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ORIGINAL ARTICLE / ORIGINALBEITRAG

Comparison of Alternative Sowing Methods in Hungarian Vetch and Triticale Cultivation in Terms of Yield and Weed Biomass

Hakan Kir[1] · Melih Yilar[2] · Tamer Yavuz[1]

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Abstract
This study aimed to compare alternative sowing methods i.e., sole, mix and intercrops sown in alternative and perpendicular rows on the productivity of Hungarian vetch-triticale farming. Similarly, the effects of these sowing methods were also inferred on weed infestation. This study was conducted during the vegetation periods of 2018–19 and 2019–20 in terrestrial climate conditions. Sowing in perpendicular rows proved more effective in suppressing weed infestation than alternative rows and increased yield by reducing weed biomass. Sowing Hungarian vetch in mixed and perpendicular rows observed the highest weed infestation and biomass along with low green herbage and dry matter yield. However, Hungarian vetch-triticale mixture (50–50%) sowed in perpendicular rows made the best use of available land, resulted in the lowest weed infestation and biomass and recorded the highest green herbage and dry matter yield. In conclusion, the sowing Hungarian vetch-triticale mixture (50–50%) in perpendicular rows was the most suitable sowing method for improving productivity and suppressing weed infestation in Hungarian vetch-triticale intercropping.

Keywords Intercropping · Row orientation · Mixture density · Herbage yield · Weed biomass

Die Wirkung verschiedener Aussaat Methoden auf Ertrag und Unkrautdichte in Ungarischer Wicken-Triticale-Mischung

Zusammenfassung
Ziel dieser Studie war es, alternative Aussaatmethoden, d.h. Einzel-, Misch- und Zwischenfruchtanbau in parallelen und Kreuzreihen, mit der Produktivität des ungarischen Wicken-Triticale-Anbaus zu vergleichen. Ebenso wurden die Auswirkungen dieser Aussaatmethoden auf den Unkrautbefall untersucht. Diese Studie wurde während der Vegetationsperioden 2018–19 und 2019–20 unter terrestrischen Klimabedingungen durchgeführt. Die Aussaat in Kreuzreihen erwies sich als wirksamer bei der Unterdrückung des Unkrautbefalls als parallele Reihen und erhöhte den Ertrag durch die Reduzierung der Unkrautbiomasse. Bei der Aussaat von Ungarischer Wicke in gemischten und Kreuzreihen wurden der höchste Unkrautbefall und die höchste Biomasse zusammen mit einem niedrigen Grünfutter- und Trockenmasseertrag beobachtet. Die Aussaat einer Mischung aus Ungarischer Wicke und Triticale (50–50 %) in Kreuzreihen nutzte jedoch die verfügbare Fläche am besten, führte zu dem geringsten Unkrautbefall und der geringsten Biomasse und verzeichnete den höchsten Grünfutter- und Trockenmasseertrag. Zusammenfassend lässt sich sagen, dass die Aussaat einer Mischung aus Ungarischer Wicke und Triticale (50–50 %) in Kreuzreihen die geeignetste Methode zur Verbesserung der Produktivität und zur Unterdrückung des Unkrautbefalls im ungarischen Wicken-Triticale-Zwischenfruchtanbau war.

Schlüsselwörter Zwischenfruchtanbau · Reihenausrichtung · Mischungsdichte · Grünfutterertrag · Unkrautbiomasse

✉ Hakan Kir
hakankir@ahievran.edu.tr

Melih Yilar
melih.yilar@ahievran.edu.tr

Tamer Yavuz
tamer.yavuz@ahievran.edu.tr

[1] Department of Field Crops, Faculty of Agriculture, Kirsehir Ahi Evran University, 40100 Kirsehir, Turkey

[2] Department of Plant Protection, Faculty of Agriculture, Kirsehir Ahi Evran University, 40100 Kirsehir, Turkey

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Introduction

Global food demand is witnessing a linear increase with rapidly growing population. Since it is no longer possible to expand the areas devoted to crop production, increasing food demand could be fulfilled by increasing yield per unit area. Farmers are looking for growing more than one species in the same area at the same time in order maximize the production from existing agricultural areas. Diversification of plant species minimizes environmental risks by using natural resources more effectively with improved increasing soil fertility, weed control, fertilizer use and reduced insect infestation. Growing of different plant species of their varieties is regarded as mixed sowing system, which increases yield per unit area due to more effective use of resources such as soil, water, light and plant nutrients (Baumann et al. 2002). Cereal-legume mixed sowing system is prefered to increase yield and quality in forage crops cultivation. Cereal and legume crops in cereal-legume sowing system complement each other since cereals have rapid development in the early period, rich in carbohydrates and produce high yields, while legumes provide nitrogen to soil and are rich in protein contents. Triticale (*Triticosecale* Wittmack) and Hungarian vetch (*Vicia pannonica* Crantz) are drought-and cold-resistant annual forage crops successfully grown in the regions receiving precipitation in late spring and early summer (Aksoy and Nursoy 2010). The upright growth habit of triticale in Hungarian vetch-triticale mixed sowing system prevents lodging of Hungarian vetch; thus, protects it from laying down, rot infestation and leaf loss. Legumes cover soil surface, create shade annealing and reduce weed populations due to their natural mulch properties. Furthermore, growth and development of different species and varieties in mixed sowing system suppress the development of weed population (Ascı and Acar 2019). Kir et al. (2018) tested the effects of Hungarian vetch-triticale and Hungarian vetch-barley mixtures on yield and quality characteristics of mixed cropping systems under the ecological conditions of Kırşehir province, Turkey. Their results revealed that Hungarian vetch-triticale mixture (50–50%) must be harvested during the flowering period of triticale for the higher yield and quality. Alaturk (2020) studied the below- and aboveground attributes of Hungarian vetch and cereals (barley, wheat, oats and triticale) grown in different mixtures and ratios. The highest biomass production was recorded for the system having the lowest ratio of Hungarian vetch, i.e., 1 Hungarian vetch +3 triticale plots. Furthermore, 2 Hungarian vetch +2 oat plot system proved the most effective in terms of land use activities. Sowing forage crops in mixtures reduced weed density compared to their sole sowing. Nonetheless, Coffigniez et al. (2021) reported that radish crop was more effective in controlling *Chenopodium album* than barley crop; however, mixture of these crops recorded higher biomass and equivalent weed control compared sole sowing of radish. It was reported that mixed cropping significantly alters qualitative characteristics and weed management in forage crops (Rad et al. 2020).

It is necessary to reveal the sowing systems capable of increasing roughage production in dry agricultural areas where production relies on precipitation. Therefore, this study was conducted to compare the effects of different sowing methods on productivity and weed infestation in Hungarian vetch-triticale intercropping system.

Materials and Methods

This study was conducted at Kırşehir Ahi Evran University (1090 m asl, 39° 08′ N and 34° 06′ E), Kırşehir during vegetation periods of 2018–19 and 2019–20 under terrestrial climate conditions. Kırşehir received 304.8 and 279.1 mm total rainfall during 2018–19 and 2019–20, respectively. The amount of total rainfall received during the study years was lower than the long-term average rainfall (319.6 mm) received in the region. The amount of rainfall received in

Table 1 The climate condition of Kırşehir province for the study years and long-term average[a]

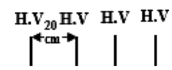
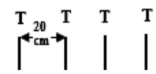
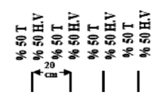
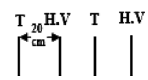
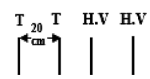
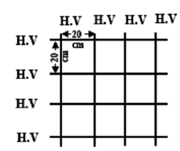
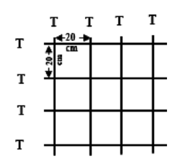
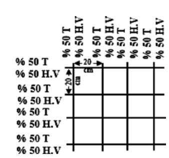
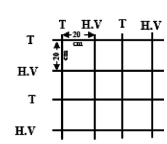
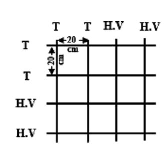
Months	Rainfall (mm)			Relative humidity (%)			Temperature (°C)		
	2018–19	2019–20	LTA	2018–19	2019–20	LTA	2018–19	2019–20	LTA
October	41.4	1.1	30.4	62.3	52.8	62.7	14.4	16.0	13.1
November	21.0	30.4	41.6	66.8	60.6	72.4	8.2	8.5	6.3
December	101.1	61.9	47.1	81.4	80.8	79.0	3.3	3.9	2.0
January	42.2	42.0	44.3	79.3	71.2	79.0	0.8	1.2	–0.1
February	42.8	60.9	31.6	71.4	73.1	74.1	4.2	2.5	1.3
March	10.2	15.4	36.7	56.4	61.6	67.2	6.3	8.0	5.6
April	29.0	25.3	42.4	64.0	55.2	63.3	9.7	10.8	10.9
May	17.1	42.1	45.6	52.7	56.6	61.3	17.5	15.9	15.4
Average/Total	304.8	279.1	319.6	66.8	64.0	69.9	8.1	8.4	6.8

LTA Long-term average
[a] Turkish State Meteorological Service

December and February during both years was higher than long-term average of December and February. The rainfall during the months of November, January, February, March, April and May was lower than the long-term rainfall of the respective months. The relative humidity was 66.8 and 64.0% during 1st and 2nd year, respectively, which was also lower than the long-term average relative humidity of 69.9%. The average temperature of the vegetation period of the study was 8.1 and 8.4 °C during 1st and 2nd year, respectively, which was higher than the long-term average (Table 1). Rainfall, relative humidity and temperature data for 2018, 2019, 2020 and long-term years average were obtained Turkish National Meteorology Data Service.

The soil samples collected from the study area were analyzed at Center for Research and Application Laboratory of Kırşehir Ahi Evran University. According to the results of soil analysis, the experimental soil was clay-loam in texture, non-saline, slightly alkaline (pH 7.99), rich in calcium car-

Table 2 Experimental design: Definitions of sowing methods (SM) by illustrating Hungarian vetch (HV) and triticale (T) cultivation on rows

Sowing methods	Description of methods	Illustration on rows
SM1	Sole sowing of Hungarian in alternate rows	
SM2	Sole sowing of tritikale in alternate rows	
SM3	Hungarian vetch-triticale mixture (50–50%) sown in alternate rows	
SM4	Alternate intercropped rows of Hungarian vetch and triticale (1 row of each crop)	
SM5	Alternate intercropped rows of Hungarian vetch and triticale (2 rows of each crop)	
SM6	Sole sowing of Hungarian vetch in perpendicular rows	
SM7	Sole sowing of triticale in perpendicular rows	
SM8	Hungarian vetch-triticale mixture (50–50%) sown in perpendicular rows	
SM9	Perpendicular intercropped rows of Hungarian vetch and triticale (1 row of each crop)	
SM10	Perpendicular intercropped rows of Hungarian vetch and triticale (2 rows of each crop)	

bonate (%22.93) and low in organic matter content (%1.00). The available phosphorus in the soil was (4.35 kg da^{-1}). The soil had slightly alkaline reaction and rich in available potassium (141.3 kg da^{-1}) (Karaman 2012).

Hungarian vetch (*Vicia pannonnica* Crantz) cultivar ‘Tarm Beyazı-98’ and triticale (×*Triticosecale* Wittmack) cultivar ‘Tatlıcak-97’ were used in the study. The seeding density of triticale and Hungarian vetch was kept as 500 and 220 seeds per square meter. The total number of seeds to be sown in different cropping systems were calculated based on these seeding densities (Onal and Egritas 2017). The experiments were carried out according to randomized blocks design with three replications. A total 10 different sole and mix cropping systems were used based on different row orientations and Hungarian vetch-triticale mixtures, as illustrated in Table 2.

When soil has adequate moisture, the seed bed was prepared in two procedures firstly, plowed by plow, secondly cultivated by cultivator. The seeds of sole and mixed crops were manually sown in plots and keeping 20 cm row spacing and each treatment unit had 5 m long 10 rows. A manual sowing tool, as hand marker, was used to determine the rows. Before sowing, diammonium phosphate fertilizer was applied to the plots keeping fertilizer rate of 4 kg da^{-1} nitrogen and 10 kg da^{-1} phosphorus. In addition, urea fertilizer was top dressed (7 kg da^{-1} nitrogen) during tillering period. The net plot size of a treatment unit was 10 m^2. Seeds of both species were sown manually in the rows opened with the marker. In the first year, the crops were sown and harvested on November 11, 2018 and May 25, 2019, respectively. Similarly, in the second year, sowing and harvesting was done on October 10, 2019 and June 6, 2020, respectively. Since cereals mature early, the harvest time was decided based on cereals’ maturation. Hungarian vetch observed full bloom, while triticale was in the early bloom stage at the same time (Kir et al. 2018). The experiments in two following years were ended for harvesting in the first week of June. The plant height was measured from the surface of soil to the top point of each plant in sole, mix and intercrops sown in alternative and perpendicular rows. Two rows from both edges of the plots and 50 cm from both heads of the plot units were excluded from the harvest to avoid the edge effect. Thus, remaining 8 m^2 area was harvested to record data (Gocmen and Parlak 2017).

The plants were harvested by using a scythe. The harvested plants were weighed to record the green herbage yield, which was then converted to yield per 1000 square meter by unitary method. A sub sample of 500 g was taken from the freshly harvested samples, dried at 60 °C until constant weight, weighed and dry matter yield was computed and converted to per 1000 square meter by unitary method (Sleugh et al. 2000). Land equivalent ratio (LER) was recorded by following (Dhima et al. 2007).

$$LER = LER_{cereal} + LER_{vetch}$$

$$LER_{cereal} = \text{cereal yield in mixed crop/ yield of cereal in sole sowing}$$

$$LER_{vetch} = \text{vetch yield in mixed sowing/ vetch yield in sole sowing}$$

Weed species prevailing within and outside experimental area were recorded. The weed species were identified according to Flora of Turkey (Davis 1965). Weed biomass was taken at the time of harvest. All weed species falling in a 1 square meter quadrate were cut from the ground level, brought to the laboratory and weighed. These were then dried in an oven at 60 °C until constant weight and weight to record dry biomass of the weeds (Kaydan et al. 2011). Data were subjected to GLM procedure of SPSS (Windows version SPSS release 15.00). The means was compared by using LSD multiple comparison test within same software according to the significance level of $p \leq 0.05$.

Results

Sowing methods affected statistically significantly the plant height of Hungarian vetch ($p < 0.01$), while triticale’s plant height was not affected statistically by sowing methods. Plant height of Hungarian vetch were 46.4–54.8 cm, while those of triticale were 98.1–102.6 cm. The shortest plants height of Hungarian vetch was noted for SM_6 and SM_1, while the highest plant height of Hungarian vetch was recorded for SM_8 (Table 3).

The applied sowing methods significantly altered ($p < 0.01$) green herbage and dry matter yield. The highest green herbage yield (2263.1 kg da^{-1}) was recorded for SM_8, while SM_1 resulted in the lowest (1058.7 kg da^{-1}) green herbage yield. The highest dry matter yield was noted for SM_7 (646.3 kg da^{-1}) and SM_8 (638.6 kg da^{-1}), while SM_1 recorded the lowest dry matter yield (299.3 kg da^{-1}) (Table 3). Sowing methods SM_5, SM_7, SM_8, SM_9 and SM_{10} resulted in higher green herbage and dry matter yield during the study (Table 3).

The applied sowing methods were highly significant ($p < 0.01$) statistically for weed biomass. The highest weed biomass (145.9 kg da^{-1}) was recorded for SM_1, while SM_8 resulted in the lowest (6.8 kg da^{-1}) weed biomass. Sole sowing of Hungarian vetch in SM_1 resulted in the lowest green herbage and dry matter yield and observed the highest weed biomass (Table 3).

Table 3 Comparison of sowing methods with respect to plant height, green forage and dry matter yield, weed biomass and land equivalent ratio

Treatments	Plant height Hungarian vetch (cm)	Plant height triticale (cm)	Green herbage yield (kg da^{-1})	Dry matter yield (kg da^{-1})	Weed biomass (kg da^{-1})	Land equivalent ratio (%)
SM$_1$	$47.8^{bc} \pm 1.11^{**}$	–	$1058.7^{d} \pm 129.7^{**}$	$299.3^{e} \pm 34.4^{**}$	$145.9^{a} \pm 0.46^{**}$	–
SM$_2$	–	98.1 ± 3.51	$1478.0^{c} \pm 44.40$	$488.6^{d} \pm 18.2$	$10.4^{f} \pm 0.32$	–
SM$_3$	$53.5^{a} \pm 1.70$	101.2 ± 2.16	$1894.0^{b} \pm 85.6$	$538.3^{cd} \pm 22.8$	$11.3^{de} \pm 0.33$	$1.43^{b} \pm 0.05^{**}$
SM$_4$	$53.4^{a} \pm 1.16$	98.9 ± 1.62	$1937.7^{b} \pm 64.8$	$565.9^{bc} \pm 19.6$	$15.3^{c} \pm 0.59$	$1.42^{b} \pm 0.04$
SM$_5$	$52.4^{a} \pm 1.05$	99.9 ± 0.54	$2025.4^{ab} \pm 76.0$	$621.5^{ab} \pm 25.0$	$9.7^{f} \pm 0.23$	$1.47^{b} \pm 0.05$
SM$_6$	$46.4^{c} \pm 0.90$	–	$1333.0^{c} \pm 55.4$	$356.5^{e} \pm 2.5$	$31.3^{b} \pm 0.33$	–
SM$_7$	–	102.6 ± 2.30	$2056.8^{ab} \pm 13.5$	$646.3^{a} \pm 16.2$	$10.3^{ef} \pm 0.60$	–
SM$_8$	$54.8^{a} \pm 3.18$	102.1 ± 2.78	$2263.1^{a} \pm 40.8$	$638.6^{a} \pm 13.9$	$6.8^{h} \pm 0.36$	$1.66^{a} \pm 0.02$
SM$_9$	$51.5^{ab} \pm 1.76$	100.3 ± 2.70	$2154.1^{ab} \pm 77.9$	$623.5^{ab} \pm 11.2$	$12.2^{d} \pm 0.59$	$1.58^{ab} \pm 0.06$
SM$_{10}$	$51.7^{ab} \pm 1.00$	101.6 ± 1.19	$2135.5^{ab} \pm 139.0$	$621.7^{ab} \pm 36.0$	$8.1^{g} \pm 0.56$	$1.56^{ab} \pm 0.09$
Means	51.4 ± 0.70	100.6 ± 0.74	1833.6 ± 74.0	540.0 ± 22.4	0.26 ± 0.18	1.52 ± 0.03

SM Sowing Methods
**: Differences between the averages followed by the same letter are not significant at $p < 0.01$ level

Weed competition negatively affected plant height. The plant heights of Hungarian vetch and triticale planted sole were lower than their heights in mixed crops. However, sole sowed triticale was more effective in competing with weeds compared to sole sowed Hungarian vetch. Sole sowed Hungarian vetch observed the lowest plant height and the highest weed biomass, and it was statistically separated from other sowing methods.

Different sole and intercrop sowing methods used in the study significantly ($p < 0.01$) affected land equivalent ratio (LER). The highest LER was noted for SM$_8$, while remaining sowing methods had similar LER (Table 3).

The weed species prevailing within, and outside experimental area were noted and identified. A total 19 weed species (18 broadleaved) and (1 narrow leaved) belonging to 9 families were recorded from the study area. Some weed

Table 4 Common and Latin names, and families of the weed species recorded outside of sowed area

English Name	Bayer code	Latin name	Family
Common bugloss	*ANCOF*	*Anchusa officinalis* L	Boraginaceae
Hoary cress	*CADDR*	*Cardaria draba* (L.) Desv	Brassicaceae
Prickly lettuce	*LACSE*	*Lactuca serriola* L	Asteraceae
Wild bishop	*BIFRA*	*Bifora radians* M.Bieb	Apiaceae
Field Gromwell	*LITAR*	*Buglossoides arvensis* (L.) IMJohnst	Boraginaceae
Bristyl foxtail	*SETVE*	*Seteria verticillata* (L.) P.B.	Poaceae
Milk thistle	*SLYMA*	*Silybum marianum* L	Asteraceae
Golden daisy bush	*EYOPE*	*Euryops pectinatus* (L.) Cass	Asteraceae
Field fumitory	*FUMAG*	*Fumaria agraria* Lag	Papaveraceae
Common fumitory	*FUMOF*	*Fumaria officinalis* L	Papaveraceae
Wild mustard	*SINAR*	*Sinapis arvensis* L	Brassicaceae
Annual meadowgrass	*POAAN*	*Poa annua* L	Poaceae
Mouse barley	*HORMU*	*Hordeum murinum* L	Poaceae
Canada thistle	*CIRAR*	*Cirsium arvense* (L.) Scop	Asteraceae
Yellow weed	*BOAOR*	*Boreava orientalis* Jaub and Spach	Brassicaceae
Field Spurge	*EPHPE*	*Euphorbia peplus* L	Euphorbiaceae
Cheatgrass	*BROTE*	*Bromus tectorum* L	Poaceae
Redstem filaree	*EROCI*	*Erodium cicutarium* (L.) L'Herit	Geraniaceae
Quackgrass	*AGRRE*	*Agropyron repens* (L.) P. Beauv	Poaceae
Spreading amaranth	*AMABL*	*Amaranthus blitoides* L	Amaranthaceae
Common lamb's quarters	*CHEAL*	*Chenopodium album* L	Chenopodiaceae

Table 5 Common and Latin names, and families of the weed species recorded in the sowed area

English Name	Bayer code	Latin name	Family
Corn cockle, conrnrose	*AGOGI*	*Agrostemma githago* L	Caryophyllaceae
Knotgrass	*POLAV*	*Polygonum aviculare* L	Polygonaceae
Annual sowthistle	*SONOL*	*Sonchus oleraceus* L	Asteraceae
Henbit deadnettle	*LAMAM*	*Lamium amplexicaule* L	Lamiaceae
Field Fumitory	*FUMAG*	*Fumaria agraria* Lag	Papaveraceae
Common fumitory	*FUMOF*	*Fumaria officinalis* L	Papaveraceae
Wild mustard	*SINAR*	*Sinapis arvensis* L	Brassicaceae
Canada thistle	*CIRAR*	*Cirsium arvense* (L.) Scop	Asteraceae
Summer pheasant's eye	*ADOAE*	*Adonis aestivalis* L	Ranunculaceae
Muskweed	*MYGPE*	*Myagrum perfoliatum* L	Brassicaceae
Field bindweed	*CONAR*	*Convolvulus arvensis* L	Convolvulaceae
Dondelion	*TAROF*	*Taraxacum officinale* F.H. Wigg	Asteraceae
Barnyard grass	*ECHCG*	*Echinochola crus-galli* (L.) P.B.	Poaceae
Yellow mignonette	*RESLU*	*Reseda lutea* L	Resedaceae
Common lamb's quarters	*CHEAL*	*Chenopodium album* L	Chenopodiaceae
Redroot amaranth	*AMARE*	*Amaranthus retroflexus* L	Amaranthaceae
Hedge mustard	*SSYOF*	*Sisymbrium officinale* (L.) Scop	Brassicaceae
Common saltwort	*SASKA*	*Salsola koli* L	Chenopodiaceae
Puncture vine	*TRBTB*	*Tribulus terrestris*	Zygophyllaceae

species observed outside the application plots were not detected in the application plots (Tables 4 and 5).

In particular, triticale plantings and cross planting methods have reduced weed coverage rates. Again, cross-planting with triticale mixture was effective on weed density in the application plots. Triticale mixture and cross-planting significantly reduced weed density.

Discussion and Conclusion

The shortest plant of Hungarian vetch was noted from SM_1 and SM_6 where it was sowed as sole crop in alternate and perpendicular rows, while remaining sowing methods observed higher plant height. Higher plant heights were noted for Hungarian vetch planted with triticale in alternating and perpendicular rows compared to sole sowing. The highest plant (54.8 cm) was observed in Hungarian vetch-triticale mixture (50–50%) sowed in perpendicular rows (SM_8), while sole sowed Hungarian vetch in perpendicular rows (SM_6) resulted in the lowest plant height (46.4 cm) (Table 3). Efficient utilization of natural resources in these sowing methods due to intra-species and inter-species competition might have resulted in the highest plat height. Nonetheless, Tuna and Orak (2007) reported that interspecies competition significantly altered plant height. İleri et al. (2020) reported that the competition for light to a certain frequency may cause an increase in plant height. Furthermore, vetch plants have creeping stems and the possibility of sufficient growth with the help of a support plant when grown in mixture could effectively increase plant height of Hungarian vetch. Yolcu et al. (2009) investigated the impacts of sole sowing and Hungarian vetch mixtures with different cereals on plant height. The researchers in research, the plant height of Hungarian vetch ranged between 34.0–36.6 cm during 1st year and 37.9–50.0 cm during 2nd year.

The minimum green herbage yield (1058.7 kg da^{-1}) was noted for sole sowed Hungarian vetch in alternate rows (SM_1), whereas 50% + 50% mixture of Hungarian vetch-triticale sowed in perpendicular rows (SM_8) recorded the highest (2263.1 kg da^{-1}) green herbage yield. Regarding perpendicular row orientation, sole cropped Hungarian vetch recorded lower green herbage yield, while remaining combinations recorded almost similar green herbage yield. All combinations of perpendicular row orientation except sole cropped Hungarian vetch along with T_5 recorded higher green herbage yield (Table 3). Singh and Uttam (1995) reported that higher green biomass was noted for grasses sown in perpendicular rows due to more nutrient intake. Crop yield in continental regions is generally dependent on seasonal distribution of rainfall, seed use per unit area, seed distribution in field. Therefore, providing an equal development area in appropriate way is extremely important for achieving higher crop yields in these regions (Kaydan and Geçit 2005).

Like green herbage yield, sole sowing of Hungarian vetch in alternate and perpendicular rows (SM_1 and SM_6) resulted in the lower dry matter yields (299.3 and 356.5 kg da^{-1}). 50% + 50% Hungarian vetch-triticale mixture sown in perpendicular rows (SM_8) and sole triticale sown in perpendicular rows (SM_7) gave higher dry matter yields (638.6 kg da^{-1}, 646.3 kg da^{-1}) (Table 3). Cakmakci et al. (2005) reported that higher dry matter yield was recorded from the crops sown in perpendicular row orientation. Dry matter yields of different Hungarian vetch and triticale mixtures, including Hungarian vetch-triticale mixture (50–50%) were 309.0 kg da^{-1}, 346.0 kg da^{-1}, 532.0 kg da^{-1} (Yıldırım and Özaslan-Parlak 2016) and 570 kg da^{-1}, 720 kg da^{-1}, 480 kg da^{-1} (Genc-Lermi 2018). Yıldırım and Özaslan-Parlak (2016) reported that higher dry matter yield in sole sowed triticale is due to the higher dry mater content of triticale. Nevertheless, Tas (2011) reported that cereals have rapid development, which enables them to produce higher dry biomass. Therefore, higher dry matter yield obtained in sole sowed triticale could be linked with the higher dry matter content of cereals.

Legumes and cereals sown in crop mixtures use different soil layers for resources uptake due as legumes have taproot and cereals possess fringe root structures. Appropriate cereal-legume mixture, on the other hand, have less competition and more root growth. Thus, the competitiveness of cereal-legume mixtures with well-developed subsoil components increase over other species (Alaturk 2020). High yield and competitiveness of cereals, nitrogen fixing ability of legumes with the help of rhizobium bacteria, strong root systems in mixed sowings and better utilization of land resources resulted in higher green herbage and dry matter yield (Alaturk 2020).

The LER of different sowing methods used in the study ranged between 1.42–1.66 (Table 3). Treatment T_8 recorded highest LER compared to other sowing methods used in the study. The lower LER was noted for alternative rows in SM_4 (Table 3). Generally, perpendicular row orientation was more efficient (LER > 0) as a result of effective land use compared to alternative sowings row orientation. The LER should be greater than one to state that mixed cropping is superior to sole sowing (Seydosoğlu et al. 2020). The LER values of Hungarian vetch intercropped with cereals have been reported 0.99–1.80 by Alaturk (2020) and 0.91–1.38 by Yılmaz et al. (2015). Dahmardeh (2013) reported higher LER values for mixed cropping compared to sole cropping. Mixed cropping systems result in higher yield than sole cropping due to effective land use (Dahmardeh 2013). In addition to effective land use, straight and cross sowings would be more advantageous than sole sowing by making optimum use of light, as the nitrogen and triticale provided by Hungarian vetch are support plants.

The lowest weed biomass was recorded for Hungarian vetch-triticale (50–50%) sowed in perpendicular rows (SM_8) due to the decreased area for weed growth, which ultimately lowered weed biomass (Table 2). Furthermore, the sowing methods which recorded higher green herbage and dry matter yield observed lowest weed infestation compared to rest of the current sowing methods in the study.

The highest weed infestation was noted for sole sowed Hungarian vetch in alternate rows (SM_1), which resulted in the lowest green herbage and dry matter yield. Mixed crops sowed in perpendicular rows lowered area available for each plant, which reduced weed biomass. Mixed cropping has higher ability to compete weeds compared to sole sowed crops. Intermediate sowing systems have some advantages over lean sowing. Intermediate planting systems can provide better pest, disease and weed control (Alaturk et al. 2018). Forage crops sowed in a mixture and in perpendicular rows reduce development area of weeds and improve weed control (Ascı and Acar 2019). Several research have reported that increasing sowing density reduced competitive ability of weeds, which reduced weed density. Kirkland (1993) reported a linear decrease in weed density with increasing sowing density. Sowing in narrow rows decreased weed biomass and increased grain yield. Olsen et al. (2006) reported that increased sowing density and uniform seed distribution in wheat caused a decrease in weed biomass and yield loss. Mixed cropping systems reduce weed density and biomass. Mixed sowing systems are advantageous in terms of weed control compared to sole sowing systems. Compared to sole sowing, mixed sowing systems allow cultivated plants to use natural resources more than weeds or suppress weeds through allelopathy (Liebman and Dyck 1993). Plants in sole sowing systems are unable to use available natural resources effectively. Therefore, weeds use the available natural resources more effectively than plants in sole sowing. Mixed sowing system is a more effective and better method due to advantages in weed control, since it uses ecological resources more effectively than sole sowing and does not leave empty space (Yıldırım and Ekinci 2017). Sowing density of 900 plants m^2 in perpendicular rows reduce weed habitat, resulting in decreased weed biomass (Kaydan et al. 2011).

In conclusion, it is extremely important to choose sowing systems, which enhance crop yield by using the available resources effectively in terrestrial climate conditions where precipitation is limited. Perpendicular sowing minimized the area for weeds, when compared to alternative rows, whose plants used resources more effectively by successfully competing with weeds, and finally increased their yields. Sowing Hungarian vetch-triticale mixture (50–50%) in perpendicular rows can be recommended for increased forage production in continental climate conditions and similar ecologies.

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Conflict of interest H. Kir, M. Yilar and T. Yavuz declare that they have no competing interests. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Hakan Kir Dr.; I have PHD degree in Field Crop Science, my expertise is forage crop cultivation, especially on mixture and intercropping in legume and grass. I have been working at the Kırşehir Ahi Evran University as an Assistant Professor in the Department of Field Crop.