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Consociation of Sunflower and Fodder Oilseeds - An Alternative for Mixed Production Systems

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Abstract: The process of agricultural development which takes place in Argentina has led to the loss of sustainability. Mixed systems could be an alternative for improving productivity and, at the same time, taking into account the environmental cost. The sowing of sunflower *(Helianthus annus L.)* consociated with other species can generate greater biomass and, in some cases, greater yield. Such practice is about the differential harnessing of resources. The aim of this work was to evaluate the production of sunflower consociation with *Trifoliumrepens L.*, *Lotus corniculatus*, and *Vicia sativa*, and to determine the conditions of the remaining stubble. Treatments consisted in the use of monoculture sunflower with and without herbicides; intercrop sunflower with red clover, lotus and vicia. The yield of sunflower grain and the total air biomass of the stubble and of its components were evaluated at the time of harvesting, and, two and three months after harvesting. The highest value of available stubble at the time of harvesting was obtained in monoculture sunflower without herbicide. Two months after, there were no variations in the stubble biomass of the treatments. Three months later, there were significant differences registered between the treatments; the intercrops with red clover and lotus reached the highest volume of stubble. Under the conditions of this test, the highest productivity of sunflower was registered when sowed in monoculture and herbicide application was employed. No differences were registered between the intercrops, or between them and the monoculture with herbicide. Therefore, these systems could be considered as a production alternative to lessen the use of synthetic inputs, such as herbicides.

Keywords: Diversity, Intercropping, Stubble, Sustainability, Yield

Introduction

Over the last couple years, a major process of agricultural development has taken place in Argentina, due to a propitious context where the relative price of grains was more favorable compared to that of meat. As a consequence, there was a significant reduction of the surface for pastures and a stagnation and relocation of beef cattle.

The productive upsurge in Argentina responds to a model of industrial agriculture with a considerable input employment, which in turn causes high costs in the product and numerous negative impacts in the agroecosystem (Pengue, 2014).

This process of agricultural development has brought undesired consequences, such as the unsustainability of agroecosystems, due to an increase of erosion, accumulation of environmental waste, and lack of biodiversity, leading to the depletion of non-renewable natural resources (Resch, 2003).

At current times, there is a greater awareness about the need to replace the previous productive paradigm, which modifies the environment adapting it to the genotype, in order to exploit its yield potential. Sarandón (2002) claims that sustainable agriculture is not in itself a system, but a way of understanding agricultural production. Therefore, there is a need to develop an agricultural system which is economically viable and sufficiently productive, at the same time that it preserves the base of natural resources and the integrity of the environment at a local, regional and global level (Sarandón and Sarandón, 1993).

Mixed systems may be an alternative to increase the economic outturn and improve the biological sustainability of production systems. It is known that the incorporation of rotating pastures improves the physical and chemical properties of the soil; however, its contribution to the agricultural production was given little value (Savilla and Pasinato, 2006). Agricultural-livestock rotation has been described as a stable and energy efficient system (Puricelli, 1985), as long as it is based on pastures and it employs a minimal external input derived from fossil fuel (Cieza and Flores, 2004).

Another strategy which contributes to the productivity within a sustainable framework is polyculture. Polycultures consist of growing two or more species during all of part of their cycle (Liebman and Dick, 1993; Sarandón and Labrador Moreno, 2002; Sarandón and Chamorro, 2003) while helping achieve diversification. Moreover, polycultures provide more efficiency in the use of resources and contribute to a better behavior against the adversities (Poggio, 2005; Malèzieux et al., 2008). For this reason, they are considered an appropriate ecological tool to help reduce the use of external input (Amador and Gliessman, 1990). However, they are not frequently put into practice in extensive production systems of temperate areas (Sarandón and Labrador Moreno, 2002).

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The most efficient use of resources in polycultures (Smithson and Leneé, 1997; Dhima, et al., 2007; Malèzieux et al., 2008) can be explained by the principle of competitive production (Vandemeer, 1981). Therefore, the morphophysiologic differences between the components of the mixture can determine a differential use of the available resources (Altieri, 1995, 2002). As a result, a greater biomass per unit of surface is obtained (Vandemeer, 1981; Poggio, 2005), as well as a greater yield (Ndakidemi and Dakora, 2007). Moreover, mixed croppings improve water infiltration, decrease erosion, provide nitrogen when the complement crop is an oilseed, and decrease the economic risk (Acciaresi and Sarandón, 2002).

Polyculture outcome depends on the characteristics of its components, the environment, the design of the technology involved, and the interactions between all these elements (Hauggaard, Nielsen et al., 2001; Malèzieux et al., 2008). The complexity of the mechanism entails the understanding of the agroecological principles governing it, carrying out a holistic and systemic analysis (Odum, 1984), and testing such practice with global criteria (Girardin and Bocktaller, 1997).

Soybean cultivation during the last years in Argentina has become practically the only cultivation in wide-ranging productive extensions, and has reached a surface of 17 million ha, sown in 2017 (MAGyP, 2019). It produced the displacement of other cultivations, such as sunflower. Also, it caused the displacement of livestock productions. This agriculture development and, in many cases, the monoculture adopted for economic or practical matters, have led to a greater input dependence, such as the use of energy, seeds and agrochemicals. These practices have also caused the damage of the soil and water, and the loss of genetic variability, biodiversity, and socio-culture. In view of this situation, it is necessary to redesign agroecosystems in such a way that productive managements are able to generate resilient systems. Therefore, the management with an agroecologycal perspective is a viable alternative (Nicholls, 2013).

Sunflower is a major crop in Argentinean extensive production systems; it is the second sown oilseed rape with an outstanding growing role in the market (MAGyP, 2019). Its production as a hybrid monoculture is oriented to maximize yield. However, Hernandez and Orioli (1994) pointed out the need to improve the capacity of the sunflower ideotype to produce under the conditions of intercropping. Some authors have tested the mixture of different species, such as mustard and sunflower (Putnam and Allan, 1992); soy and sunflower (Calviño, 2005; Lande et al., 2012); maize, sunflower, giant múcura and creole pumpking (Borsuk et al., 2005); tomato and sunflower (Claro et al., 2005).

In Argentina, Eirin et al. (2015) observed that the intercrop of sunflower and red or white clover, sown in different spatial arrangements, showed no alterations in the productivity of sunflower. It also maintained the stubble availability and improved its protein quality. Moreover, the consociation of sunflower and red clover or lotus registered a higher portion of oilseeds in the stubble, and achieved an acceptable grain yield, compared to the monoculture (Sánchez Vallduví et al., 2012). The sowing of sunflower and an oilseed rape is expected to become a strategy to improve the stubble utilization for livestock. The aim of this work was to evaluate sunflower productivity both in monoculture and intercrop with *Trifolium pratense* L., *Vicia sativa* L., or *Lotus corniculatus* L., as well as to study the quantity and quality of the remaining stubble in different moments of the sunflower harvesting.

Materials and Methods

This study was carried out in a plot of the Experimental Unit "Julio Hirschhorn" of the School of Forestry and Agricultural Sciences of the National University of La Plata (UNLP), located in Los Hornos, Argentina (34º 52' SL, height 15 masl).

An analysis of the soil in the surface horizon (0-20 cm) was conducted and the results obtained were: Ph (1: 2.5): 6; C: 1.79 %; P: 12 ppm and OM: 3.09 %.

Treatments:

1. Sunflower monoculture with pre-emergent herbicide (HS).
2. Sunflower monoculture (*Helianthus annuus* L.) without herbicide (S).
3. Sunflower and vicia intercrop (*Vicia sativa* L.) without herbicide (VS).
4. Sunflower and red clover intercrop (*Trifolium pratense* L.) without herbicide (CS).
5. Sunflower and lotus intercrop (*Lotus corniculatus* L.) without herbicide (LS).

An experimental randomized block design with four replications was used. Conventional tillage practices were performed. A commercial sunflower hybrid (Paraíso 20) was sown on October 13th, 2013 with a density of 57,000 pl/ha^{-1} , in plots of 8 meters of length and 5 furrows separated at 0.7 m from each other. Oilseeds were sown by hand randomly on the same date as the sunflower. Sowing densities consisted of: vicia 45 kg.ha^{-1}, red clover and lotus 16 kg.ha^{-1}. In the treatment of sunflower monoculture with herbicide, fluorocloridone 25% was applied, at a rate of 3 l.ha^{-1}, as pre-emergent herbicide. The sunflower phenological stages during the study were registered in accordance to the Schneiter-Miller-Koop registration key (1981) (Table 1). The precipitations and mean temperature during the fallow and cultivation cycle were also registered (Figure 1).

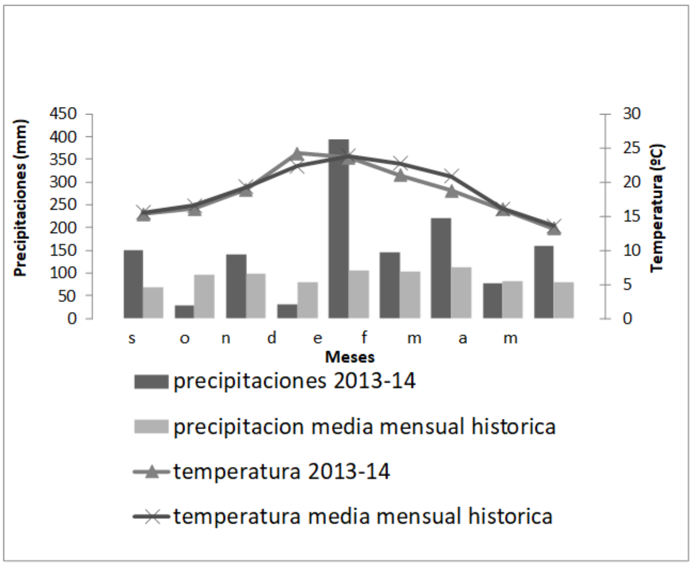
Table 1: Phenological stages of sunflower. La Plata, Argentina. 2013/2014

Phenological stage	Description	Date
VE	Seedling emergence	24/10/2013
V7	7 real leaves, first odd leaf	16/11/2013
R1	Inflorescence surrounded by immature bracts becomes visible	2/12/2013
R5	Flowering	27/12/2014
R9	Physiological maturity	19/02/2014

Sunflower was harvested on 26/02/2014. Grain yield and total biomass of the sunflower and stubble were evaluated (sum of vegetative biomasses of sunflower, oilseeds and vegetative spontaneous community). This last variable was registered and evaluated in three different moments: at the harvesting of sunflower, and, after harvesting, on 21/4/2014 and 26/5/2014. Sunflower biomass was determined from composite samples of four plants per treatment cut above ground level, whereas for oilseeds and spontaneous vegetal community species, two cuts of 0.25 m^2 above ground level were performed per treatment. All the material was oven dried at 60 °C until constant weight was obtained. Data were analyzed by means of variance analysis, and LSD method was used for the means comparison at a 0.05 level of probabilities.

Results and Discussion

Rainfalls during the cultivation cycle were of 721 mm, a higher value to one pointed out by Andrade and Sadras (2000) to cover the hydrological requirements of sunflower. However, we can observe from the rainfalls distribution that, during November and December, the amount of occurred rainfalls was lower than the historical amount of the place where the test was carried out, and significantly higher in January. Temperatures showed no variation compared to the historical month means. (Figure 1)



Rainfalls (mm) – Temperature (°C) – Months S O N D J F M A M
Rainfalls 2013-2014
Historical mean monthly rainfall
Temperature 2013-14
Historical mean monthly temperature

Figure 1: month rainfalls and mean monthly temperatures during the experiment and their respective historical month means.

At harvest time, the composition of spontaneous species was different depending on each treatment. In monoculture with herbicide, there was a lower proportion of species variety than in the other treatments. The treatments with the greatest proportion of variety were *Solanum chacoense* (mount potato) and *Cyperus rotundus* (green onion). Sunflower monoculture without herbicide and intercrops showed a greater species veriety and the species of greater scope were *Solanum chacoense* (mount potato), *Amaranthus quitensis* (yuyo colorado), *Chenopodium álbum* (quinoa), *Digitaria sanguinalis* (lent grass), *Anoda cristata* (mallow) y *Cyperus rotundus* (green onion).

Sunflower grain yield and total air biomass were significantly higher in monoculture with herbicide than in the rest of the treatments. No differences were observed between sunflower monoculture without herbicide and intercrops (Table 2). In this trial, intercrops showed no yield improvement compared to the register of Putnam and Allan (1992), or Eirin et al. (2015). However, these results suggest that the consociation with oilseeds can be an acceptable production alternative, for it guarantees a sufficient sunflower productivity. All the treatments showed to have a yield above the national mean, 2039 kg.ha^{-1} for the season 2018/19 (MAGyP, 2019), one of the requirements by Sarandón and Sarandón (1993) for an agriculture to be considered sustainable.

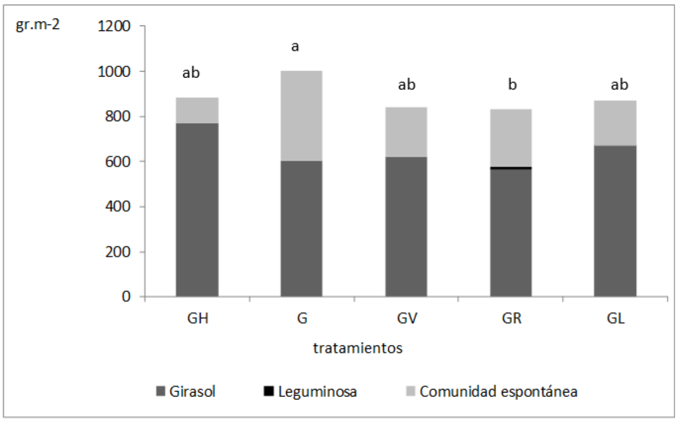
Table 2: yield in grain and total air biomass of monoculture sunflower with (HS) and without herbicide (S) or in intercrop with vicia (SV) red clover (SC) or lotus (SL). La Plata, Argentina. 2013/14.

	Yield ($g.m^{-2}$)	**Sunflower Total Biomass ($g.m^{-2}$)**
SH	390 a	1158 a
S	288 b	890 b
SV	288 b	908 b
SC	224 b	790 b
SL	272 b	938 b

Values within the same column followed by the same letter do not differ to a 0.05 level of probability according to LSD test.

When evaluating the composition of the stubble after sunflower harvest, differences between the three registered moments were observed. (Figure 2)

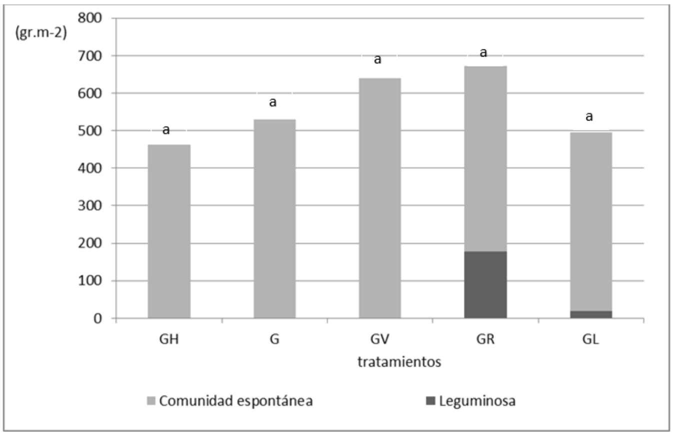
The higher value of available stubble at the time of harvest was in monoculture sunflower without herbicide. This was related to a greater biomass of spontaneous species, compared to the other treatments. The sunflower and clover intercrop showed the smallest residue weight, but approximately a 10 % of its biomass was composed of oilseed.
Sunflower and vicia intercrop residue showed no presence of oilseeds due to the fact that the cycle of the latter ended at the time of sunflower harvest. Yet it was present during the development of the cultivation.



Treatments
Spontaneous plant community
Oilseeds
Sunflower

Figure 2: residue biomass after sunflower harvesting (26/02/14) and its composition: oilseeds, spontaneous plant community and monoculture sunflower with (SH) and without (S) herbicides, and in intercrop with vicia (SV), red clover (SC), or lotus (SL).

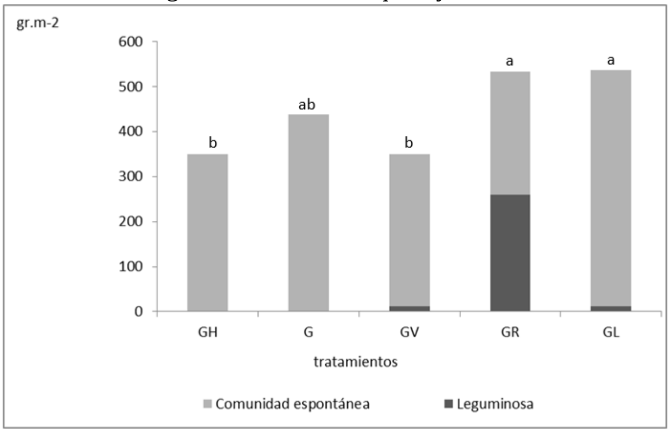
Stubble biomass two months after sunflower harvest showed no variation between treatments (Figure 3). However, if we observe the contribution of oilseeds to the composition of stubble, there is a significant presence of oilseeds in the sunflower and red clover intercrop, where the contribution of red clover consists of 24 % of its weight. In the case of sunflower and lotus intercrop, oilseeds make almost 5 % of the stubble weight. Therefore, protein quality of the stubble would be significantly higher, as it was suggested by Eirin et al. (2009), and Eirin et al. (2015).



Treatments
Spontaneous plant community
Oilseeds
Sunflower

Figure 3: residue biomass two months after sunflower harvesting (26/02/14) and its composition: oilseeds and spontaneous plant community in a cultivation of monoculture sunflower with (SH) and without (S) herbicides and in intercrop with vicia (SV), red clover (SC) or lotus (SL).

Significant differences were registered between the treatments in the evaluation of the stubble biomass after three months of the sunflower harvest (Figure 4). At this moment, it was observed that both sunflower and red clover, and sunflower and lotus intercrops reached the greatest volume of stubble, and showed no differences with the monoculture without herbicide. In the sunflower and red clover intercrop, oilseeds represented 50 % of the stubble total weight, and 2 % in the case of the sunflower and lotus intercrop. In the sunflower monoculture with herbicide and sunflower and vicia intercrop, a smaller stubble biomass was observed. However, there was a 3 % of oilseed weight. These results suggest that, despite the small amount of oilseeds in stubble at the moment of harvesting, their amount increased with time, especially in the case of red clover, thus contributing to a better fodder quality of the stubble.



Treatments
Spontaneous plant community
Oilseeds
Sunflower
Figure 4: residue biomass three months after sunflower harvesting (26/02/14) and its composition: oilseeds, spontaneous plant community in a cultivation of monoculture sunflower with (SH) and without (S) herbicides and in intercrop with vicia (SV), red clover (SC) or lotus (SL).

The fodder production obtained from the sunflower-oilseed consociations at the moment of harvesting was higher than the values mentioned by Correa Luna (2008) for maize and soy stubbles, two most commonly used crops in the Argentine Pampa Region, varying between 3000 and 5000 kg DM/ha. Whereas, after the 60 and 90 days of sunflower harvest, the availability of stubble was lower than the registered amount at the time of harvest (3840 kg/ha y 5200 kg/ha).

The composition of the system's biomass (sunflower, oilseeds and weeds) showed differences between the treatments in the different cutting times (Figures 2, 3 y 4). Sunflower and red clover intercrop achieved the highest weight value of oilseeds in every evaluated moment. It is common to expect that sunflower consociation with these oilseeds, especially red clover, contributes to a more diverse harvest residue, as regards the number of species composing it, and its quality improvement, due to the nitrogen content of oilseeds. This is important both for soil incorporation (Park & Cousins 1995) and for livestock feeding of the stubble, since it is expected to contain a higher nutritional value, as suggested by Eirin et al (2009), who observed a higher protein value in sunflower and red clover intercrop, compared to the one in sunflower monoculture.

Conclusion
Under the conditions of this study, the higher productivity of sunflower was registered when sown in monoculture with the use of herbicide. However, intercrops showed acceptable values of productivity for the region.

Intercrop of sunflower and red clover was found to improve the quality of the stubble at harvest time as well as after it. This system can be considered a tool which may contribute to the agroecological management of the sunflower cultivation, for low input models of production. Moreover, after harvest times, these treatments can provide a higher quality stubble for animal feeding than the one provided by monoculture sunflower. Finally, the incorporation of harvest residue to the soil may be an alternative to the use of synthetic fertilizers and it may help reduce their use.

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