first year (2014-2015). However, although not significant, hay yield was more at the high seed ratios (140-160 kg ha⁻¹) (Table 3) while seed yield was relatively more at the low seed ratios (80-100 kg ha⁻¹) (Table 5). According to the combined years tillage systems in order to CT>RT>ZT for hay yield and RT>ZT>CT for seed yield. Seed ratio, is

significant component of crop production, varies between at 80-160 kg ha⁻¹ in a pure stand *HV* in Turkey conditions (Albayrak et al., 2011; Tenikecier et al., 2017; Copur Dogrusoz et al., 2019). Increasing seed rate in *HV* up to 160 kg ha⁻¹ produced higher biomass and seed yield (Uzun et al., 2004). Previously, different seed yields were reported for *HV* as 1403 kg ha⁻¹ (Uzun et al., 2004) and 1141.0 kg ha⁻¹ (Iptas, 2002).

The superiority of ZT or RT over CT has been demonstrated in many plants and in many ways. On the basis of a long-term study (from 1991 through 2015), Schlegel et al. (2018) reported significant yield and water productivity benefit in the order ZT > RT > CT for sorghum and wheat, but especially in sorghum. The report by (FAO, 2012) stated that during Kazakhstan's 2012 drought and high temperatures, wheat grown under no-till practices were more resilient and yielding compare to conventionally cultivated crops. Similarly, in Zarghan-Iran, higher yield and water productivity was detected in wheat and maize grown under RT than was in CT (Khorami et al., 2018). On the contrary, in a three-year study in the Midwestern United States, greater yield was reported in maize (18%) and soybean (10%) grown with CT than ZT, but the authors recommended ZT as it reduce field operations and labor (Mourtzinis et al., 2017).

In terms of protein content, tillage systems, seed ratios and years were significant in both hay and seed production of *HV*, with exceptions. According to combined years, protein content of hay was similar at all the seed ratios, but it superior in ZT and CT (Table 4). Seed ratio was significant for protein content in seed, and ZT was superior to RT and CT for seed crude protein content (Table 6).

Comparing the profitability of the tillage systems, quite promising results were obtained. Yield performances and low costs made ZT and RT economically more advantageous than CT both in hay and seed production, which is very hopeful in terms of agricultural sustainability. But this situation was depended on seed ratio (Figure 3). The ultimate aim of forage crop production is to produce high quantity and quality hay or seed at the lowest cost. In this respect, it will not be the right method to evaluate the economic data independently from the yield. On the other hand, the importance of protection systems in terms of sustainable production has also to be taken into consideration. Considering the yield and economy, ZT has seen as a more suitable system in *HV* cultivation with the seed ratio of 100 kg ha⁻¹ for seed and 140 kg ha⁻¹ for forage purposes. In addition, year was been determinative on the success of tillage systems; the rainy-warm year (2014- 2015) was suitable for hay yield and quality (protein content) while dry-hot year (2015-2016) for seed yield and quality.

With a range of commonly known potential environmental and economic benefits, a well-developed and properly integrated conservation tillage practice can contribute toward the sustainability of an agricultural production and environment (Kassam et al., 2009).

Among the conservation tillage systems, especially ZT and RT have been documented in the literature as practices that improve physical, chemical and biological properties of soil, crop yield (Busari et al., 2015) as well as reduce the greenhouse gases effect (Krauss et al., 2017). The superiority of minimum tillage has been related with favorable condition in soil such as lower nutrient leaching especially nitrates (Khan et al., 2017), more stable structure (Chang and Windwall, 1989), high water store capacity (He et al., 2009), greater organic matter content and biological quality (Martinez et al., 2013). An additional economic benefit of ZT is saving fossil fuel costs due to reduced equipment use (Islam and Reeder, 2014). Also there is data previously recorded that expressing both negative and positive effects of RT on crop yields (Arvidsson et al., 2014). These conflicts are may be due to differences in crop type, rotation and tillage depth (Alskaf et al., 2020).

CONCLUSION

As a result, this two-year study has clearly demonstrated that *HV* cultivated with conservation tillage systems can produce favorable or better results than conventional tillage in terms of yield, quality and economy. The role of the seed ratio was also found important. That is, the superiority of conservation tillage systems is closely related to seed ratios and may be possible at the certain seed ratios. Additionally, seed ratio exhibited different results depending on forage or seed harvest therefore, different seed ratios should be determined for each purpose to achieve the desired results.

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