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Original article

Forage Production of Oat-Berseem Clover Intercropped at Different Tillage Systems and Seeding Proportions

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An experiment was conducted in the field during the winter growing seasons of 2022 – 2023 and 2023 − 2024 in the western region of Iraq to investigate the effect of three tillage systems, including conventional tillage, reduced tillage and no-tillage, on oat (*Avena sativa* L.) berseem clover *(Trifolium alexandrinum* L.*)* intercropping with seed proportions of 100 : 0, 75 : 25, 50 : 50, 25 : 75, 0 : 100%. A factorial experiment using a randomised complete block design in a split-plot arrangement with three replications was employed. The results showed that conventional tillage recorded the highest dry matter yield, crude protein yield, dry matter digestibility yield, and the best land equivalent ratio for dry matter, with no significant difference from reduced tillage at the same time. Deterioration was observed when no-tillage was applied. The seed proportions of 75% oat to 25% berseem clover produced the highest dry matter yield, dry matter digestibility yield and land equivalent ratio. Seed proportions of 25% oat: and 75% berseem clover produced the greatest crude protein yield. Intercropping achieved land equivalent ratio higher than 1 at all tillage systems with all seed proportions according to the T-test. In conclusion, it is possible to reduce tillage instead of traditional tillage, as this does not cause a deterioration in the yield. Intercropping with all seed proportions had an advantage in exploiting land area.

Key words: conventional tillage, reduced tillage, no-tillage, cereal-legume intercropping, dry matter, digestibility, land equivalent ratio

Conservation agriculture is one of the now widely applicable concepts for sustainable agriculture. Important elements of conservation agriculture are intercropping (Bitew & Abera 2018) and little or no disturbing soil (Holland 2004; Derpsch 2007). Reducing tillage has many positive effects, such as a reduction in soil erosion (Morris *et al.* 2010) and an improvement in the water content (Boydaş & Turgut 2007). Reduced tillage and no-tillage (NT) have the benefit of conserving organic matter and preventing soil degradation (Stošić *et al.* 2022). However, not disturbing soil can hinder seed germination, root growth, and reduce crop yield (D'Haene *et al.* 2008). Two main categories of tillage systems are often used: conventional tillage (CT), which is deep inversion tillage and reducing tillage, which is surface non-inversion tillage. Intercropping is more stable than monoculture, so it is popular in the developing world (Horwith 1985), which is to grow two crops or more at the same time on the same land. Intercropping aims to make better use of the available land area, increase yield by mutual benefits among the intercrops, better exploitation of energy sources and construction, as well as improve the quality of the crop yield due to the diversity. Relying on the cultivation of cereal crops to produce animal feed

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will give a rich yield, but it will have low quality, so the presence of legume crops in the forage mixtures will enhance the nutritional value (Papastylianou 2004; Ammar *et al.* 2010). Several previous studies indicated that seed proportions are one of the important factors in cereal-pulse intercropping (Vasilakoglou & Dhima 2008; Kheradmand *et al.* 2013; Yilmaz *et al.* 2015; Yazgı *et al.* 2017). Oat is one of the crops that have recently been introduced to Iraq, and studies are required to be conducted to find out their adaptation to the conditions of the region and under different farming systems. Berseem clover is one of the most important crops that local farmers rely on to produce green fodder during the winter season when fodder is limited. In Iraq, farmers rely on traditional deep tillage and are reluctant to apply reduced surface tillage and do not risk applying no-tillage due to the lack of studies in the region on the feasibility of applying different limited tillage systems in the climate and soil conditions of the region, and the flood irrigation method is usually used in the region. These areas suffer from deteriorating fertility and soil structure due to the reliance on excessive tillage methods. In addition, the intercropping system is rarely applied to produce green fodder (fresh forage), dry matter (DM) yield and crud protein yield are among the most important gains sought by farmers. The land equivalent ratio (LER) is also one of the most important indicators. Cereals-legumes intercropping improves soil fertility, and these systems feature higher equivalent ratios than single crops, whether from cereal-legume rotations or continuous grains (Li *et al.* 2020; Tang *et al.* 2021). The agricultural advantages of intercropping can be assessed using the land equivalent ratio (LER) indicator (Ghosh 2004; Midya *et al.* 2005), to describe the relative land area needed to grow a sole crop (monoculture) to produce equal amounts of yield from intercropping (Mead & Willey 1980). The equivalence index is used to assess the effectiveness of intercropping for the exploitation of inland areas (Mead & Willey 1980; Dhima *et al.* 2007), If the LER value is less than 1, the effect of intercropping is not useful, but if it is greater than 1, the effect is useful (Ofori & Stern 1987; Caballero *et al.* 1995). This study aimed to investigate the possibility of reducing tillage and the benefit of intercropping oat and berseem clover with the appropriate seeding proportions to produce dry matter and crude protein (CP) and the efficiency of utilizing the available land area.

MATERIAL AND METHODS

A field experiment was conducted and repeated in the two winter seasons of 2022−2023 and 2023−2024 in the western region of Iraq (Latitude: 33° 25' 14.02" N Longitude: 43° 18' 28.01" E), on the Euphrates Riverside. The experimental land was previously planted with sesame, and various weeds are spread throughout it. A sample of field soil layer 0−30 cm thick was taken before starting the experiment for chemical and physical analysis in the laboratories of the Agriculture College of the University of Anbar. The results are shown in Table 1.

Electrical conductivity (EC) was measured according to the EC 1 : 5 method, by adding 50 g of soil to 250 ml of dH_2O_2 to form the suspension. The suspension was shaken 4 times, then EC was measured by the EC meter.

The monthly climatic conditions including temperature, relative humidity, precipitation, and wind speed, during the experimental period are presented in Table 2, based on data from the NASA database.

In the current study, two factors were included: tillage systems (Conventional tillage − CT), Reduced tillage − RT), No-Tillage − NT), and forage crops intercropping in different seed proportions of oat (*Avena sativa* L.) and berseem clover (*Trifolium alexandrinum* L.*)* (75% : 25%, 50% : 50% and 25% : 75%) based on the seeding rate of 450 seeds/m^2 for oat, and 1,000 seeds/m^2 for berseem clover (about 170 and 30 kg/ha respectively) in the sole crop, and 338 : 250, 225 : 500 and 113 : 750 seeds/m^2 corresponding 75 : 25, 50 : 50 and 25 : 75 seeding proportions for oat: berseem clover intercrops. A factorial experiment using a randomised complete block design (RCBD) in a split-plot arrangement with three replications was employed in this study. Tillage systems in the whole plots. Crops of oat and berseem clover as sole crops and intercrops, with seeding proportions in the sub-plots. The weeds and remains of the previous crop were removed by a hoe. The conventional tillage that is being practiced mostly in this region was applied in this study by ploughing the soil with a three-furrow plough to a depth of 25 cm, and after a week, a field cultivator was used then harrowing and rolling to 8 cm depth. Reduced tillage was applied by using a chisel plough to 8 cm depth. The no-tillage plots were left without any tillage to sow directly, but the experimental units were surrounded by shoulders made of soil brought from outside the experimental area for irrigation. The whole plots are divided into sub-plots are farming panels with dimensions of 3 m × 3 m. In this study, the Ganzania oat cultivar (*Avena sativa* L.) which was introduced to Iraq was adopted, along with the berseem clover (Cultivar Miskawi) (*Trifolium alexandrinum* L.). Seeding was carried out manually on November 22/ 2022 in year 1, and November 24/ 2023 in year 2. The planting was done with a row spacing of 25 cm, and the panels included 12 rows. All rows have been planted with oat and all berseem clover for the sole crops of oat 100% : 0% and berseem clover 0% : 100%. In intercropping, three oat rows are followed by one berseem clover row, one oat row is followed by one berseem clover row, and one oat row is followed by three berseem clover rows, for the seeding proportions of 75% : 25%,

T a b l e 1

Some physical and chemical analyses of the soil of the experimental land before planting for the two years of 2022 − 2023 and 2023 − 2024

Analysis	Method	Result	
		Year 1 (2022 − 2023)	Year 2 (2023 − 2024)
Clay	Hydrometer method	30.00 g/kg	
Silt		654.00 g/kg	
Sand		316.00 g/kg	
Soil texture		Silt loam	
Bulk density	Use a metal ring for soil sampling, then dry at 105°C for 24 hours, then weigh, and divide the weight by the volume of the soil samples	1.3 g/cm^3	
pH	pH meter	7.20	7.20
Organic matter	Walkley-Black method and humus analysis	5.60 g/kg	5.20 g/kg
Total nitrogen	Spectrophotometry	127.00 mg/kg	107.00 mg/kg
Available phosphorus		7.10 mg/kg	7.60 mg/kg
Available potassium		124.00 mg/kg	117.00 mg/kg
Electrical conductivity (EC)	EC meter	2.65 dS/m	2.40 dS/m

T a b l e 2

Climatic conditions data during the planting seasons of 2022 − 2023 and 2023 − 2024

	Year 1 (2022 − 2023)						Year 2 (2023 − 2024)					
	Nov	Dec	Jan	Feb	Mar	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Temperature [°C]	10.96	10.30	11.02	13.67	13.19	14.10	11.12	11.1	11.55	11.40	13.63	14.63
Relative Humidity [%]	51.24	65.39	69.57	51.42	50.53	39.13	50.11	57.89	58.33	60.23	47.65	35.26
Precipitation [mm/month]	12.70	19.81	22.72	2.80	27.51	13.22	9.26	8.86	7.35	23.38	25.33	11.58
Wind Speed [m/s]	2.49	2.62	2.73	2.63	3.69	3.46	3.06	2.90	2.72	2.99	3.52	3.29

50%:50% and 25%:75%, respectively. Flood irrigation was carried out for the experiment whenever 50% of the available water was used up, with equal timings for each experimental unit to ensure that they received equal amounts of water. No fertilisers were added, and no disease or insect infestation occurred that would require the use of pesticides. However, weed control was carried out manually. A square meter was adopted as a sample for the study, from the middle of each experimental unit. Harvest dates for crops included in this study are shown below (Table 3).

The herbage dry matter (DM) of each of the two crops was estimated separately by taking the yield per square meter and drying it in a drying oven at 65°C until the weight was constant. Then it was converted to the DM yield per hectare by multiplying by the hectare area (10,000 m). Crude protein (CP) using "CP, method ID 984.13", according to AOAC (1999). The procedure used to estimate *in vitro* DM digestibility simulated the general conditions described in the standard method for laboratory fermentation (Goering & Van Soest 1970) with modifications suggested in the ANKOM-DAISY procedure (Ammar *et al.* 1999). CP and *in vitro* DM digestibility converted to CP yield and DM digestibility yield Mg/ha by multiplying the DM yield. DM yield data has been entered into a Microsoft Excel, and the "Land Equivalent Ratio (LER)" was calculated according to the following:

LER = LER oat + LER berseem clover

$$\text{LER oat} = \frac{\text{Intercrop oat DM yield}}{\text{Sole oat DM yield}}$$

$$\text{LER berseem clover} = \frac{\text{Intercrop berseem clover DM yield}}{\text{Sole berseem clover DM yield}}$$

Statistical analysis of variance was conducted for the data of dry matter yield, crude protein yield, and LER for dry matter yield. The averages were compared using the least significant difference (*LSD*) method at a probability level of 0.05 (Al-Rawi & Khalaf Allah 1980). Genstat was used to perform the analysis.

RESULTS AND DISCUSSION

Dry Matter Yield [t/ha]

Figure 1 indicated a significant effect of the tillage system on the accumulation of dry matter in both oats of berseem clover. However, the conventional tillage recorded the highest value of total dry matter 14.69 and 14.12 t/ha in two years, it is worth noting that reduced tillage did not differ significantly from conventional tillage in dry matter production, and this was confirmed in both years. However, no-tillage led to a significant deterioration in dry matter production, less than conventional tillage and reduced tillage, in both years, as non-tillage produced the lowest dry matter yield of 13.77 t/ha and 12.79 t/ha in the first and second years. This may be because both conventional tillage and reduced tillage have led to a similar degree improving the porosity and aeration of the soil, mixing the residues of the previous crop into the soil and exposing organic matter in the soil that was previously sheltered. These conditions improve root and plant growth. Sohail *et al.* (2021) found in a previous study that conventional tillage recorded a higher yield of green forage than no-till from cereal and legume as sole crops and intercropping. Seed proportions affected the dry matter production in crops included in this study

Table 3

Cutting dates of oat and berseem clover during two years

Year	Crops	1st cutting		2nd cutting	
		Date	Day after planting	Date	Day after planting
2022 − 2023	Oat	21 Jan	60	7 Apr	128
	Berseem clover	21 Feb	91	26 Apr	147
2023 − 2024	Oat	23 Jan	60	3 Apr	130
	Berseem clover	23 Feb	91	22 Apr	149

(Figure 2). Intercropping with a seed proportion of 75% oat : 25% berseem clover gave the highest dry matter yield of 17.15 t/ha in the first year and 16.57 t/ha in the second years, and was superior over all other seed proportions, followed by the treatments of 50% : 50% and 25% : 75% of oat: berseem. The lowest mean was obtained at 100% berseem clover with 9.45 and 8.91 t/ha in the first and second year, respectively. The superiority of the seed proportion 75% oat to 25% berseem clover in dry matter yield may be attributed to the fact that it achieved the highest degree of equivalent and mutual benefit between the two crops, which increased in the growth rate and dry matter accumulation. Ross *et al.* (2004) also concluded that increasing the plant density of cereal crops in intercropping led to an increase in DM yield. The advantage of intercropping is shown by the land equivalent ratio scale, which

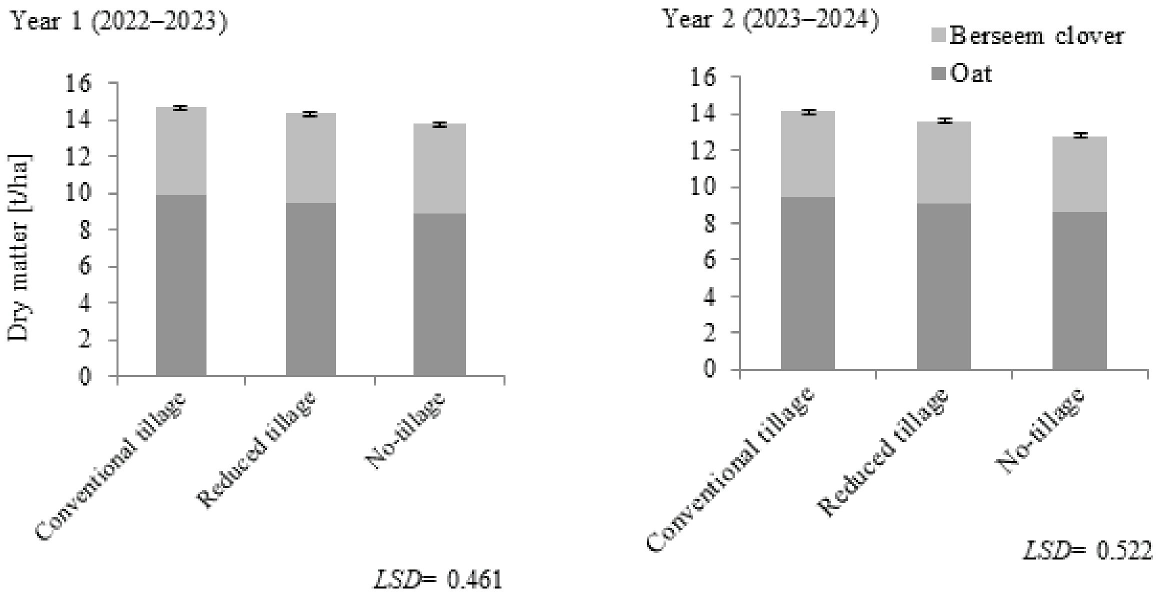

Figure 1. Total dry matter yield of oat-berseem clover intercrops at three tillage systems in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

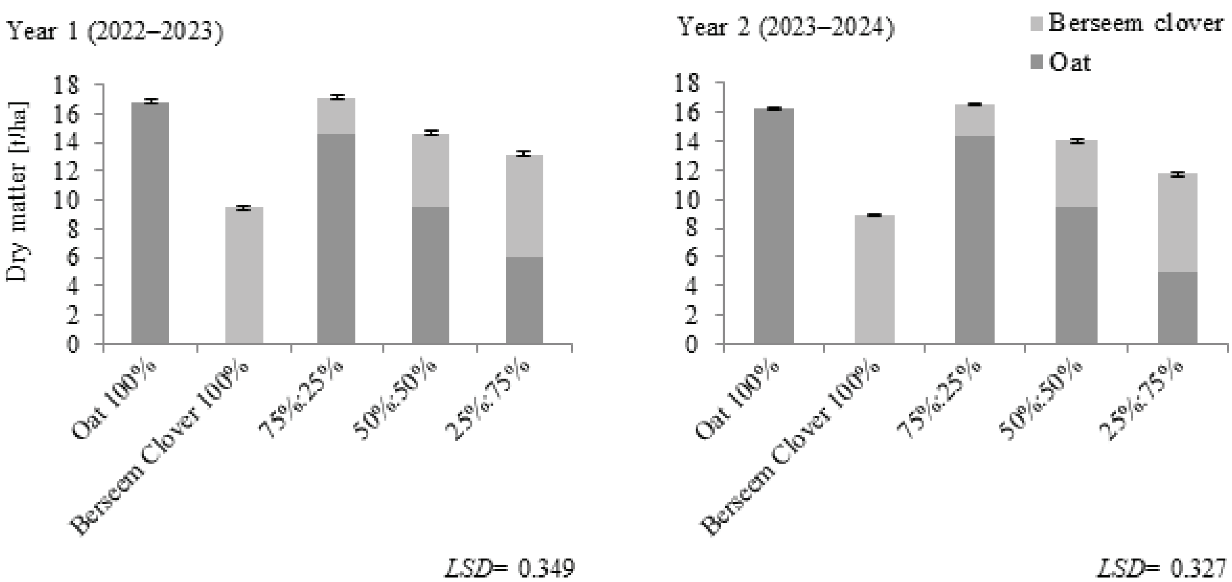

Figure 2. Total dry matter yield of oat-berseem clover intercrops with various seeding proportions in two years (Mean ± SE, n=3). Note: *LSD* − least significant difference.

will be shown later. The two-way interaction of tillage systems with seed proportion showed a significant effect on the dry matter yield in the second year only. The reason may be due to the difference in environmental conditions in the two years, which led to a difference in the degree of response of dry matter yield to seed proportion within tillage systems. However, 75% oat and 25% berseem clover at conventional tillage had the highest dry matter. In the same context, 100% berseem clover at no-tillage had the lowest dry matter yield (Figure 3). The higher dry matter yield under CT and RT compared with NT can be attributed to the improvement of soil aeration, reduction of bulk density, enhancing the root penetration, and finally improving water and nutrients uptake (Morris *et al.* 2010; Ingraffia *et al.* 2023). Combining berseem and oat with a ratio of 75% oat: 25% berseem would maximise biomass by merging the high growth rate of oat with the nitrogen contribution from berseem, without excessive interspecific competition (Ross *et al.* 2004).

Crude Protein Yield [t/ha]

It is noted in Figure 4 that conventional tillage gave the highest crude protein yield of 1.64 and 1.61 t/ha but did not differ significantly from reduced tillage in both years. While no-tillage gave the lowest value of CP 1.52 and 1.51 t/ha and was significantly different from reduced tillage in the first year only. The reason may be that the application of tillage enhanced the ability of the soil to supply the nitrogen necessary for protein anabolism in the plant, compared to no-tillage, as Ingraffia *et al.* (2023) indicated that applying no-tillage reduced the supply of nitrogen to the plant. It appears from Figure 5 that the seed proportion had a significant effect on crude protein yield. The seed proportion of 25% oats : 75% berseem clover recorded the highest crude protein yield of 1.79 and 1.76 t/ha without a significant difference from the seed proportion of 50% : 50%, while 100% oat recorded the lowest protein yield of 1.09 and 1.10 t/ha in years 1 and 2, respectively. Perhaps the reason was that this combination of intercropping achieved the greatest degree of equality and mutual benefit between the cereal and the leguminous crop, especially benefiting from the nitrogen fixed by the leguminous crop. Baghdadi *et al.* (2016) found that intercropping the leguminous crop with the cereal crop improved the crude protein content in the forage, and this was attributed to the availability of nitrogen. Addaheri *et al.* (2023) found that increasing the proportion of clover in intercropping improves soil nitrogen sustainability. Figure 6 shows that the response of crude protein yield to the effect of the two-way interaction of tillage systems and seed proportions was not significant. The higher production of crude protein in the mixtures with larger berseem proportion is due to the legume's assimilation of atmospheric nitrogen, which increases protein content in plant parts (Baghdadi *et al.* 2016). On the

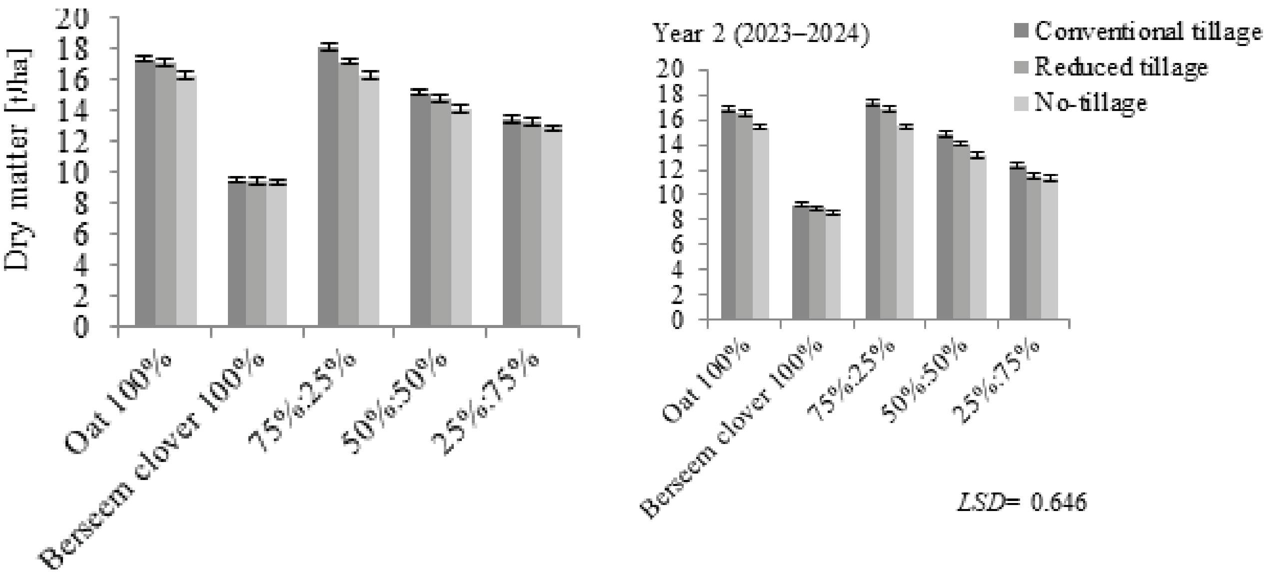

Figure 3. Total dry matter yield of oat-berseem clover intercropping at tillage systems and various seeding proportions %, in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

contrary, it was found that treatments with higher oat proportions produced more biomass but lower protein due to the cereal's lower nitrogen contribution.

Dry Matter Digestibility Yield [t/ha]

It appears from Figure 7 that the digestible dry matter yield was significantly affected by the tillage systems during the two years, with conventional cultivation achieving the highest digestible dry matter yield of 8.28 and 8.00 t/ha, and the use of reduced tillage did not reduce this trait in a statistically significant way. However, the use of the no-tillage system resulted in a significant decrease compared to conventional tillage, as the lowest digestible dry matter yield was achieved, reaching 7.56 and 7.30 t/ha. The fact that digestible dry matter production did not deteriorate when using reduced tillage is a good indicator that allows farmers to dispense with conventional tillage. It appears that reduced tillage was sufficient to achieve the desired benefit from full tillage. One of the important results observed in this study from Figure 8 is that intercropping with

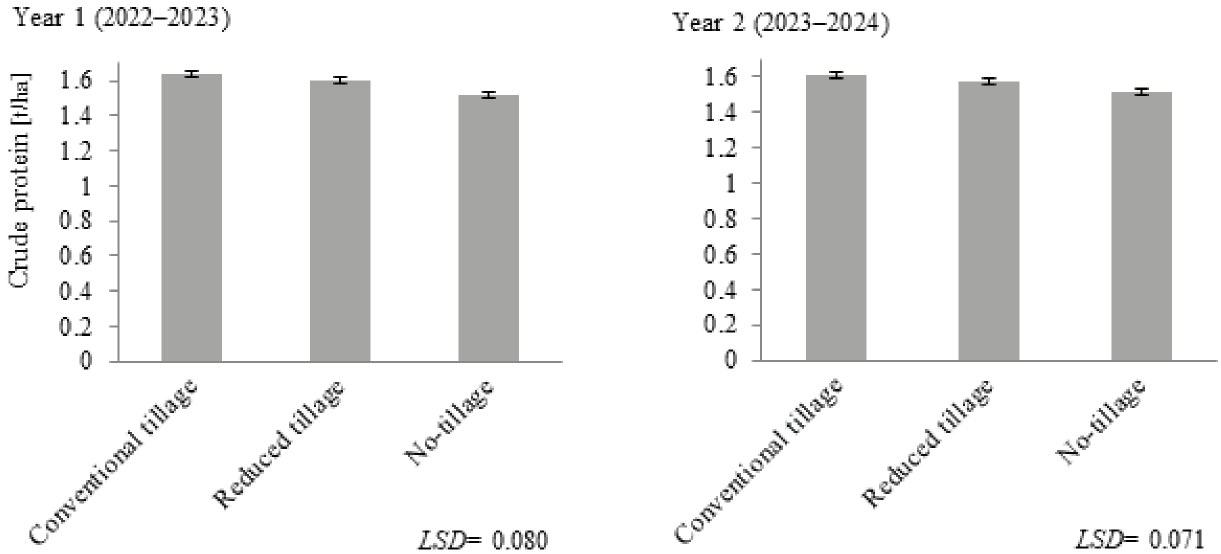

Figure 4. Crud protein yield of oat-berseem clover intercrops at three tillage systems in two years (Mean ± SE, n = 3).
Note: *LSD* − least significant difference.

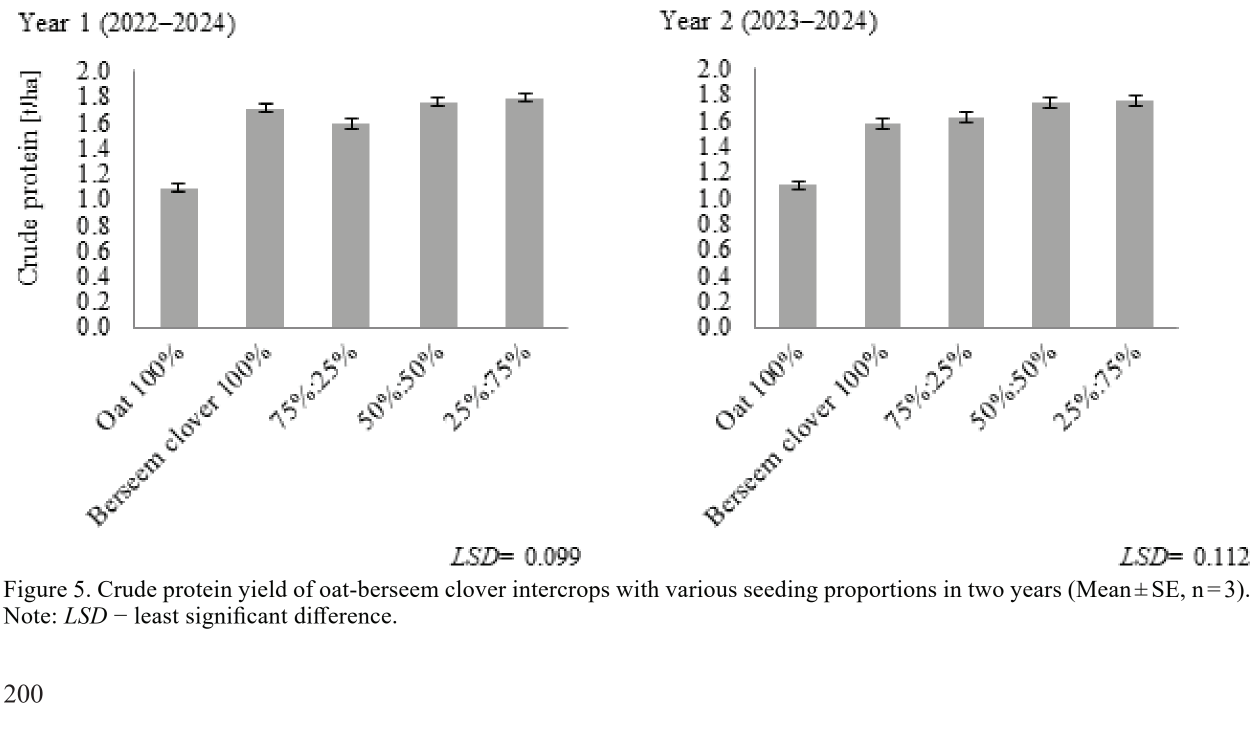

Figure 5. Crude protein yield of oat-berseem clover intercrops with various seeding proportions in two years (Mean ± SE, n = 3).
Note: *LSD* − least significant difference.

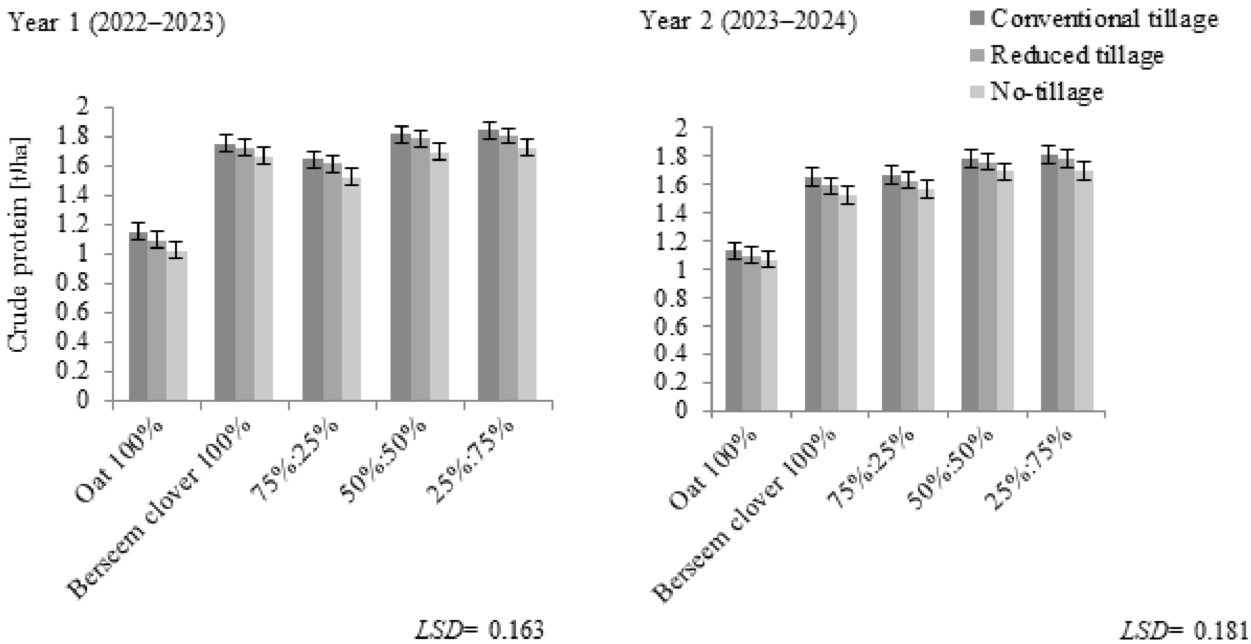

Figure 6. Crude protein yield of oat-berseem clover intercropping at tillage systems and various seeding proportions, in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

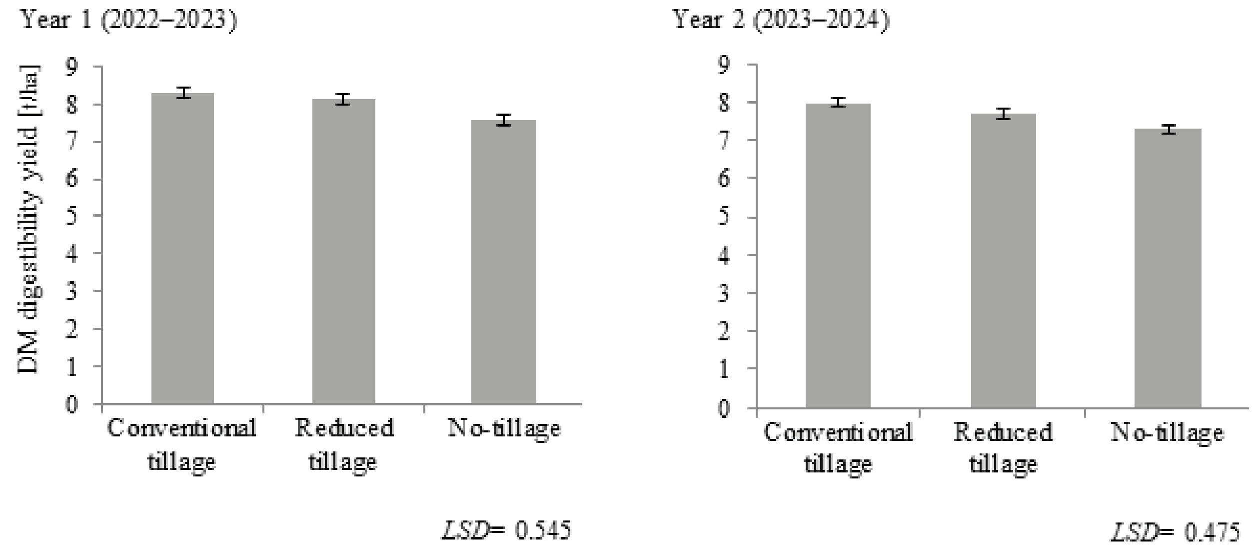

Figure 7. Dry matter digestibility yield of oat-berseem clover intercrops at three tillage systems in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

a seed proportion of 75% oat : 25% clover achieved the highest digestible dry matter yield of 8.58 and 8.32 t/ha, while the lowest digestible dry matter yield was achieved by clover alone. The superiority of the 75% oat to 75% berseem clover seeding proportion in the digestible dry matter yield is due to its superiority in the dry matter yield (Figure 2), because the dry matter digestibility yield is the product of the percentage of digestible dry matter multiplied by the total dry matter yield per hectare. It is noted from Figure 9 that the two-way interaction between the tillage system ratios and the seed ratios did not result in a significant effect during the two years. The response similarity between the dry matter production and its digestibility would reflect the impact of the total biomass on the amount of digestible nutrients. The optimum digestibility was obtained when the two crops were combined at a ratio of 75% oat

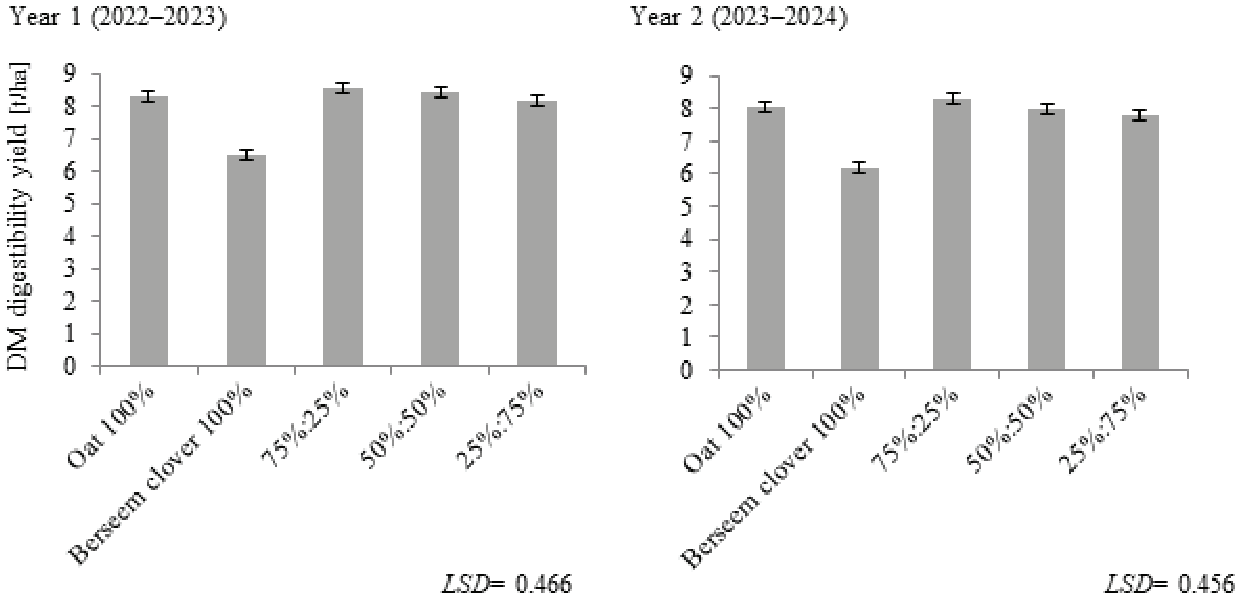

Figure 8. Dry matter digestibility yield [t/ha] of oat-berseem clover intercrops with various seeding proportions % in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

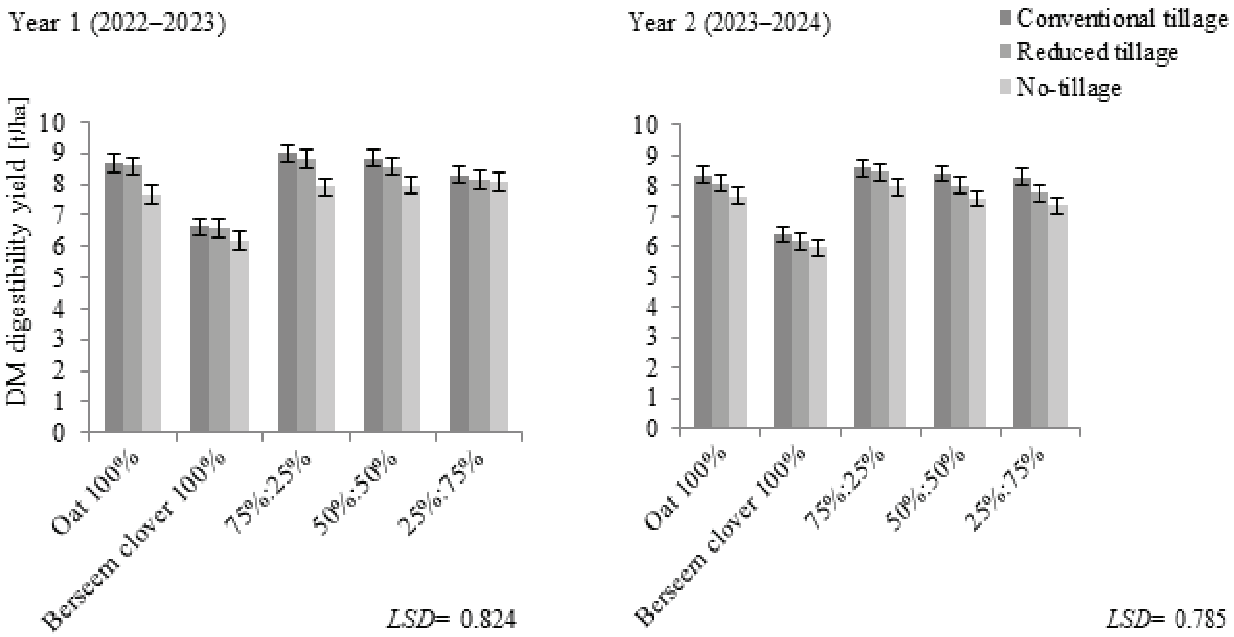

Figure 9. Dry matter digestibility yields oat-berseem clover intercropping at tillage systems and various seeding proportions %, in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

and 25% berseem, where the berseem contributed the required nitrogen and oat provided the structural carbohydrates (Ammar *et al.* 2010).

Land Equivalent Ratio (LER)

Statistical analysis for LER of oat-berseem clover intercropping resulted in a significant effect of tillage systems and seed proportions, but there was no effect of the two-way interaction. The results in Figure 10 showed that conventional tillage had the greatest LER of 1.13 and 1.11 significantly higher compared to no-tillage, but was not significantly different from reduced tillage, in the two study years. The seeding proportions of 75% : 25% recorded the highest LER of 1.13 with a non-significant difference from the seed percentage of 50% : 50% and a

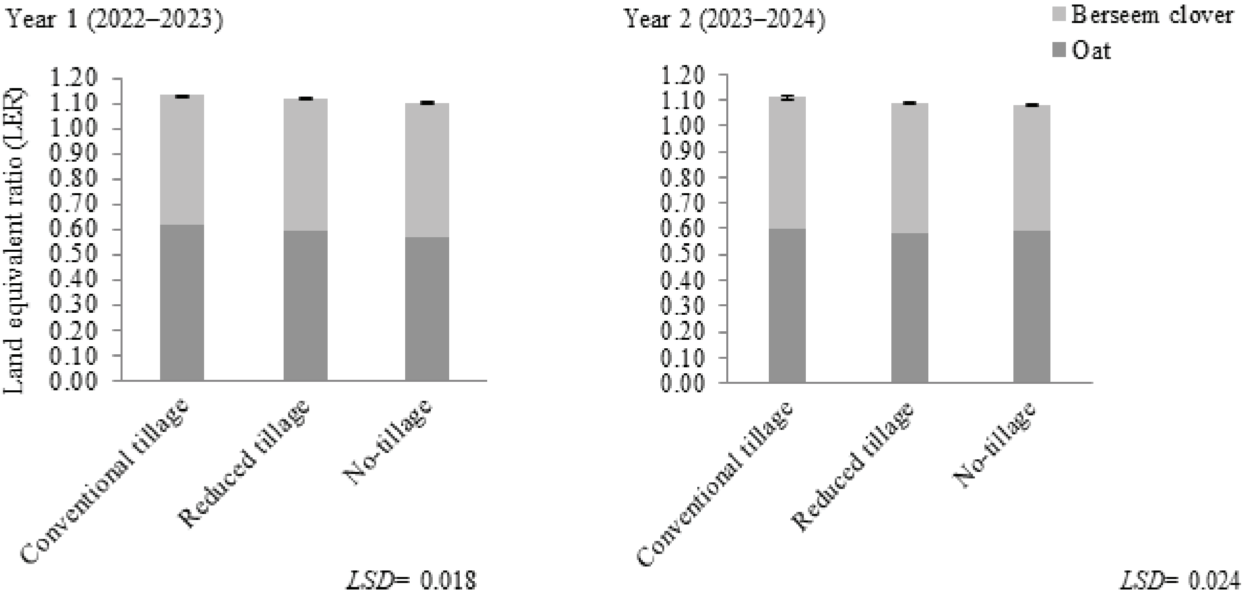

Figure 10. Land equivalent ratio (LER) of dry matter of oat-berseem clover intercrops with various tillage systems, in two years (Mean±SE, n=3). Note: *LSD* − least significant difference.

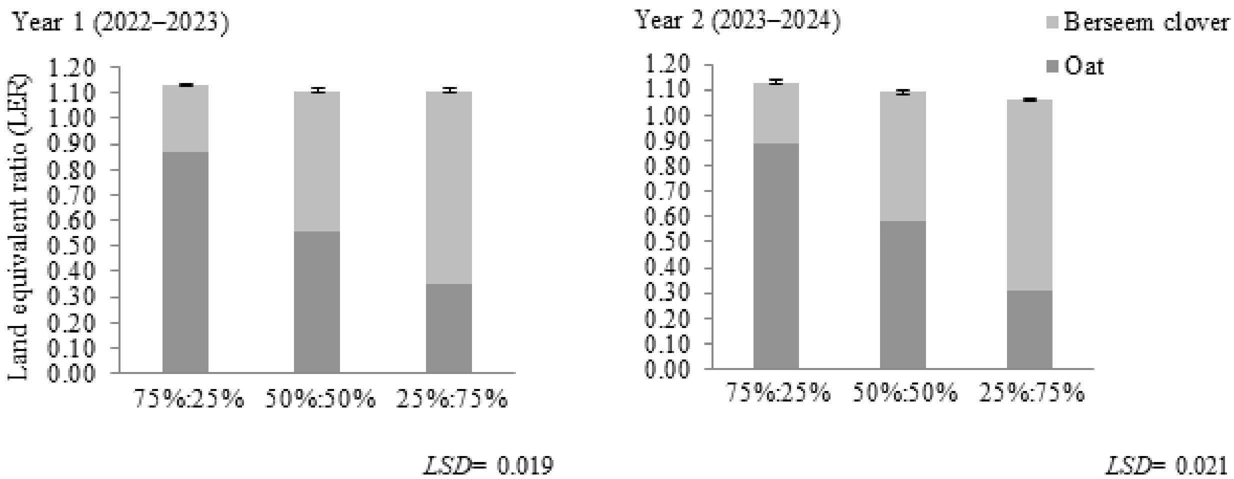

Figure 11. Land equivalent ratio (LER) of dry matter of oat-berseem clover intercrops with various seeding proportions %, in two years (Mean ± SE, n = 3). Note: *LSD* − least significant difference.

significant difference greater than the seed proportions of 25% : 5%, which recorded the lowest value of LER reached 1.10 and 1.06 in years 1 and year 2, respectively (Figure 11). Generally, the LER values were greater than 1 according to the T-test at all tillage systems and seeding proportions. This explains that intercropping agriculture led to the ideal exploitation of energy sources, e.g., water and nutrients (Dwivedi *et al.* 2015). In addition to that, legumes supply N through biological N fixation, which enhances plant growth and development (Deori *et al.* 2019). The land productivity was confirmed by obtaining LER values more than 1, and this explains the complementary resources use, including rooting depth differences, uptake of the available nutrients, timing and the canopy structure (Li *et al.* 2020; Tang *et al.* 2021). This system efficiency was enhanced by the nitrogen fixation by berseem.

CONCLUSIONS

Based on the aforementioned outcome of this study- that reducing tillage does not lead to a deterioration in dry matter yield, protein yield, land equivalent ratio, and dry matter digestibility yield, less than conventional tillage, which allows farmers who rely on conventional tillage to be content with reduced tillage using a chisel plough to a maximum depth of 8 cm, to save costs and effort and reduce soil damage that may result from unjustified deepening of tillage. To achieve the highest benefit from intercropping in terms of land equivalent ratio for dry matter yield and dry matter digestibility yield, this study recommends adopting a seed proportion of 75% oat : 25% berseem clover. For protein yield, it is preferable to use a seed ratio of 25% oat to 75% berseem clover.

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