AP AGRO PRODUCTIVIDAD

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Forage evaluation based on oat on scenarios of intercrop and organic nutrition

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ABSTRACT

Objective: To evaluate the behavior of yield with different varieties of oat under monoculture and association conditions, applying different sources of nutrition.

Design/Methodology/Approach: Oat varieties were sown under monoculture conditions and 50% association, applying three sources of plant nutrition and a control, in the autumn-winter cycle. A completely randomized design with a factorial arrangement (3×3×4) was used, with the factors being the varieties of oats (chihuahua, turquesa, karma), the associations (monoculture, triticale and vetch) and the sources of nutrition (*Glomus fasciculatum* mycorrhiza, liquid bat guano, combination and control).

Results: Chihuahua stood out in dry matter (DM) yield, productivity index, leaf: stem ratio, harvest index and leaf area index, the karma variety stood out in botanical composition, Land Equivalent Ratio (LER), height and number of leaves. The association with triticale stood out in DM yield, productivity index and botanical composition. The vetch stood out in LER, leaf: stem ratio, harvest index and leaf area index. The monoculture stood out in the height of plants and number of leaves. The guano highlighted the harvest index, maintaining statistical equality with the mycorrhiza in LER.

Study Limitations/Implications: The results are based on the interaction of the factors with an irrigation regime in the temperate climate of the Valles Centrales of Oaxaca, Mexico.

Findings/Conclusions: The variety that stood out the most was the karma variety; however, the quality of the chihuahua variety can be discussed when comparing the relationships of the variables. The crop association that generated the best results was vetch, while triticale generated higher yields. The nutrition that generated the best results was guano, and there were a large number of statistical equalities with the control.

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INTRODUCTION

Oat (*Avena sativa* L.) is a fodder crop from temperate climates, of agronomic interest in Mexico, since a growth of 1.28% has been estimated for annual production between the year 2016 and 2030 according to data from SAGARPA (2017). It is a plant that stands out due to its use in livestock feed, because of its nutritional wealth that can be attributed to avenanthramides that are present in different amounts according to the variety of oat, as mentioned by Raguindin *et al.* (2021) and Ortiz-Robledo *et al.* (2013).

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When it comes to yield, Mendoza-Pedroza *et al.* (2021) mentions that the chihuahua variety present yields of note throughout its productive life. In this regard, Flores-Juárez *et al.* (2019) indicate that the varieties turquesa and chihuahua do not present significant difference in the production of dry matter (DM).

Crop association in oat production is a technique used to improve yield and resources, and in this regard, Colque-Romero (2002) conducted trials with triticale, associated with oat and vetch, obtaining results that are statistically equal in terms of DM yield. However, Lithourgidis *et al.* (2006) mention that oat height decreases in association, compared to its monoculture.

In contrast, in the oat-vetch association yields have been obtained of 16.6 t ha^{-1} (Flores-Nájera *et al.*, 2016). In this sense, the association of oat and vetch has been described as a technique to generate higher yields of green fodder, DM and fodder quality, compared to the oat monoculture, according to Espinoza-Montes *et al.* (2018). Vetch has been shown to reduce loss of fertile soil (Rodrigo-Comino *et al.*, 2020), that is, it contributes to soil mechanics. The quality of vetch as a nutritional element has been proven when used as a substitute for soy flour (25%) for lamb feed (Gül *et al.*, 2005); however, it has been noted that its use in monogastric animals is not favorable (Huang *et al.*, 2017).

Organic nutrition, when considering the systematic processes of soil and its microbiology, such as the application of beneficial microorganisms, has shown favorable improvements in the rhizosphere of crops (Li *et al.*, 2020; Trujano *et al.*, 2008). The application of biofertilizers like bat guano improves the amounts of organic matter, C, N, Ca and Mg, and increases the soil microflora (Sridhar *et al.*, 2006). As complement, the mycorrhiza *Glomus fasiculatum* facilitates the absorption of P, Ca, Fe, Mg, Zn, N (Rodrigues & Rodrigues, 2020), causing an increase in the development of the oat's leaf area and DM yield, without affecting the leaf:stem rate and plant height (Flores-Juárez *et al.*, 2019). About this, Torres *et al.* (2016) and Santana-Espinoza *et al.* (2020) mention that in oat production, results can be obtained that are statistically equal in 100% inorganic nutrition and 100% organic nutrition, which is opposite to that found by Montaño-Carrasco *et al.* (2017) who recommend the use of organic fertilizers to improve the yield and quality in the production of fodder oat.

The objective of the study was to evaluate the yield of different oat varieties in conditions of monoculture and association, applying different sources of nutrition.

MATERIALS AND METHODS

The study was conducted in the autumn-winter cycle (November-March) at the facilities of Instituto Tecnológico del Valle de Oaxaca, with address Ex Hacienda de Nazareno Sn Agencia de Policía Nazareno, Centro, 71230 Santa Cruz Xoxocotlán, Oaxaca (17° 01' 07.4" N and 96° 45' 51.5" W) at 1558 masl. The crop was maintained under irrigation conditions.

A completely randomized design was used with factorial arrangement ($3 \times 3 \times 4$), where the factors were the oat varieties (chihuahua, turquesa and karma), the crop association in 50:50 proportion (monoculture, triticale and vetch), and the organic nutrition (control, mycorrhiza *Glomus fasiculatum*, liquid bat guano, and a combination of the two), for a total of 36 treatments established in plots of 16.67m^2.

Plowing tasks and broadcasting sowing with a density of 120 kg ha^{-1} for each treatment were carried out; sowing was done under equal conditions, since all the seeds were found without alterations at the time. Depending on the treatment, the following were applied weekly: 4 l ha^{-1} of leaf bat guano, 6 kg ha^{-1} of mycorrhiza *Glomus fasciculatum* via soil (on the soil) diluted in water (20 spores per gram of soil, with purity of 85-98%), and the combination which had an application of 50% guano and 50% mycorrhiza; in every case a spray pump with capacity of 20 l was used.

The DM yield was obtained by cutting fodder (120 days) in four samples of 0.25 m^2 for each treatment, making use of a metallic square of 0.5 m per side, which was thrown randomly, and collecting only the plants that sprouted within the sampling area; then the total weighing of each sample was carried out in a digital scale of 20 kg capacity, obtaining the estimation of green matter yield. A subsample was obtained which was subjected to 6 days in a drying chamber at 70 °C to calculate the percentage of DM and thus estimate the DM yield (kg ha^{-1}). The ratio between yield in DM and the days to harvest, which in every case was 90 days, was calculated in order to obtain the productivity index. The botanical composition was calculated for each sample obtained, in a scale of 0 to 1, based on the ratio between the oat weight in the sample and the total weight of the sample. With the objective of defining whether there was a benefit in the oat yield compared to its monoculture, the Land Equivalent Ratio (LER; Mead & Willey, 1980) was calculated, using the following formula:

$$LER = Y_{ai} / Y_a$$

where Y_{ai}=oat yield in association and Y_a=oat yield in monoculture.

The leaf:stem ratio was calculated based on the subsamples, which were separated into their morphological components and weighed after drying, through the calculation of weight (leaf)/weight (stem). The harvest index was calculated from the ratio of weight of the leaf subsample and total weight of the subsample. The leaf area index was calculated from the weight of 1 cm^2 of leaf DM (per species), making use of the digital Vernier and an electronic gram scale; then, the leaf DM yield per treatment was calculated from data obtained from the harvest index and DM yield, and next the relation between this 1cm^2 and the leaf DM yield was calculated for each species and for each treatment.

Non-destructive sampling of five plants selected randomly was conducted at the time of cutting, where the distance between the ground and the spike (or the maximum point) of the plant was measured with a tape measure. A non-destructive count of the number of leaves from five samples per treatment was performed; vetch has compound leaves, so these were considered for the count.

The corresponding data were recorded in a spreadsheet and analyzed through the statistical software SAS On demand version, performing analysis of variance and means comparison with Tukey's test ($P \leq 0.05$).

RESULTS AND DISCUSSION

As Table 1 shows, the chihuahua variety presented the highest yield, which outperformed the turquesa and karma varieties by 14 and 77%, respectively, which agrees with what was reported by Mendoza-Pedroza *et al.* (2021), presenting different results from those mentioned by Flores-Juárez *et al.* (2019). Regarding the variables of interspecific competition, the karma oat stood out in botanical composition, since it allowed higher coexistence with its associations, and since it is the variety with highest LER, it can be noted that these associations increased the productivity yield, compared to its monoculture, which has a LER value of 1.4629; therefore, it is interpreted that the associations generated 46% more of karma oat production compared to the monoculture.

The association with triticale presented higher yields in fodder and botanical composition, meaning that having a better response with the oat allowed for both the oat and the triticale to produce sufficient DM, compared to the association with vetch and the monoculture, having different results from those reported by Colque-Romero (2002). However, the association with vetch stands out in LER, so that due to its value being 1.7754, it can be interpreted that it increases oat production by 77.54%, although since its contribution is minimal in botanical composition, since oat covered 96.35%, it can be understood that the values of yield and productivity index are statistically equal to monoculture, result that differs from what was described by Espinoza-Montes *et al.* (2018) and Flores-Nájera *et al.* (2016).

The application of bat guano and the mycorrhiza *Glomus fasciculatum* did not present a difference in the yield variables with the control, which is different from what was reported by Flores-Juárez *et al.* (2019), who reported higher yields with the use of mycorrhiza. However, Li *et al.* (2020), Montaño-Carrasco *et al.* (2017) and Sridhar *et al.* (2006) mentioned that when observing both the mycorrhiza and the guano, the latter in kind, they were a factor that contributed to oat being able to stand out in LER, since the application of

Table 1. Means comparison of the variables of fodder yield and interspecific competition.

Factor	Level	Yield		Interspecific competition	
		Yield kg DM ha^{-1}	Productivity index	Botanical composition	LER*
Variety	Chihuahua	8720.75 a	96.897 a	0.9757 c	1.1759 b
	Turquesa	7620.64 b	84.674 b	0.9444 b	1.2660 b
	Karma	4929.17 c	54.769 c	0.9105 a	1.4629 a
Association	Monoculture	6647.76 b	73.864 b	1.0000 c	1.0000 b
	Triticale	7991.65 a	88.796 a	0.8671 a	1.1294 b
	Veza	6631.14 b	73.679 b	0.9635 b	1.7754 a
Nutrition	Witness	7173.64 a	79.707 a	0.9554 a	1.0110 c
	Combined	7048.70 a	78.319 a	0.9427 a	1.2167 bc
	Micorriza	7054.06 a	78.379 a	0.9399 a	1.4359 ab
	Guano	7084.33 a	78.715 a	0.9361 a	1.5429 a

*Earth equivalent ratio.
Treatments with different letters in the column are statistically different (Tukey $P \leq 0.05$).

these nutrients allowed the oat in association to have higher production compared to the monoculture.

Table 2 shows that the chihuahua variety presented higher values in the variables of leaf production, being that the leaf:stem ratio was equal to the karma variety. About the associations, vetch stood out in terms of the leaf production in every case. Regarding the nutrition, guano was constant in its influence for leaf production, being that the variables of leaf:stem ratio and harvest index did not have significant difference with the control. The mycorrhiza favored the leaf area index, which agrees with what was reported by Flores-Juárez *et al.* (2019), although this variable did not have a significant difference with guano or with the combination of nutrients.

Table 3 shows that the karma variety was the one that generated a higher number of leaves, both for itself as oat and for its associations, since the greater heights were for this

Table 2. Means comparison of the variables related with the fodder leaf.

Factor	Level	Leaf:stem ratio	Harvest index (leaf)	Leaf área index
Variety	Chihuahua	0.739 a	0.3487 a	3.9458 a
	Turquesa	0.507 b	0.2335 c	1.9127 b
	Karma	0.688 a	0.2744 b	2.2441 b
Association	Monoculture	0.581 b	0.2576 b	1.922 b
	Triticale	0.483 c	0.234 b	2.133 b
	Veza	0.804 a	0.3649 a	4.046 a
Nutrition	Witness	0.7056 a	0.309 a	2.322 b
	Combined	0.5947 b	0.271 b	2.743 ab
	Micorriza	0.6067 ab	0.273 b	3.039 a
	Guano	0.6735 ab	0.288 ab	2.698 ab

Treatments with different letters in the column are statistically different (Tukey P≤0.05).

Table 3. Means comparison of the growth variables per species.

Factor	Level	Oats		Triticale		Vetch	
		Plant height cm	Number of sheets	Plant height cm	Number of sheets	Plant height cm	Number of sheets
Variety	Chihuahua	94.11 b	7.61 b	109.29 b	5.85 a	33.075 c	8.90 c
	Turquesa	101.10 a	8.18 a	123.45 a	5.25 a	40.340 b	10.55 b
	Karma	106.12 a	8.28 a	95.83 c	5.00 a	57.705 a	14.75 a
Association	Monoculture	115.50 a	8.95 a				
	Triticale	103.29 b	7.58 b				
	Veza	82.54 c	7.55 b				
Nutrition	Witness	102.48 a	8.42 a	117.82 a	5.66 a	40.16 b	11.33 a
	Combined	102.30 a	8.04 ab	103.92 ab	5.80 a	36.68 b	9.00 b
	Micorriza	92.90 b	7.62 b	102.27 b	5.06 a	53.55 a	12.93 a
	Guano	104.08 a	8.02 ab	114.08 ab	4.93 a	42.42 b	12.33 a

Treatments with different letters in the column are statistically different (Tukey P≤0.05).

variety of oat and for its association with vetch. However, statistically, the monoculture presented a greater height and number of leaves than its associations, datum that agrees with what was mentioned by Lithourgidis *et al.* (2006). Regarding nutrition, statistical equality can be seen between the guano and the control, being that the predominant values are mostly those of the control.

CONCLUSIONS

The chihuahua variety presents a similar behavior in leaf:stem rate to the karma variety, which is the variety of smallest size and with the least number of leaves. The dry matter yield is higher indicating that the number of leaves per ha will be higher than the karma variety can produce. The karma variety was more benefitted with the associations. Triticale and vetch were benefitted with the karma variety, with the highest number of leaves found with this variety. The botanical composition was predominantly oat, and although the dry matter yield of vetch is similar to that of the monoculture, it was generated with just half of the oat seed. In the growth variables, the mycorrhiza generated better results in the associations with vetch, not so in the monoculture or in the association with triticale. The guano and the mycorrhiza stood out as factors that allowed the oat to increase LER and botanical composition in the associations.

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