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WEEDS IN CROPS OF AVOCADO, TREE TOMATO, PASTURE AND FORAGE AND THEIR RELATION TO YIELD AND PRODUCTION COSTS

Arvenses en cultivos de aguacate, tomate de árbol, pastos y forrajes y su relación con el rendimiento y costos de producción

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ABSTRACT. Moderate cold weather areas in Colombia is characterized by different production systems highlighting avocado crops, tree tomato, pastures and forages for animal feed. Among the most limiting factors for its production is the weed plants. This study has as objectives to recognize associated weed and management practices, in addition to identifying the relations of these with the yield and the costs of production in avocado, tree tomato, pastures and forages crops. Municipalities were selected with moderate cold weather in Antioquia and in each one, three lots. With theses systems, all weeds were identified taxonomically, also management, yield and production costs were determined for each one. With the data of incidence, diversity, and practices of management of weeds and through a logistic regression model was evaluated its relation with the yield and costs of production. This work found that weeds associated with tomato crops, pastures and forages, present a greater imbalance with respect to the production system avocado, which gives rise to the lower diversity and high incidence of a few species for these systems. Meanwhile the practice is more widespread and higher cost generated was chemical control, although under avocado production system there are other management measures, as the use of mulches, mechanical control, among others. It is necessary to determine an integrated management plan for the weeds, in search of greater ecological sustainability and an economic and environmental use of the secondary species within agroecosystems.

Key words: abundance, chemical control, diversity

RESUMEN. Las zonas de clima frío moderado en Colombia se caracterizan por presentar distintos sistemas productivos, destacándose los cultivos de aguacate, tomate de árbol, pastos y forrajes para la alimentación animal. Dentro de los aspectos limitantes para su producción se encuentran las plantas arvenses. Este trabajo tuvo como objetivos conocer las arvenses asociadas y sus prácticas de manejo, e identificar las relaciones de estas con el rendimiento y los costos de producción en cultivos de aguacate, tomate de árbol, pastos y forrajes. Se seleccionaron municipios con clima frio moderado de Antioquia y en cada uno de ellos tres lotes con estos sistemas. Se realizó la identificación taxonómica de las arvenses asociadas, asi como se determinaron las prácticas de manejo, rendimiento y costos de producción. Con los datos de incidencia, diversidad y prácticas de manejo de arvenses y mediante un modelo de regresión logística se evaluó su relación con el rendimiento y costos de producción. En el estudio se encontró que las arvenses asociadas a los cultivos de tomate, pastos y forrajes, presentan un mayor desequilibrio con respecto al sistema productivo de aguacate, dando origen a que en estos sistemas haya una menor diversidad y alta incidencia de unas pocas especies. Por su parte la práctica de manejo más generalizada y que mayor costo representó fue el control químico, a pesar de que bajo los sistemas de producción de aguacate existen otras medidas de manejo como el uso de coberturas, control mecánico, entre otros. Se hace necesario determinar un plan de manejo integrado para las arvenses, en busca de una mayor sostenibilidad ecológica y un uso económico y ambiental de las especies secundarias dentro de los agroecosistemas.

Palabras clave: abundancia, control químico, diversidad

INTRODUCTION

The zone of moderate cold climate in the department of Antioquia, Colombia, is characterized by presenting different productive systems, which are characteristic of each zone and some common ones. Among the latter, the cultivation of avocado (*Persea americana* Mill), tree tomato (*Solanum betaceum* Cav), pastures and forages for animal feed stand out. The first is a perennial type system, which is based on the sowing of commercial varieties such as the Hass, whose area has grown in recent years,

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as a result of an unsatisfied offer and the export expectations that this fruit presents (1). For its part, the cultivation of tree tomatoes is an Andean fruit with broad perspectives of development as a productive alternative, given its nutritional and flavor qualities (2,3). With regard to the cultivation of pastures and fodder in the high Andean areas of Colombia, a high proportion is occupied by the species called Kikuyo grass (*Pennisetum clandestinum* Hoechst Ex Chiov), which makes it the main forage species for feeding milk-producing cows in cold weather (4,5).

Weeds are vegetable species that coexist with economic crops, where their presence can affect production, which is why management practices are required to avoid inter-specific competition during the critical period of the species under exploitation (6). The effect of this competition is reflected in the quantitative and qualitative reduction of production, in addition to increasing the operational costs of the harvest and the benefit of the agricultural product (7). It is reported that the decrease in the yield and quality of the harvests as well as the costs of the control of weeds can represent from 10 to 15 % the value of the production (8).

In unregulated inter-specific competition, weeds may become the most severe problem in world agriculture, given their direct damages such as competition for resources; in addition, their indirect role, where they can participate as hosts of pests and diseases (9). On the other hand, it is important to highlight that not all the flora considered as weed is harmful, since in many cases it has positive effects, leading to a greater ecological balance, which can translate into lower levels of pests and diseases, conservation of the soil resource, among others (8,10). It is important to highlight that the deleterious effect of these will be associated with the critical stage, where the species of importance is more susceptible to competition for resources (6).

The related studies on the identification of weeds associated with productive systems of avocado and tomato tree in moderate cold weather in Colombia, are scarce, which have addressed the issue in a general manner, without reporting a systematic sampling (11,12). On the other hand, at grass and forage level some weed reconnaissance work has been carried out, but in other climatic conditions (13,14). Given this condition, this work aimed to determine the incidence of weeds associated with productive systems of avocado, tree tomato and fodder in moderate cold climate, management practices developed by producers, in addition to identifying the relationships of these with performance and production costs in these production systems.

MATERIALS AND METHODS

Location of field sampling and processing of botanical samples in herbarium

The field sampling phase was developed in three regions of the Department of Antioquia, in moderate cold weather during the periods between 2013 and 2014. The selected municipalities were San Pedro de los Milagros, Entrerrios and Donmatías in the Northern Altiplano region, San Vicente, La Ceja, La Union and Sonsón in the East and Amaga and Jardín in the Southwest. In each municipality, three lots were selected for each evaluated production system (avocado, tree tomato, pasture and forage), which were located in an altitudinal profile of 1,800 up to 2 400 ma.s.l, with a range of temperature and precipitation of 16-22 ºC and 1800-2600 mm year^{-1} respectively (Figure 1). The laboratory phase was developed in the “Medel” herbarium of the National University of Colombia, Medellin.

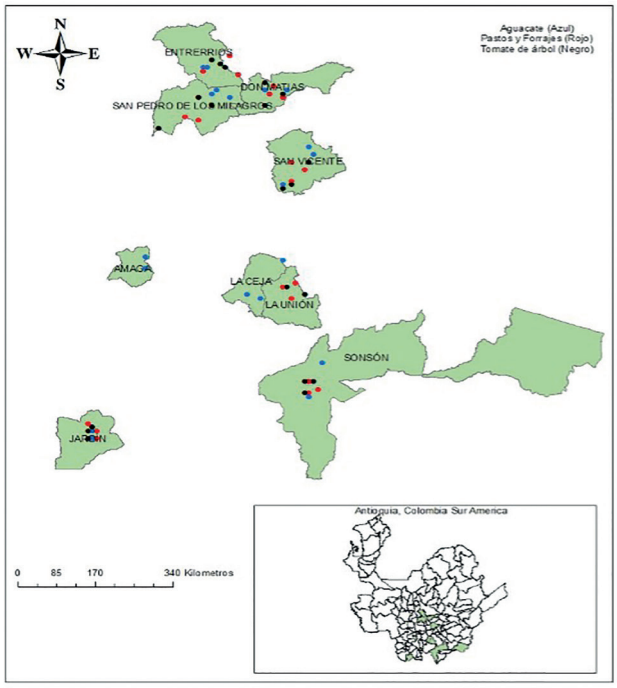


Figure 1. Geographic location of the lots sampled in avocado, tree tomato, pasture and forage crops in moderate cold climate of the Department of Antioquia, Colombia

Field sampling and taxonomic identification of weed species

In each of the selected municipalities, three lots were selected for each production system (Figure 1). For the avocado production system, only lots planted with the Hass commercial variety were sampled. On the other hand, for those associated with pastures and forages, the sampled farms were those established with the grass known as "Kikuyo" (*P. clandestinum*) and dedicated to cattle raising for the production of milk, so in the region of the Southwest only sampling was done in the municipality of Jardín. In each of the lots, 30 sites were selected at random, and a frame was launched with an area of 0,25 m^2 (0,50*0,50 m). The existing plant species were determined over the entire covered area. We proceeded to the identification by classic taxonomic characters, following the field guide for recognition of weeds in the central coffee zone of Colombia (15). For the case of plant species whose identification was not possible through this strategy, botanical samples were collected, including vegetative and reproductive parts. They were pressed in newspaper for transport to the Medel herbarium, where they were dried in an oven at 60 °C (Binder®) for three days; then the technical assembly was carried out for its identification in the herbarium by means of the comparison with the existing specimens. To each of the morphotypes found, a photographic record was taken, which was used as an aid for their taxonomic identification.

Determination of variables associated with weeds in the evaluated production systems

Based on the data obtained from the recognition of weeds, the incidence was determined, quantified as the number of presences of a given species, divided by the total of sampled sites. The diversity existing in each of the production systems was evaluated using the Shannon diversity index (equation 1). In each farm sampled, a characterization of the variables associated with its management was carried out; for which a structured survey was designed with a series of questions associated with the specific practices that can be used for the management of weeds, with dichotomous answers (yes or no), according to whether they were carried out or not by the producers. For each system, the production costs were determined, in addition to the average yield, quantified in avocado and tree tomato as the average quantity produced per year (t ha^{-1}); while for pastures and forages, this value was associated to the quantity of biomass produced by grazing cycle (40 days). Value determined by gauging with the same frame of sampling of the weeds and expressed in quantity of biomass per hectare (t ha-1).

Equation 1= $H' = -\Sigma_{i=1} (pi) (\log_2 pi)$

where:
H = Shannon Index
S = Number of species (species richness)
Pi = Proportion of individuals of species i with respect to the total of individuals (ie the relative abundance of species i), ni / N
n*i* = Number of individuals of species *i*
N = Number of all individuals of all species

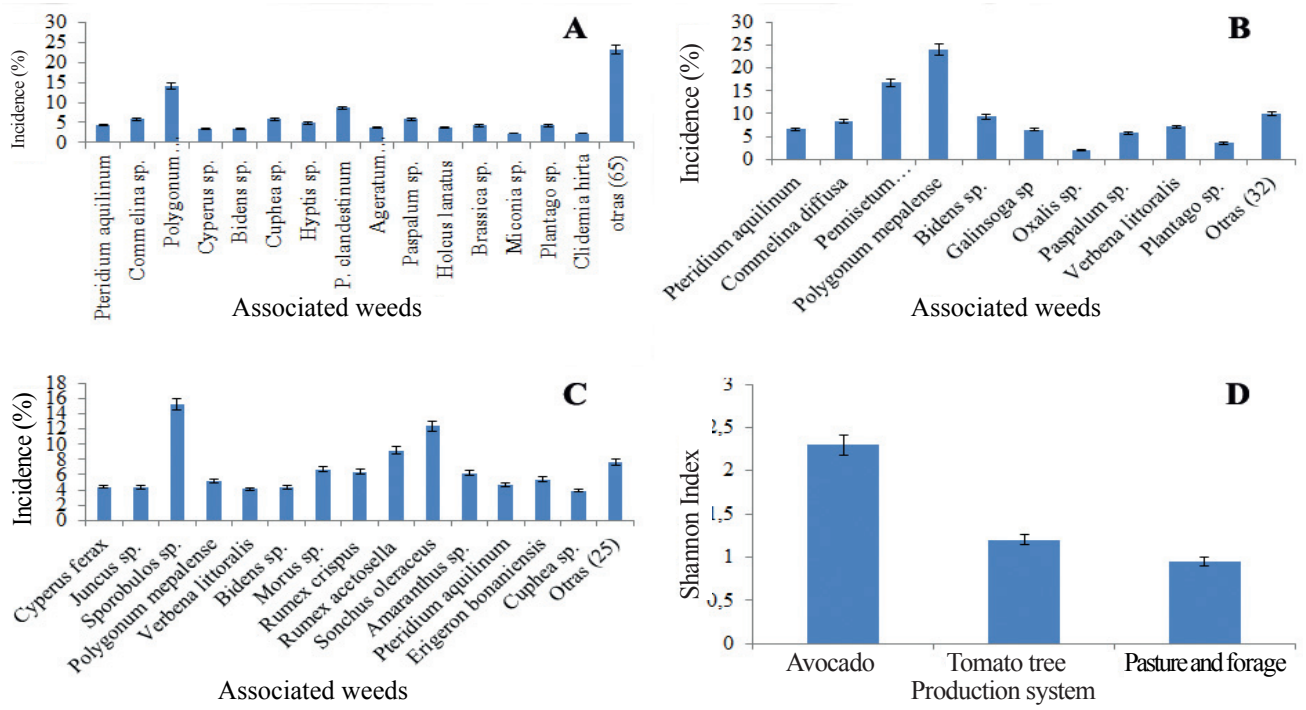
Analysis of data

For each production system, the incidence mean of each species of associated mate and the related management practices were determined, to which the confidence interval was calculated. The homoscedasticity and normality of the data were evaluated for the result of the Shannon diversity index ($P < 0.01$), using the Levene (16) and Kolmogorov-Smirnov (17) trials, respectively. The data were analyzed by variance analysis and Tukey's mean separation test (18), with a level of significance of 95 %. In order to establish the relationship between the weeds with the highest incidence (5 species) and the tasks for their management with the yields and costs associated with each production system, a generalized linear model was constructed, using logistic regression. All calculations were made using the r computer program.

RESULTS AND DISCUSSION

Recognitions and incidence of weeds present in production systems of avocado, tree tomato, pastures and forage

The weeds associated with avocado crops belonged in 75,8 % to a group of 15 species, which were homogeneously distributed in the three study zones, while the remaining 24,2 % were associated with 65 species, with location common and specific to a certain region. Among the most prevalent species, *Polygonum nepalense* Meisn., *P. clandestinum*, *Commelina* sp., *Cuphea* sp. and *Paspalum* sp. (Figure 2A). Some found in greater proportion and others reported in this work, have been enunciated as the main monocotyledonous and dicotyledonous species associated with avocado crops in cold climate zones in Colombia (12).



A:incidence of weeds in the avocado production system B: incidence of weeds in productive tree tomato system
C: incidence of weeds in productive system of pastures and fodder
D: shannon diversity index of weeds in productive systems of avocado, tree tomato and fodder
The bars in the figures represent the confidence interval of the means, where the superposition of these indicates that there are no significant differences (P>0.05).

Figure 2. Weeds and diversity associated with production systems avocado, tomato tree, grass and forage in cold weather in Antioquía

In the case of the tree tomato production system, 90 % of the incidence of weeds was represented by ten species, with homogeneous distribution in the three zones of study, while in the remaining 10 % it was associated with 32 species. The distribution in this system showed that there are weeds with a high incidence as is the case of *P. nepalense*, *P. clandestinum*, *Bidens sp*., *Commelina difusa* Burm. F., *Verbena listoralis* Kunth., Among others (Figure 2B). Some of these have been reported as weeds associated with this productive system, product of the ecology and presence in a certain area of life, but not of a systematic sampling whose objective has been the identification of weed species (11).

In the production of pastures and fodder, a situation similar to that of tree tomato was presented, since 14 species had an incidence of 92,4 %, while the remaining 7,6 % was associated with only 25 species. In this productive system the presence of weeds like *Sporobulos* sp., *Sonchus oleraceus* L, *Rumex crispus* L, *Morus* sp, among others (Figure 2C) stood out.

For the three production systems evaluated, the most relevant weeds were found to be associated with the family Poaceae, Hypolepydaceae, Poligonaceae, Conmelinaceae, Verbenaceae, Amaranthaceae, Cyperaceae, among others, which agrees with reports where it is considered that within weed species with greater prevalence and aggressiveness in different ecosystems are those that belong to the Poaceae family, although the Cyperaceae family can also stand out (19). Among the results found, species difficult to manage are reported due to their high interference capacity with the target species such as *Pteridium aquilinum* Kuhn, *Paspalum* sp., *Erigeron bonaniensis* L, *Cyperus ferax* L, *Cyperus* sp., among others (20). This situation generates the need to carry out the respective monitoring and determine the impact that these species of weeds present on the commercial crop, in addition to identifying the critical stages and fundamental aspects of their ecology, in order to achieve a technical management of the problem.

Index and diversity of weeds in production systems of avocado, tree tomato, pastures and forage

The evaluation of diversity levels of weeds (Figure 2D), using the Shannon index, showed that in avocado production systems this indicator was statistically higher (P<0,05) than the value found in tree tomato,

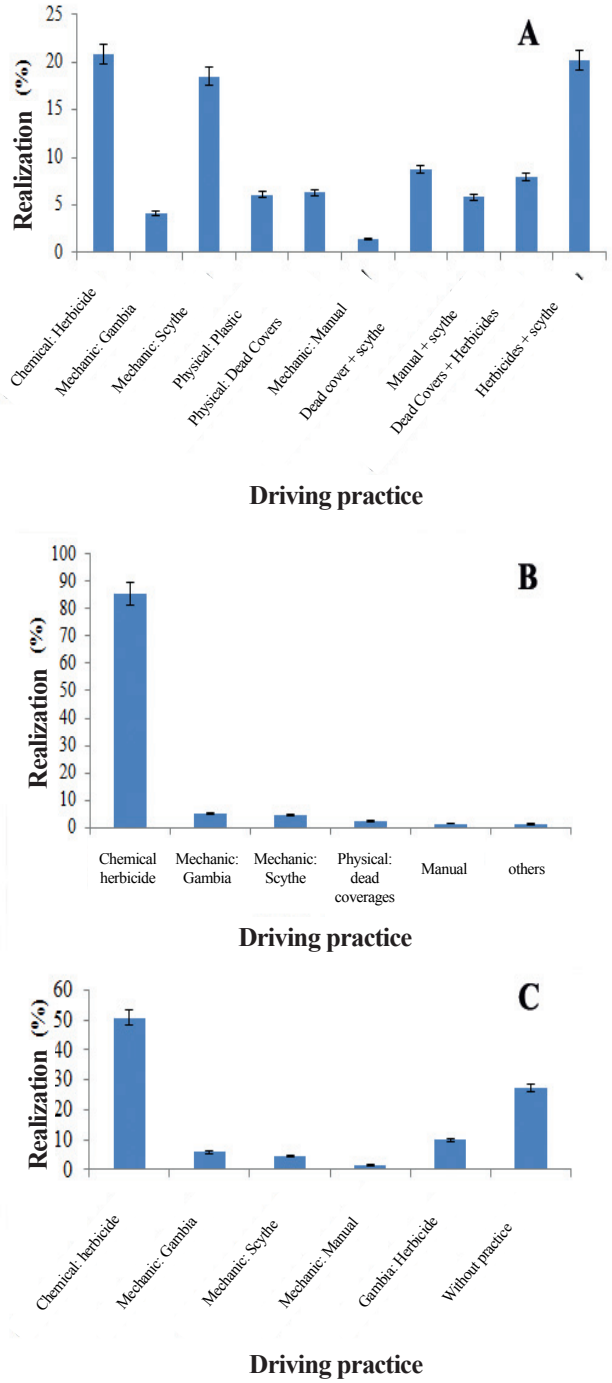
pastures and forages; the differences found in these last two were not statistically different (P> 0,05). These results are shown in Figures 2A, B and C, where it could be identified that for the avocado production system the incidence of weeds is more homogeneous without very high levels of a certain species, in addition to the existence of a more of these. Otherwise, it occurs in the production systems of tree tomatoes, pastures and forage, where some weeds show high incidences and a smaller number of species.

Weed management practices in production systems of avocado, tree tomato, pastures and forage

The management practices associated with avocado, tree tomato, pasture and forage production systems were grouped into different measures; of chemical type, when an herbicide was used; mechanical, when a tool like the small knife or the scythe was used, or when this work was done manually. On the other hand, in physical practices, management measures were grouped as the use of plastic covers or with dead plant residues.

Within this context, the results showed that the management practices were dominated by the use of herbicides, as the only measure, with realization percentages of 20,8; 85,3 and 50,7 % for avocado, tree tomato, pastures and forage respectively, (Figure 3A, B and C). This practice also presented higher values in the avocado, pasture and forage crops, when combined with other strategies such as dead cover (8 %) and the use of the scythe (20,2 %) in avocado and for pastures and forages with the use of the small knife (10 %), (Figure 2A, B and C).

Avocado production systems stood out for the alternative use of management measures other than chemical control. The scythe, the covers of plastics and dead presented values of realization of 18,5; 6,1 and 6,3 % respectively, while the combination of the scythe and the dead coverage presented a value of 8,7 %. Other work carried out in this production system was the use of the small knife, manual and the combination of the latter with the scythe. In the case of tomato tree cultivation practices such as the use of the small knife, scythe, dead cover and manual did not exceed 5 % in the field. Very similar situation occurred in the system of pastures and forage, where the use of these was less than 5,8 % (Figure 3A, B and C), with the difference that 27,3 % of farms do not make any these practices, since they consider that with an adequate program of fertilization, loading and rotation of pastures, weeds are kept at very low levels and the use of one of these practices is not necessary.



A: avocado production systems
B: tree tomato production systems
C: productive systems of pastures and fodder
The bars in the figures represent the confidence interval of the means, indicating statistical differences (P>0.05)

Figure 3. Work associated with the management of weeds in production systems avocado, tree tomato, pastures and fodder in cold climate in Antioquia

The failure to carry out management practices in pasture or forage systems may be due to the fact that the main economic species was *P. clandestinum*. For the zone of moderate cold climate it presents a good adaptation, for its perennial condition of invasive nature and enjoys a good acceptance by the producers (4,5), which makes it an excellent competitor with respect to other species, decreasing thus the negative impact of the weeds, causing all this not to carry out management practices in pasture or forage systems.

Coinciding with what has been found in this work, it is reported that although weeds are considered economically important by forage producers in hot climates in Colombia, most do not perform any type of management or perform it improperly (15). For the case of the farms that carry out some management practices, the use of chemical products or the burning of the pasture stands out.

The photographic record of the weed management practices in the different production systems is shown in Photo 1. For its part, in Photo 2, a visual report is made of the problems associated with the inappropriate use of herbicides, which can to cause damage to the tissues of the cultivable species, whose most associated symptomatology was chlorosis, necrosis and tissue atrophy. This situation can be due to multiple situations, highlighting the use of overdoses, the application process, cross contamination by an inadequate washing of the spray equipment, among others.

These results indicate that there is a lack of knowledge and application of an integrated weed management program; where only in the avocado production system and in a minimum part in the pasture and forage make the combination of different strategies, whose most critical case is presented in tree tomato, where management is based almost exclusively on the use of chemical control (Figure 3 and Photo 1). In the three production systems, the high dependence on the use of herbicides was identified (Figure 3), whose problem is aggravated by the inadequate use of these; where overdoses are commonly used and continuous use of the same active ingredients. This situation could lead to the occurrence of the resistance phenomenon in some weeds, adding other problems such as crop toxicity, water contamination and soil loss due to the lack of noble plant cover (13).

It should be noted that the concept that it needs in the cultivation of tree tomato, of not having any weed (Photo 1F), it is not the right one because it aims to eliminate all existing plants except the species of commercial interest. This strategy does not consider the conservation of certain levels of weeds, which can actively participate in the integrated management of pests by increasing beneficial insects (10,21), in addition to their role in the protection of soils (20).

A-E: avocado production system
F-H: tomato tree production system
I: herbicide
A: herbicide. B: scythe
F: herbicide
J: gambia
C: dead coverage
G: dead coverage
K: scythe
D: plastic cover
H: gambia
E: gambia
I-K: forage production system

Photo 1. Visual aspect of weed management practices in production systems of avocado, tree tomato and pastures in cold climate in Antioquia

A: avocado seedling B: tree tomato
C: prairie in pasture P. clandestinum

Photo 2. Visual aspect of phytotoxicity problems due to herbicides in production systems of avocado, tree tomato and pastures in cold climate in Antioquia

In the productive systems evaluated, extremely important parameters for the management of weeds are unknown as the critical periods, where it is necessary to carry out some management rules; otherwise the damages can be irreversible (9). In addition, the three fundamental pillars associated with the management of this problem are unknown, such as the ecology of the weeds, the characteristics of the productive system and the knowledge and resources that the farmer possesses (22).

The inadequate and excessive use of herbicides can be considered one of the causes of the low levels of diversity found in the systems, where this practice presented very high levels of use (Figure 3). It is stated that one of the causes by which the prevalence of a certain tree is increased in a productive system, is by the continued use of herbicides, which eliminate the species with lower survival capacity, selecting the ones with greater ecological plasticity (10). In some jobs it is reported that the proportion of weeds in warm climate pastures is related to the diversity of these and the presence of bare soil, resulting in the highest prevalence of a species in productive systems with low levels of diversity and uncovered soils (13).

It is important to mention that irrational management has negative consequences on the agroecosystem, given the harmful effect on plant species that are erroneously considered weeds. This situation contradicts the principles of a modern agriculture, in which it is sought to be the most sustainable and friendly with the environment. With this panorama it is necessary a change in the way of facing the management of the weeds, where a holistic vision is required, framed in the knowledge of fundamental aspects for the management of weeds as it is the spatial, temporal dynamics, the ecological relations existing, among others.

That is why the integrated management of weeds should make use of the mechanical, chemical, manual, cultural and biological tools, with the aim of reducing the populations that cause interference in the main species, with a low use of resources and environmentally sustainable methods. These practices should seek to favor those species that are less aggressive, of low competition and that present benefits such as soil protection, hosts of beneficial populations, among others (9, 22, 23).

Relationship of the species with the highest incidence and management practices with the yield and production costs of the evaluated systems

The incidence of weeds in the evaluated production systems was only related to the yield for two species associated with pastures and forages (Table I), and whose negative sign indicates that their presence leads to a decrease in the amount of biomass produced.

These results indicate that in the other two systems the presence of weed plants does not affect the yield, which could occur due to the strict management that is done in tree tomato with the indiscriminate use of herbicides or in the case of avocado, the practices anthropic or the natural effect of litter accumulation on the dish, which prevents competition for light and nutrients that affects production.

The results associated with Table I, reveal that not all species of weeds present negative impacts, indicating the need to make an adequate use of them, such as the production of forages, medicinal use and in the recovery of degraded soils (14).

Another alternative is as dead cover, with excellent results in the management of phytosanitary problems and activator of beneficial soil microbiota (24). In this regard, it is suggested that many weeds may be necessary to house populations of beneficial species, which act as predators or parasitoids of harmful insects, giving rise to the need to identify and maintain these plants in areas close to commercial cultivation (10).

An example of this type occurs in the cultivation of tree tomatoes, where beneficial insect species that participate in the predation of the fruit borer (*Neoleucinodes elegantalis* Guenée), are found in a greater proportion in weeds of the Asteraceae family such as cadillo. (*Bidens pilosa* L), the goat weed (hierba de chivo) (*Ageratum* spp.), the yellow button (*Jaegeria hirta* Lag) (el botón Amarillo) and the family Polygonaceae as the wounded heart (el corazón Amarillo) (*P. nepalense*) (21).

Table I. Relationship between the most important weeds and the yield of avocado, tree tomato, pasture and forage production systems

Specie of weed	Statistical results		Production systems		
P. nepalense	-0,56[1]	0,56[2]	+[3]	+[4]	[5]
P. clandestinum	1,28	0,35	+	+	
Commelina sp.	0,021	0,67	+		
Cuphea sp.	0,97	0,43	+		
Paspalum sp.	1,0	0,39	+		
Bidens sp.	0,35	0,23		+	
C. difusa	2,5	0,28		+	
V. listoralis	1,23	0,10		+	
Sporobulos sp.	-3,45	0,004**			+
S. oleraceus	-1,45	0,045*			+
R. crispus	-1,1	0,15			+
Morus sp.	0,23	0,09			+
R. acetosella	0,31	0,06			+

[1] value estimated by the model
[2] P value: *with statistical significance (p<0,05)
[3] avocado [4] tree tomato [5] pasture and forage

The total value of the costs of weed management in avocado, tree tomato, pasture and forage was 8.5, 12 and 9 % respectively, which corroborates what was previously stated in the tree tomato production system, where it over-controls the species that are not the main crop, which leads to an increase in production costs (Table II).

With regard to the relationship between management practices and production costs, it was found that the number of tasks that have a significant relationship in the production systems evaluated (Table II), is associated to the percentage of realization of these (Figure 3). All the coefficients presented a positive sign, indicating that the realization of each of them increases production costs. The practice called chemical control in the production systems of tree tomato, pastures and forage, presented significance, in addition to a high participation on the total production costs. On the other hand, in the avocado production systems, the mechanical management (scythe) represented the most costly work (Table II).

These results indicate the economic importance associated with the management of weeds, where higher costs are associated with the use of herbicides, which is taxed by the inadequate management that is made of them. On the other hand, it is fundamental to redefine the concept of weeds and their role in agroecosystems; therefore, it is necessary to determine if a plant species acts as a competitor in a productive system depending on the objective sought. In the case of the cultivation of avocado and tree tomato, the species *P. clandestinum* was found to be a high incidence weed, but for the forage production system it was the commercial species. This situation generates the need for the first strategy within an integrated weed management program to be recognized, after which it is recommended to evaluate which ones present the greatest interference with the target species and thus be able to define its economic impact.

Table II. Existing relationship between weed management practices and costs in avocado, tree tomato, pasture and forage production systems

Management practice	Statistical results			Production costs (%)		
Chemical	2,3 *[1,2]	12,5*[1,3]	8,7*[1,4]	2[2]	12,5[3]	5,2[4]
Hanical (scythe)	3,1*	0,31	0,9*	3,7	0,1	1,2
Hanical (hoe)	0,031	0,61	1,1*	0,5	0,2	2,1
Hanical (manual)	0,17*	0,013	0,15	1	0,1	0,5
Physical (dead coverage)	1,0	0,19	0,00	0,1	0,1	0
Physical (plastic)	0,45*	0,13	0,00	1,2	0	0

[1] value estimated by the model; * with statistical significance (p<0,05); [2]avocado; [3] tree tomato; [4]pasture and forage

It should also inquire about the various relationships that are established between them; as well as those with other organisms that inhabit the agroecosystem (20,21).

On the other hand, it is necessary to generate weed management strategies friendly to the environment, where they can be given an added value, which could be from an ecological and economic perspective; since in the case of avocado production systems, one of the most frequent weeds was *P. clandestinum*, which could be used in a commercial way in the production of silage for the feeding of ruminants.

CONCLUSIONS

The production systems of tomato of tree and pastures and forages, presented low diversity of weeds in comparison with the production system of avocado, giving place to high incidences in few species. Regarding the management of this problem, it was found that there is a great ignorance of the basic concepts of integrated weed management, causing an inadequate use of chemical control. The inexistence of an environmental and ecological strategy of the weeds leads to these become a problem, not only by the increase in the incidences of some species, but by the cost of their control, so it is necessary to redefine the weed concept and be able to make economic and environmental use of these in agroecosystems.

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