



## **WP3: Resilient agroecological solutions for circular economy**

**Task3.3 Evaluate the suitability for integrating agro-pastoral grazing requirements**

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### Task 3.3 Evaluate the suitability for integrating agro-pastoral grazing requirements

#### 1. Evaluate Fodder quality and quantity associated with the agro-ecological intervention

Task 3.3 main goal was to evaluate the agro-ecological intervention such as intercropping to produce better quality and quantity of fodder. These agroecological activities were conducted and merged with agropastoral activities at various levels in 4 countries including Lebanon (cutting, Awassi sheep on Barley), Italy (sheep on intercropped fields), Algeria (El Hamra sheep on wheat and Barley with various management of fields), and Morocco (Biomass analysis for potential grazed areas with cutting and intercropping). Each country addressed a different aspect of grazing assessment.

Results on biomass analysis is summarized in table 1. Briefly, similar trend for biomass yield increase was observed for Barley following cutting mid tillering or grazing at the same stage, and from agroecological compared to farmer practices. Various intercropping conditions and combinations with winter or summer cereals further showed the viability of such a practice, especially with the increase biomass or protein. Benefits though vary with season and will require further repetition.

**Table 1:** Summary of agropastoral practices for the analysis of pasture potential of barley or wheat as grazing.

Country	Sowing	Practice Evaluated	Yield (t/ha)	
			No cuts	With cut
Lebanon	Barley	multiple cuts: grazed or cut vs uncut	1.7	2.25
Morocco	Barley cultivars M, A, 6 and 7	cut mid tillering stage vs uncut	0.74	2
			Grain (T/ha)	Straw (T/ha)
Algeria	Barley	Agro-Ecological management	3.21 ± 0.89	2.01 ± 0.48
		Farmer Practices	2.46 ± 1.32	1.62 ± 0.76
Morocco	Triticale (x Triticosecale L)	intercropping under agroferstry (apple) with vetch ( <i>vicia villosa</i> )		5.25 T/ha
	Triticale <i>Juanillo</i>	open field intercropping with vetch villosa Salhouma		3.63 T/ha
			Fresh	Dry
Italy	Autumn Cereals	Intercropping with clover, <i>Trifolium repens</i> and Huja	0.93	0.33
	Spring Cereals		1.87	0.47

Projections for next period will be to analyze protein and nutrient content across all practices proposed. Double purpose variety will also need to be identified and planted on research stations.

In addition to this procedure, the different genotypes will also be tested for their suitability as “double purpose” varieties. Separate trials will be set up at four research stations with replicated plots of 20 m in length. These plots will then be divided into five parts of 4m each: one part not cut, one part cut once, one cut twice, one cut three times, and one cut four times. The cutting will be done at different times depending on the specific season, but always before a forecast rain. The collected biomass will be weighted.

## 2. Evaluate Animal performance on grazed fodder under various strategies

A second main goal of task 3.3 was to directly assess animal performance under various cropping strategies. This goal was further assessed in 3 countries, with various focuses, as summarized in table 2.

**Table 2:** Grazing activities across the various cropping strategies

Country	Sowing	Practice Evaluated	Grazing Practices	Assessment	Other assessments
Lebanon	Barley	Rotational grazing vs semi-intensive - multiple cuts	- 36 Awassi sheep - grazing 8 hrs/d - rotation every 10 d	Animal growth, milk components	Grazing reject/ stocking rate
Italy	Cereals	Intercropping	- Sheep - 5 hrs grazing/d - once	Behavior/ palatability	Ground coverage
Algeria	wheat Barley	Agroecological vs farmer practices	- El Hamra sheep - 4hr grazing/d - 15days	36% stubble reduction 41% stubble reduction	Soil compaction

Results showed a slight advantage in milk fat content of Awassi sheep managed under rotational grazing vs a semi-intensive traditional system, with no changes in animal weight or performance. Intercropped fields further showed increased palatability, as shown by animal behavior analysis or stubble reduction. However, disadvantages of animal grazing fields directly was observed in increased soil compaction and left over non grazed fodder, possibly due to high or low stocking rates, respectively.

Recommendations for next phase to unify measurements on animal performance, biomass yield and nutrient content, as well as assess viability of rotational grazing across all countries involved in the study. Alternative methods for evaluating animal performance is suggested in cutting fodder and presented it to animal via a feed trial rather than direct grazing.

# 1. Lebanon

## D3.3.1 Analyse grazing solutions on station

For Lebanon, This study was conducted in Terbol (33°48'23.4"N, 35°59'30.6"E); a village located in the Zahle District of the Beqaa Governorate, in Lebanon at the research centre of the *Lebanese Agricultural Research Institute* (LARI). LARI is an institute managed by the Lebanese ministry of agriculture, specialized in breeding and selection of Awassi sheep and Shami goats; it is also known to be one of the first research centers for the feeding and management of small ruminants, the use of agro - industrial by - products in ruminants diet, the evaluation of ruminants feeds and their nutritive content and the evaluation of the effect of the several management methods on ruminants health and productivity.

Terbol-Beqaa located at an elevation of 916 meters above sea level, has a Mediterranean, hot summer climate with a yearly average temperature of 16.22°C (61.2°F) -3.7% lower than Lebanon’s averages with an average minimal temperature of 1.21 °C in winter and an average maximal temperature of 35 °C in summer. Beqaa typically receives about 71.77 millimeters (2.83 inches) of precipitation and has 91.46 rainy days (25.06% of the time) annually (The Global Historical Weather and Climate Data).

The Beqaa governorate is known to be home to extensive and intensive dairy farming in Lebanon, covering 44% of the country’s total farming land. Nearly 75%-80% of Lebanon’s cows, 45% of goats and 35% of sheep are raised in the region, yielding a total of 188 tons of milk a day (Board, 201

6)For the case of Algeria this experience was conducted with genotypes premises during the first year, this is the reason for which it is merely compare only between the two practices

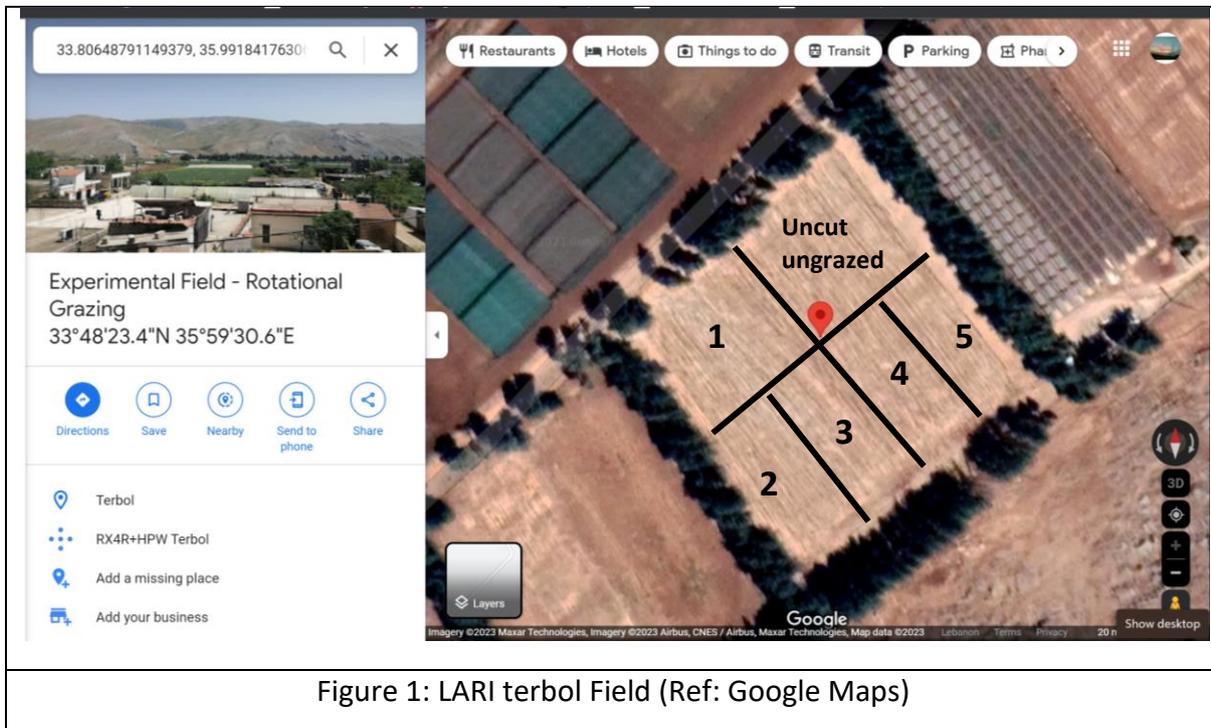
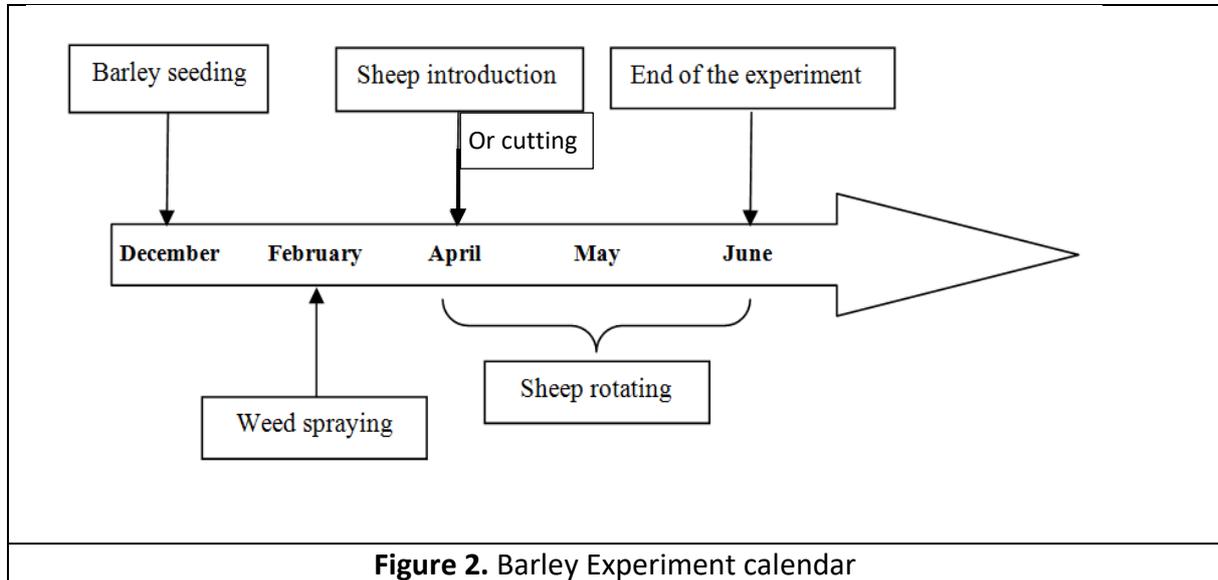


Figure 1: LARI terbol Field (Ref: Google Maps)

### Barley seeding and rotational grazing

Barley seeds (*V. morales*) were plowed and seeded at a rate of 180Kg/ha in early December 2022, on a land of 10 000 m<sup>2</sup> divided into six different plots (figure 1). Weed spraying was conducted in February 2023. Watering was planned in March, but two consecutive rain storms allowed proper irrigation without the need of supplementation.



The experiment lasted from mid of April to mid of June 2023. Two different semi-intensive sheep rearing management systems were tested and compared: (i) a traditional semi-intensive sheep rearing, consisting of a traditional grazing on the Lebanese wild flora, typically composed of wild flowers and grasses like Cretanweed, Blessed milkthistle, Cheesweed mallow or chamomile; supplemented with 0.5 Kg of a daily mix composed of 35% corn, 10% wheat, 20% bran and 35% barley. (ii) A barley rotational grazing system, consisting of sheep rotating for two months in a restricted and divided area where only barley was grown. The flock of Awassi Ewe-Lamb pairs for the study were from the experimental Awassi sheep flock maintained at LARI. Ewes BW was 47±1.2 Kg, and lambs averaged 1 to 4 weeks in age.

### Barley yield and grazing carrying capacity

**Table 1.** Effect of the number of barley cuts on barley yield and Ewes /Lambs ADG

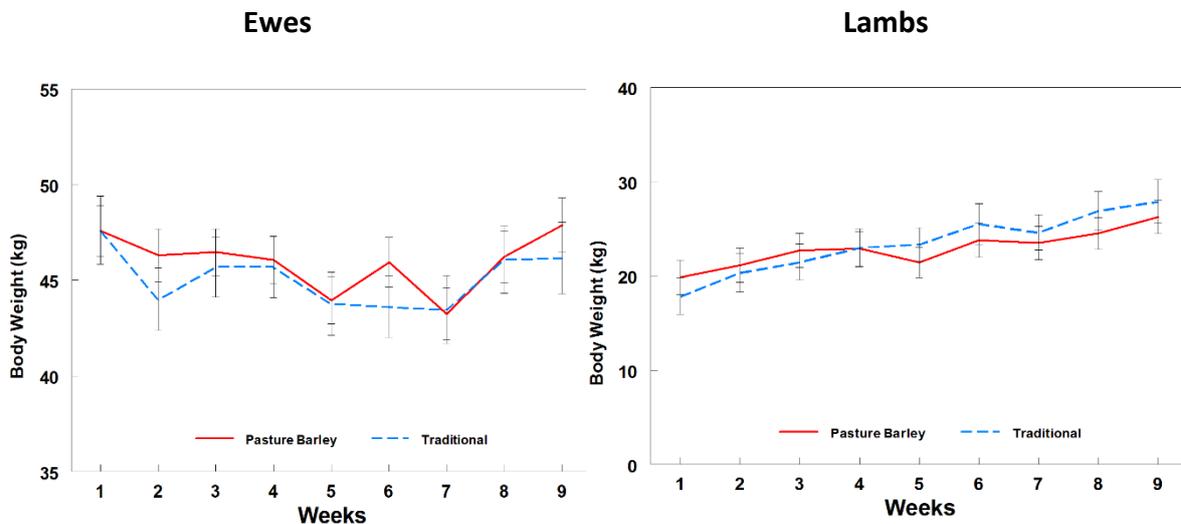
Cut	Yield (Kg/m <sup>2</sup> )	Total T/ha	Ewes	Lambs
			ADG (Kg/day)	ADG (Kg/day)
Initial	0.34±0.004	1.688	0.17 ±0.09 <i>a</i>	-0.1667±0.07 <i>a</i>
1		0.24497	0.099±0.09 <i>b</i>	0.0134±0.05 <i>b</i>
2	0.12±0.015	0.2896	0.08±0.09 <i>ab</i>	0.209±0.05 <i>c</i>
Left in field		0.02776		
Traditional			0.012±0.06 <i>ab</i>	0.028±0.03 <i>b</i>

Results showed an increase in barley yield as a result of cutting from 0.17 to 2.25 T/ha in barley biomass, following cutting or grazing. Though the stocking rate was reduced after period 1, 10 days of grazing were not enough to uniformly graze the individual plots, and on average a period of 40 days was allowed before reintroducing the flock into the same plot, still not enough time to allow for ample growth. Grazing period started at a later stage than tillering. Therefore, grain will need to be estimated and possibly stem height at a later stage, as well as nutritional value variation between the various cutting stages.

Ewes ADG decreased with the progression of the experiment, indicating the need to either use intercropping with clover or a more protein dense crop to meet the animal requirements.

### Ewe-Lamb performance

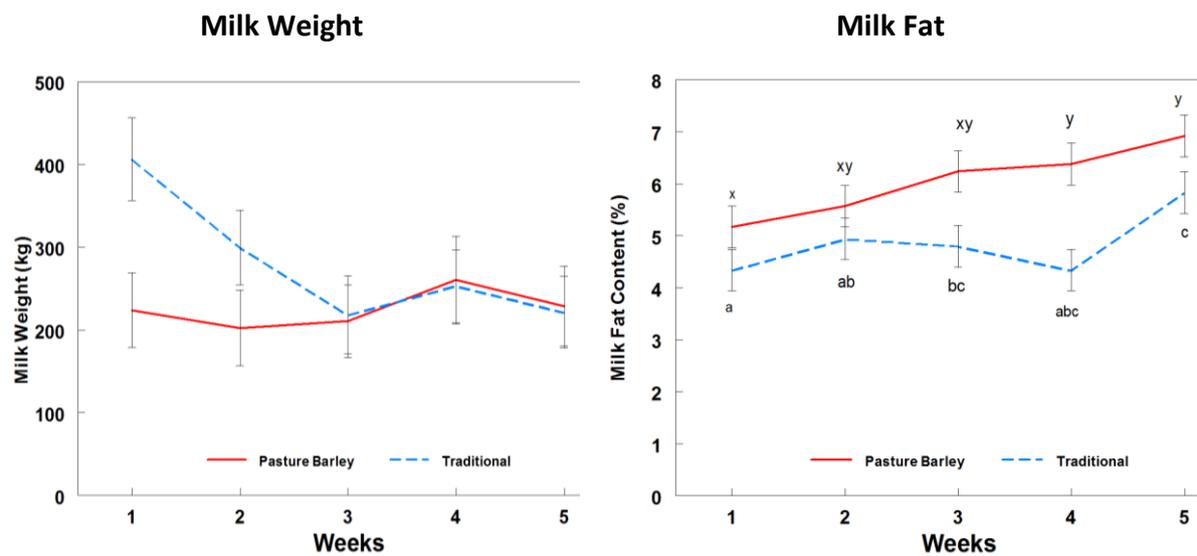
Barley rotational grazing did not affect ewe or lamb body weight evolution (as shown in figure 3), or milk components and yields (as shown in table 2) as compared to a traditional semi-intensive (supplemented) rearing system, therefore indicating the potential of rotational grazing to provide agro-ecological alternatives to grain feeding or overgrazing. In fact, even though milk quantities remained stable within the rotational grazing, milk fat increased and was higher (figure 4) in ewes fed barley as compared to traditional system.



**Figure 3:** Effect of Barley Rotational grazing on Ewe-Lamb weight evolution

**Table 2.** Effect of barley rotational grazing (*Barley*) on the milk quantity and components of Awassi ewes

	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5
Milk Weight (g)	Traditional	406.3±38.3	345.5±41.1	290.8±42.8	316.2±42.8	276.8±42.8
	Barley	292.9±41.1	312.9±44.7	325.5±44.7	368.7±42.8	324.2±42.8
SNF (%)	Traditional	9.45±0.16	9.33±0.18	9.37±0.18	9.44±0.18	9.60±0.18
	Barley	9.65±0.18	9.40±0.19	9.45±0.19	9.62±0.18	9.45±0.18
Density (kg/m <sup>3</sup> )	Traditional	33.69±0.80	32.46±0.86	31.90±0.89	32.54±0.89	32.77±0.89
	Barley	33.45±0.86	32.18±0.93	31.96±0.93	32.42±0.89	31.32±0.89
Lactose (%)	Traditional	4.27±0.07	4.19±0.08	4.21±0.08	4.24±0.08	4.31±0.08
	Barley	4.31±0.08	4.22±0.08	4.25±0.08	4.32±0.08	4.25±0.08
Protein (%)	Traditional	5.52±0.08	4.43±0.08	4.45±0.09	4.48±0.09	4.56±0.09
	Barley	4.56±0.08	4.46±0.09	4.50±0.09	4.57±0.09	4.49±0.09



**Figure 4:** Effect of barley rotational grazing on the milk quantity (kg) and fat content of Awassi ewes

## 2. Morocco

### 1. Fodder analysis results and selection of the best varieties

There were significant differences between barley genotypes in both on farm and on station trials. Average yield was 1.67 T/ha and 0.93 T/ha respectively. The best genotypes were 3, 6, 10, 11 and 12 at Annoceur station with an average biomass yield of 1.07 T/ha and the genotypes 4 and 12 were the best at Guigou producing 2.55 T/ha as average.

These results highlight the good performance of the genotype 12 in both environments (Annoceur and Guigou). The genotype 12 is the local landrace adapted to Moroccan mountains.

### 2. Measurement of the biomass of dual purpose barley

Four barley cultivars were subjected to an agronomic evaluation for double purpose ability (forage and grain). Cultivars M, A, 6 and 7 were cut at mid tillering stage (4.5 feeks) and were compared to uncut checks left for grain and straw production.

Cereals were sown into a prepared seedbed on November 24th 2022 in Annoceur experimental station of INRA, Morocco (Latitude 33°41'5.2"N, Longitude 4°51'19.9"W, Elevation 1440 m) on a shallow loamy soil (organic matter content 0.79%). Manual sowing within 20 cm spaced rows at the density of 250 plants/m<sup>2</sup> was performed. Elementary plots had six rows of 5 m length. Started fertilizer was applied at sowing time and consisted of 10 kg/ha of nitrogen, 30kg/ha of phosphate and 10 kg/ha of potash. A top dressing of ammonitrate (33%N) was applied at jointing stage.

The design was a randomized complete block with three replications.

The plots were cut at the appropriate moment with hand shears to a height of 3 cm. A sample of 500 g was collected and oven dried at 70°C for 48h and weighed to determine dry matter. The uncut plot plus the regenerated ones were harvested for grain at the physiological maturity. Lodging and disease rating were scored during the growing season. Data were analyzed using SAS General linear Model for complete randomized design.

#### ***Climatic Data***

The received rainfall was around 381 mm. It was well distributed throughout the winter months. However, only 13 mm was received for both March and April. Abundant rainfall estimated at almost 40% of the total rainfall was concentrated in May and June. A hailstorm occurred in early June causing significant crop losses.

#### **Main Results**

Plants emergence occurred on December 9th and was quite homogeneous for all plots. It was estimated between 80 to 95% three weeks after sowing.

- Forage production:

Dry matter production averaged 0.74 t/ha for cutting at tillering stage. The variance analysis showed a highly significant effect of the genotypes ( $P < 0.001$ ).

The Forage production of M and A genotypes was more or less similar and averaged 1 T/ha. This yield exceeded significantly that of 7 and 8 genotypes. Indeed the genotype 7 was the least performing and has produced barely 0.4 T DM/ha.

The difference in producing dry matter is related to number of tillers per plant, which was variable between genotypes.

- **Grain yield:**

Cutting barley at early vegetative stage had a depressing effect on grain production of tested genotypes. It resulted in a reduction that varied from 7 to 15% compared to uncut control.

Grain yield after cutting averaged 2 T/ha. Differences were revealed between genotypes for grain yield with or without vegetative cutting. Results showed that 7 genotype was the least yielding in both case, while the other genotypes produced closer grain yield. However, this effect was not significant on straw production.

### 3. Cereal–legume mixtures under agroforestry

Triticale (x *Triticosecale* L), a widely adapted cereal, to climatic and edaphic Moroccan conditions, was intercropped with vetch (*vicia villosa*) for forage production under the trees of an apple orchard, located at Annoceur (Latitude 33°41'5.2"N, Longitude 4°51'19.9"W, Elevation 1440 m), and was compared to triticale-vetch conducted in open field. The seeds sown initially of Triticale Juanillo and vetch villosa Salhouma were 250 seeds / m<sup>2</sup>, with proportions of 30% and 70% for Triticale and vetch respectively.

Four plots of 15 m<sup>2</sup> (5m x 3m) with 10 rows each were distributed on either sides of an apple tree row.

Plots were sown manually, on December, 11th 2022, after opening surface furrows using manual hoes. Mineral fertilization was not applied. The fifth plot is located a few meters from the apple orchard.

Measurements and observations concerned the emergence and plant vigor of the canopy, phenology, forage yield. Cutting was accomplished at flowering for vetch corresponding to triticale heading. Three (3) square meters were harvested in each plot. Samples were weighted and separated into the two components. Dry weights were determined from 500 g samples of each, in 70°C oven for 48 hours.

Samples were ground and forage quality were determined.

## Main Results

### Forage production

Average mixture yields were of 5.25 and 3.63 T dry matter/ha for hairy vetch-triticale when cultivated under tree or in open field respectively. Within apple orchard, the mixtures produced one and half times more than their open field production.

The yield increase could be explained by the higher organic matter content in the soil under trees because of the fall of the leaves and branches from previous tree pruning.

Another possible explanation for this increase in yields is related to tree shade that reduced soil transpiration without reducing plant photosynthesis. It is to remember that apple trees have deciduous leaves along the growing cycle of forages. In addition, the soil water content under apple tree is significantly more important than in open field.

The vetch proportion at harvested forage differed through the two environments. Vetch contributed by 10% within forage harvested under apple tree. This share was higher than harvested in open field, which did not exceed 5%. This result underlines the environment impact on final proportion of legume at harvest. It seems that hairy vetch, had more ability of using the environmental resources for its growth and development under apple trees. The sown environments also affected forage quality. Crude protein content in vetch-triticale mixture was one point higher than mixture conducted in open field due to higher legume share.

### 3. Algeria

For the case of Algeria this experience was conducted with genotypes premises during the first year, this is the reason for which it is merely compare only between the two practices is ignoring the difference observed between the genotypes, and the average yields obtained in the two practices at the site of the station of Setif are presented in the following table :

**Table 01 : the average grain and straw yield of two practices in the station of Setif.**

Crop	Practice	Grain yield (t/ha)	Pgoes yield (t/ha)
Wheat	Agro-Ecological management (AE.P)	3,01 ± 0,61	1.94 ± 0.35 in
	Farmer Practices (F. P)	2,8 ± 1,08	1,94 ± 0,56
Barley	Agro-Ecological management (AE.P)	3,21 ± 0,89	2,01 ± 0.48 To
	Farmer Practices (F. P)	2.46 ± 1,32	1,62 ± 0,76

The comparison between the two practices (farmer and agro-ecological) has shown that the yield of grain in the AE.P obtained in wheat around the **3,01 t/ha** with a maximum of the **3.94 t/ha**, whereas in F. P the yield is lower and it is around **2.8 t/ha**, which shows that during the first year of the practices AE.P have shown their performance in yield of grain.

For the yield of straw at harvest time, it was noticed that the average performance is similar and estimated to 1.94 t/ha for the two practices.

For barley, the comparison between the two practices showed that the grain yield is estimated to 3.21 t/ha in AE.P and it is superior to the performance obtained in F. P , which is 2.46 t/ha, and it's the same thing for the yield of straw, 2,01 t/ha in AE.P and 1.62 t/ha in F. P.

#### **Charge of animal per hectare :**

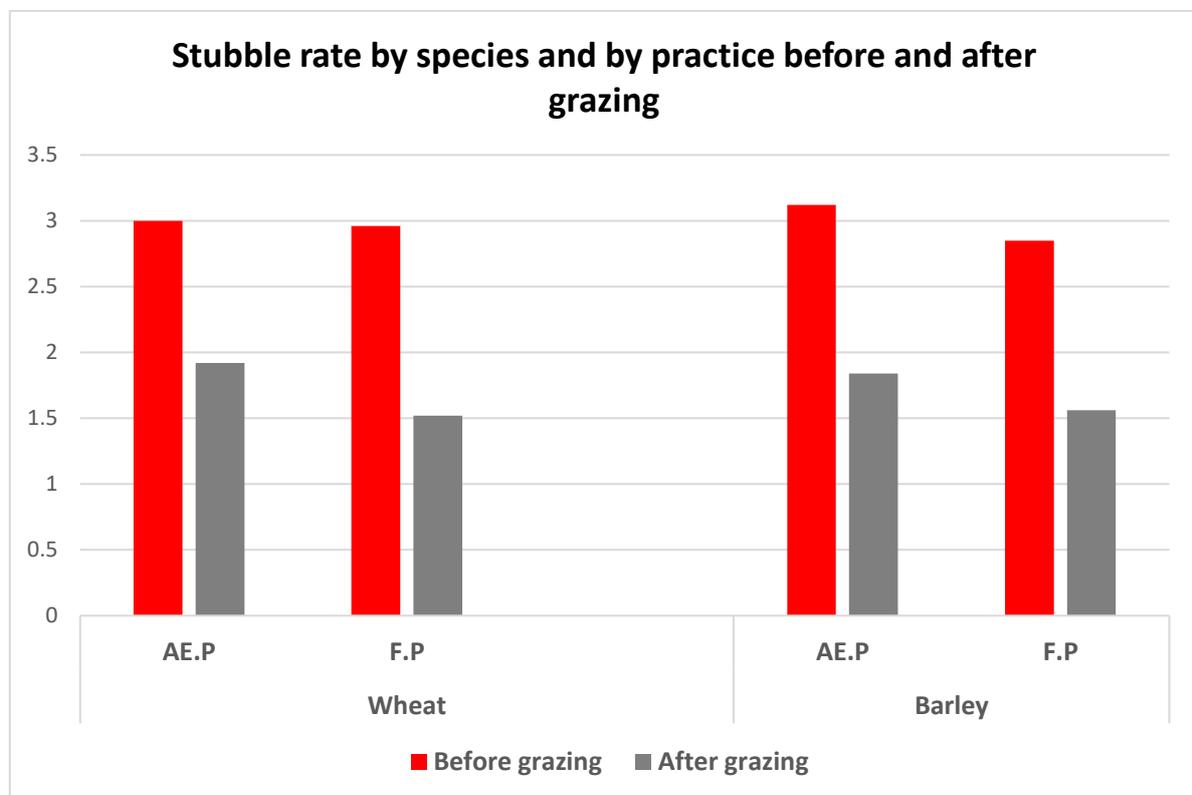
A trial of charge in hectare is performed, to estimate the impact of grazing on the rate of stubble in the soil, as well as on the physico chemical properties of the soil.

The sheep used for this experiment is characterized by :

- 8 heads of sheep (age between 8 and 22 months)
- Race : El Hamra.
- Grazing for 15 days, beginning July 20, 2023 and stop in 04 August 2023,
- Pasture for 4 hours /day

The pasture was conducted on a surface of 2500 m<sup>2</sup> with a complement of 250 g/head of concentrate-based bran and barley every day.

Measurements of the rate of stubble before and after grazing were carried out on each plot for each species and in each practice, and they are given the results presented in the graph below :



The periode of grazing chosen is 15 days after harvest, the amounts of the stubble left after harvesting in the practices AE are estimated at **3 t/ha** of durum wheat and **3,12** for barley, while quantities remain after grazing on the set of varieties that vary between 1,92 t/ha for wheat and hard 1,84 for the barley, which is equivalent to less than 36% in wheat and 41% for barley. These variations depend on the preference of the animals for each type of stubble, and even there are preferences for each variety, but have not been taken into consideration due to the small size of the plots (12 m<sup>2</sup>), and the absence of a physical separation between one variety and another.

The amounts of stubble left after harvesting in the F. P are estimated to be 2.96 t/ha of durum wheat and 2.85 t/ha for barley, while quantities remain after grazing on all varieties vary between 1.52 t/ha for wheat, durum and 1.56 t/ha for the barley, which is equivalent to less than 48% wheat and 45% for barley. These variations depend on the preference of the animals compared to the type of stubble.

In all cases, more than 50% of the stubble are left in the ground regardless of the species and the practices adopted, generally composed by des stems, because the grain and the leaves are eaten during the first 10 days of grazing. In fact, it has been recommended to farmers in our studies, to graze the sheep for 05 to 10 days and stop the pasture as soon as the grain and leaves are exhausted.

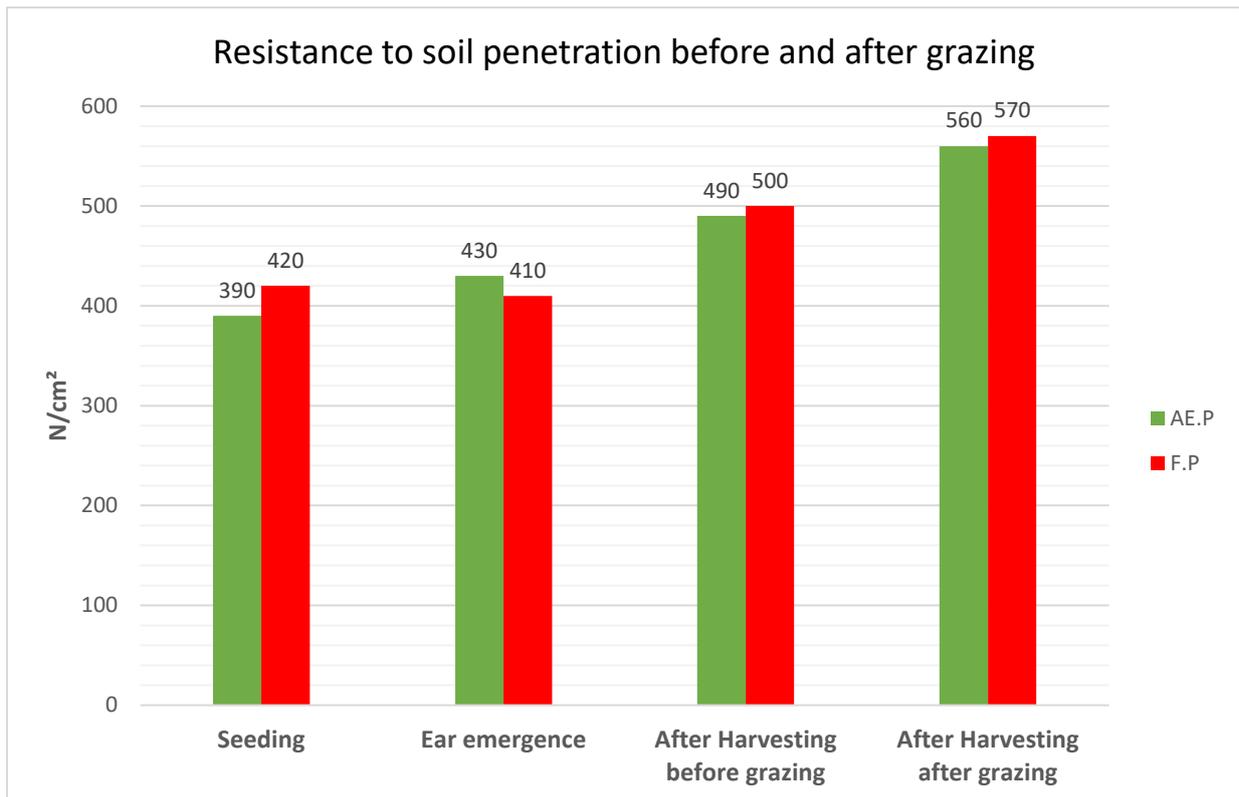
#### **Resistance to penetration of the soil:**

This method consists of estimating the impact of grazing on the characteristics, soil physical, and the main indicator of this is the effect of grazing on soil compaction and it can be measured using a penetrometer of precision that donne readings in figures (Figure 01) and the penetration resistance is given by a formula that results in  $N/cm^2$ .



**Figure 1: penetrometer**

Measurements on the ground were carried out using a penetrometer to estimate the impact of the animal on the physical characteristics of the soil and the main results are presented in the graph below :



The resistance to penetration was followed for the two species on the points chosen at random on all of the trial and in the two culture systems (AE.P and F. P) at stages seedling, jointing to heading, after harvest before grazing and after grazing.

At the stage of seedlings, it is noticed that the F. P has the highest value with 420 N/cm<sup>2</sup>, exceeding slightly the AE.P that displays 390 N/cm<sup>2</sup>. In the phase of elongation to heading, the data are almost similar, with the F. P showing 410 N/cm<sup>2</sup> and the AE.P 430 N/cm<sup>2</sup>. This observation have several explanations, par exemple, it could indicate that the horizons of the soil for the AE.P and f P are almost similar in terms of resistance to penetration and has not deference since it is in the first year of experience and the soil has not yet undergone changes in their structure.

However, we note that after the harvest and before the pasture we record values more high with 490 N/cm<sup>2</sup> for the AE.P and 500 N/cm<sup>2</sup> for the F. P. More values are more important after grazing or the resistance to the penetration increase at 560 N/cm<sup>2</sup> for the AE.P and 570 N/cm<sup>2</sup> to F. P. This shows that grazing increases soil compaction is what that is the practice. However, The penetration resistance is strongly correlated to the humidity, as water plays an important role in acting as a lubricant. When the soil is dry, the resistance to penetration is generally more elevated, because the soil particles are more compact and have greater resistance to the force of penetration.

## 4. Italy

### 4.1 Intercropping

#### Metodology

As regards as the intercropping (White clover, *Trifolium repens*, Huja variety).

Broadcasting sowing was carried out on April 5, 25 kg/ha, over the entire agroecological technique plot area, including the plots where durum wheat and barley had been sown in the fall.

At the time of threshing, three samples of clover were taken in both areas, fall and spring sowing of the cereal, over an area of one square meter each. Where the clover was sown at the same time as the cereal, the "yield" was about twice as high as in the area where the cereal was already present (autumn planting).

#### *Yield of intercropping clover (average of three reps)*

	fresh produce Kg/m <sup>2</sup>	dry production Kg/m <sup>2</sup>
AUTUMN CEREALS SOWING	0.93	0.33
SPRING CEREALS SOWING	1.87	0.47

#### Results

The emergence of the clover occurred regularly and with optimal density. At the time of wheat threshing, the ground was evenly covered.

#### Considerations

The species is correctly identified (next year we may add *Trifolium pratense*).

It is recommended to continue with a lower density after grain emergence (spring sowing of intercropping on fall sown grain), because such abundant presence of intercropping delayed wheat maturity and its considerable growth made harvesting operations difficult.



## 4.2 Grazing

Immediately after the harvest, a small flock of sheep (about 40 heads) was introduced into the innovative field and grazed in the field for about 5 hours.

### Results

The cattle seemed to really appreciate the new forage: for the entire time they were there, no animal moved outside the area where the clover was.

### Considerations

Since mowing forage and grazing areas are abundant in the area, the technique does not seem viable except occasionally. Is to take into consideration in the areas where we carry out the trial, livestock only graze in the spring/summer period, making it impossible to carry out grazing practices on the cereal crops in the trial.

Every autumn, in fact, the animals are moved from the mountains to the plains, and are brought back only in spring. This is called vertical transhumance (<https://ich.unesco.org/en/RL/transhumance-the-seasonal-droving-of-livestock-along-migratory-routes-in-the-mediterranean-and-in-the-alps-01470>).

the cows raised in the area are aimed at the production of Parmigiano Reggiano whose specifications rigidly establish the feeding of the animals (only hay and grass: <https://www.parmigianoreggiano.com/product-guide-parmigiano-reggiano-grana-padano>)

Keep in mind that, according to the bibliography, an adult sheep produces about 1.64 kg of feces/day (about 600 kg/year).



Fig. 4: sheep grazing in the experimental field on August 9<sup>th</sup>, 2023





Empowering women in mountain farming communities

