Weeds and compacted soil in the establishment of an urban garden using the biointensive approach: Experiences and limitations

Malezas y suelo compactado en el establecimiento de una huerta urbana utilizando el enfoque biointensivo: experiencias y limitaciones

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ABSTRACT

The interest of people in consuming their own agricultural products is on the rise, leading to an increase in the number of urban gardens established in Bogotá over the past years. These gardens operated using the biointensive method as a model for urban agriculture present an environmentally sustainable alternative. However, this system comes with challenges and limitations that may hinder the establishment of such a project. To test this, an urban garden focused on biosystems with high levels of agricultural biodiversity was established within a greenhouse of the Universidad Nacional de Colombia, Bogotá campus. This was carried out in an area with a covered and an uncovered section. A weed germination trial was conducted in planting containers, assessing the relative representation of weeds in two random samplings taken from different containers over a two-month measurement period and a previous soil analysis was realized to evaluate the physical and chemical conditions of the soil. Consequently, 13 weed species were identified in the soil bank of weeds, with *Veronica* spp. being the most relatively represented in both samplings. However, within the established orchard, the predominant plants were those belonging to the Poaceae family, such as *Lolium temulentum* and *Cenchrus clandestinus*. Finally, through the biointensive method and the addition of organic materials such as biochar and regular topsoil, soil properties like structure, porosity, and friability were improved. This, in turn, enabled better root development and the successful establishment of various cultivars in the garden.

Key words: urban agriculture, diverse gardens, weed management, invasive grasses, clayey soil.

RESUMEN

El interés de las personas por consumir sus propios productos agrícolas va en aumento; esto ha conducido a un incremento del número de huertas urbanas establecidas en Bogotá durante los últimos años. Las huertas, explotadas mediante el método biointensivo como modelo de agricultura urbana, representan una alternativa sostenible desde el punto de vista medioambiental. Sin embargo, este sistema conlleva retos y limitaciones que pueden dificultar el establecimiento de un proyecto de este tipo. Para probarlo, se estableció un huerto urbano centrado en biosistemas con altos niveles de biodiversidad agrícola dentro de un invernadero de la Universidad Nacional de Colombia, sede Bogotá. Este fue llevado a cabo en un área con una sección cubierta y otra descubierta. Se preparó un ensayo de germinación de malezas en materas, evaluando la representación relativa de las malezas de dos muestreos aleatorios durante dos meses y se realizó un análisis de suelo previo para evaluar condiciones físicas y químicas del mismo. En consecuencia, se encontraron 13 especies de malezas en el banco de semillas de malezas del suelo, siendo *Veronica* spp. aquella con mayor representatividad relativa en ambos muestreos. Sin embargo, dentro de la huerta establecida, las plantas predominantes fueron aquellas pertenecientes a la familia Poaceae tales como *Lolium temulentum* y *Cenchrus clandestinus*. Finalmente, con el método biointensivo y adición de materia orgánica como biochar y tierra negra común, las propiedades como estructura, porosidad y friabilidad del suelo fueron mejoradas, permitiendo a su vez un mejor desarrollo radicular y el establecimiento de distintos cultivares en la huerta.

Palabras clave: agricultura urbana, huertas diversas, manejo de malezas, pastos invasores, suelo arcilloso.

Introduction

Urban agriculture is understood as the activity within or on the fringe of a city or metropolis where a variety of mainly food products are raised, cultivated, processed, and distributed (Degenhart, 2016). Worldwide, the largest proportion of the population lives in cities, and around 25-30% of this population are involved in the agro-food sector (Orsini *et al*., 2013. Urban agriculture is an activity that has spread due to its great impact on environmental sustainability. It is also characterized by a high level of variety and diversity, a more organic production, and the presence of new growers

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and other stakeholders who possess historical or traditional knowledge (Hernández, 2006).

The establishment of urban gardens gives rise to numerous positive effects for a more solid local economy. These benefits include food and employment for the most disadvantaged and sustainable urban development, which is related to the conservation of the landscape and rural heritage (López, 2014). Colombia has had similar results with cases of urban gardens in cities such as Popayán, Medellín, and Bogotá or municipalities such as Villamaría in Caldas, strengthening food security and taking advantage of organic waste (Gómez, 2014; Martinez *et al*., 2022).

There are different methodologies and processes to establish an urban garden, among which is the biointensive agriculture methodology. This method consists of a production system based on the use of local inputs, with no machinery or commercial inputs implemented to avoid damage to the environment, animal and human health, and ecosystems (Ruiz, 2013).

Despite the various advantages of urban agriculture, it requires dedication and constant labor for its management and maintenance. Some of these practices include weed control, optimal fertilization, and the maintenance of soil moisture for the development of the plants of interest. In this regard, some limitations can interrupt the social fabric, affecting the continuity and presence of people in the gardens. An example of such limitations is the COVID-19 pandemic, which occurred when the garden of Universidad Nacional de Colombia was established. This pandemic limited the development of activities and triggered two problems that were then identified and that remain until now: the presence of difficult-to-control weeds and soil conditions that limit plant growth. Therefore, we proceeded to conduct a study of these two problems to identify possible solutions.

In this context, the objective of this research was to determine the main limitations associated with the implementation of an urban garden using the biointensive method, considering the influence of the soil characteristics and the bank of weeds in the soil on greenhouses at the Universidad Nacional de Colombia.

Materials and methods

Study area

The garden studied was called "Huerta UNAL" (UNAL Garden) within the framework of the Agrobiodiverse Biosystems project funded by "Convocatoria Nacional de Alianzas Interdisciplinares" (National Call for Interdisciplinary Alliances). The garden was located in a plastic-covered greenhouse of the Faculty of Agricultural Sciences of the Universidad Nacional de Colombia - Bogota campus (4°38'8.9" N, 74°05'21.7" W) at 2640 m a.s.l., with an area of 280 m^2. The average maximum temperatures external and internal to the greenhouse fluctuated between 18°C and 20°C and 22°C and 24°C, respectively. At dawn, the minimum external temperature was between 8ºC and 10ºC, and the average total annual rainfall in the area is 797 mm, distributed in two dry seasons and two rainy seasons. The characteristics of the soil are shown in Tables 2 and 3.

For the physical-chemical analysis of the soil, samples were collected from the first 30 cm of soil depth; the first 2 cm of soil was removed, and the sample was extracted, taking about 10 sub-samples throughout the length and width of the area, which were then mixed in the bucket to form one soil sample. Following the IGAC (2021) methodology, a zigzag pattern was formed throughout the area, as it is the most appropriate and simple method to recollect the 10 soil sub-samples. The samples were sent to the Agrosoil laboratory (Bogotá) for analysis. The soil texture was determined according to the Bouyoucos (1936) method, the soil organic matter content was quantified according to the Walkley and Black (1934), the bulk density was determined with the paraffin-coated clod method according to Blake and Hartge (1986), and the real density was taken from FAO (2022). Furthermore, the description of soil structure was based on characteristics defined by Jaramillo (2002), in which the soil structure is classified by shape, kind and evolution grade.

Soil preparation

The soil was initially very compacted and degraded and had high contents of clay (52%) and a low content of organic matter (3.1%) and nitrogen (0.21%) (Tab. 2). The interpretation of compaction was made by taking the value of bulk density of the studied soil of 1.3 g cm^{-3} and comparing it with the reference values presented by Jaramillo (2002), who describes that those predominant soils of fine texture greater than 1.3 g cm^{-3} indicate soil compaction. Potassium (0.88 cmol kg^{-1}) and calcium (6.38 cmol kg^{-1}) were in excess, unbalancing the ionic relations in the soil (Tab. 3). To prepare the soil, intensive amendments with organic matter were applied 15 d before transplanting, using products from commercial brands Lombritenjo® granulated worm humus (Vermiculture of Tenjo, Tenjo, Colombia, 2 kg m^{-1}), Solidblend® organic fertilizer with biochar (Biodiversal, Bogotá, Colombia, 2 kg m^{-1}) or material from other greenhouses which was transported on wheelbarrows to be evenly incorporated into the soil of the study area using a hoe.

Before transplanting, the double digging method was used and weeds were removed manually based on the Las Cañadas Agroecological Center (Centro Agroecológico las Cañadas, 2009) methodology, using a biointensive approach (Jeavons, 2001) to ensure that the crop management was in line with agroecological principles. After building the sections, 1 kg m^{-2} of commercial biochar (Pentón Fernández *et al*., 2021) was added to the soil 15 d before transplanting, with beneficial microorganisms such as phosphorus-solubilizing fungi *Penicillium janthinellum* (Fosfobiol®, Biocultivos, Ibagué, Colombia - 5 ml L^{-1} - soil drench application) and plant-pathogenic fungi controllers such as *Trichoderma* spp. (Fitotripen®, Natural Control, La Ceja, Antioquia, Colombia - 2 g L^{-1} - soil drench application) applied 15 d after transplanting.

Garden design and establishment

The 280 m^2 area was divided into two half-greenhouses measuring 14 m x 20 m. The first half was covered with a plastic roof, and the second was left uncovered. Inside each part of the greenhouse, six beds of 6 m x 3 m were spaced 0.4 m apart (Fig. 1); this was done to observe the emergence of the distinct kinds of weeds in the garden where several species were planted at a conventional density for each species (Tab. 1) since production was for self-consumption. The plant species established were vegetables, aromatic herbs, fruit trees, tubers, legumes, and cereals, with the largest number of species in the first two categories. Inside the main cultivated species were tomato, corn, potato, vegetables such as lettuce, carrot, radish, and herbs such as basil and oregano. These species were planted with the biointensive cultivation method, with the distances between plants and rows reduced to achieve a higher density of plants per 1 m^2 and boost yield (Pérez & Hernández, 2022).

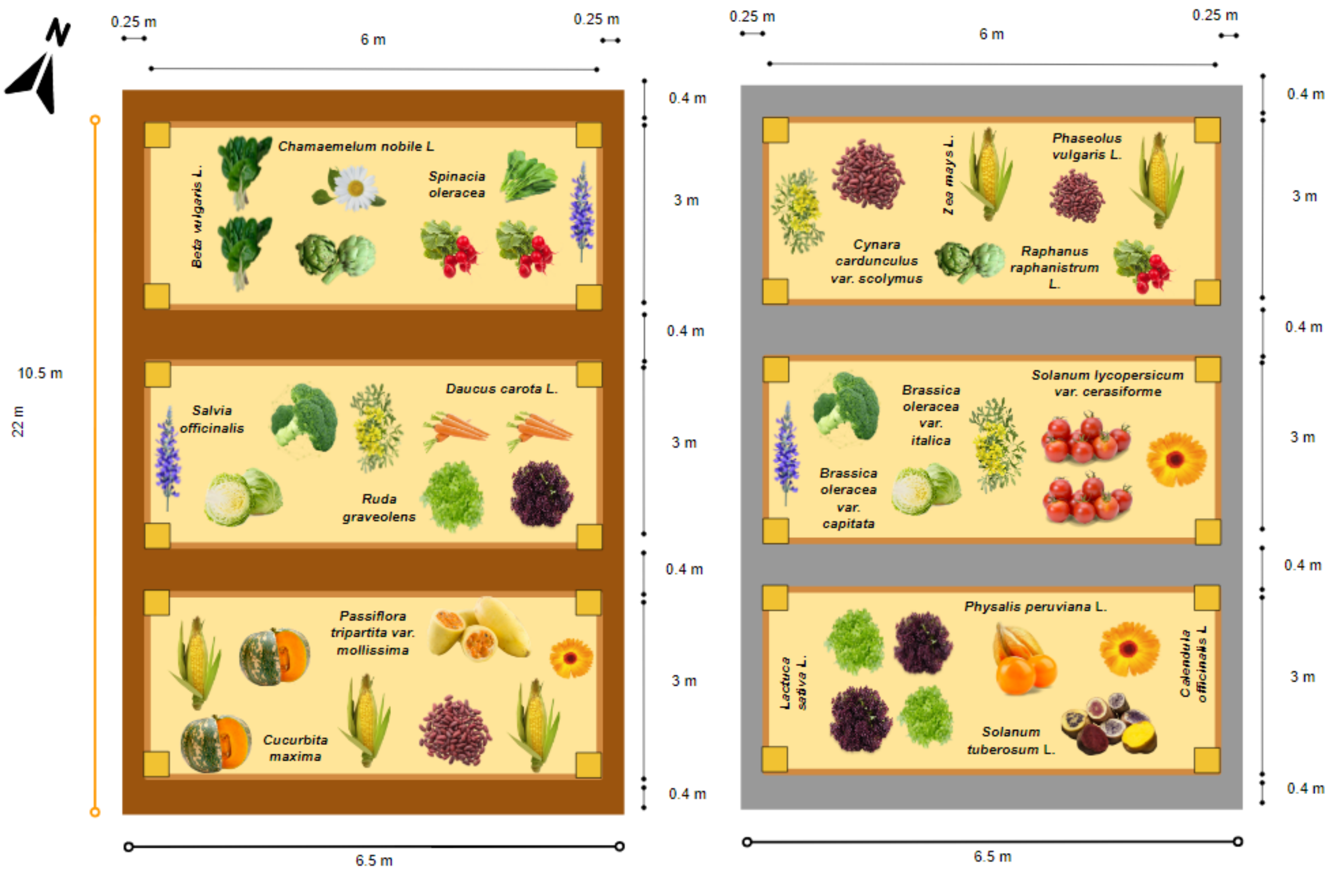

FIGURE 1. Greenhouse sections layout. The 280 m^2 area was divided into two half-greenhouses measuring 14 m x 20 m. The first part of the greenhouse was covered with a plastic roof (gray background), and the second was an open space (brown background). Some of the species cultivated are shown.

TABLE 1. Productive species grown in the garden and sowing distance.

Species	Days to harvest	Sowing distance (cm between plants x cm between rows)	Number of plants per section (18 m^2)
Solanum tuberosum L.	90-120	25 x 90	20
Phaseolus vulgaris L.	90-120	20 x 100	45
Physalis peruviana L.	90+	200 x 200	2
Lactuca sativa L.	80-90	25 x 25	150
Spinacia oleracea	49-64	15 x 15	200
Daucus carota L.	105-120	8 x 40	140
Cucurbita máxima	210	100 x 300	3
Zea mays L.	150-160	40 x 100	25
Passiflora tripartita var. *mollissima*	250-270	400 x 200	2
Beta vulgaris L.	75-90	35 x 40	65
Cynara cardunculus var. *scolymus*	120-180	80 x 80	15
Solanum lycopersicum var. *cerasiforme*	120	35 x 80	35
Raphanus raphanistrum L.	35	10 x 15	350
Brassica oleracea var. *italica*	90-110	40 x 40	50
Brassica oleracea var. *capitata*	90-110	40 x 40	50

Source: Ruiz (2013).

The seedlings were germinated and cared for before transplanting to the seedling production area of the Universidad Nacional de Colombia. Their planting and distribution were previously designed considering some relationships between plant species; for example, plants of the family Lamiaceae, such as *Mentha spicata,* that exhibit allelopathy (Islam *et al.,* 2022) that would facilitate management and reduction of phytosanitary problems, such as pests, through its insecticidal, antimicrobial, and antifungal capacity inside the garden.

For the transplanting, maintenance, and harvesting processes, collaborative workdays (*mingas*, in Spanish) were promoted through different means to invite university students to participate. As a result, the activity would strengthen learning about the establishment and care of an urban garden among people unfamiliar with the basic processes of agricultural production.

Biological products were used for pest and disease management. For pest management, some of these products were applied at different times of the day, including *Bacillus thuringiensis* (Subticrop®, Bio-Crop, Palmira, Colombia - 2 ml L^{-1} - soil drench application), *Beauveria bassiana*, *Lecanicillium lecanii*, *Metarhizium anisopliae and Bacillus thuringiensis* (Sáfermix WP®, Sáfer, Medellín, Colombia - 2 g L^{-1} - soil drench application), potassium soap (Bonfyton®, Biorracionales de Colombia, Bogotá, Colombia - 2 ml L^{-1} - foliar application), and for disease management *Trichoderma harzianum* (Fitotripen®, Natural Control, La Ceja, Antioquia - 2 g L^{-1} - soil drench application), and copper sulfate (Antrasín®, Sáfer, Medellín, Colombia - 2 g L^{-1} - foliar application) were used.

Finally, crop fertilization was based on the application of products such as Actiphyl Kfruto® and Nutriponic® (Ingeplant, Colombia) and compost obtained from biodigester bales located in a greenhouse near the garden, prepared openly and in piles, as schematized by FAO for its preparation in Latin America (Román *et al.,* 2013).

Soil seed bank behavior

The germination conditions mirrored those of the garden location, with a temperature of 22°C±4°C, relative humidity ranging from 40 to 90%, and a standard photoperiod of 12 h. The analysis was conducted under conditions similar to those of the garden to gain insight into the species that germinate more rapidly and predominate in the garden's soil.

The weed characterization was made to identify invasive and competitive species in the garden soil. This information was used to plan the planting of species in the next planting cycle, selecting those that could outcompete the rapidly emerging weeds. Additionally, it allowed implementation of a preventive weed management strategy.

For the analysis of weed behavior, soil samples were collected in the uncovered area of the garden, after three months without any intervention and prior to the next planting cycle, on March 14, 2022. The samples were gathered from the first 30 cm at four points in the garden (Cardenal Rubio *et al.,* 2016) and placed in 20 pots of 10 cm in diameter. Irrigation was carried out daily to allow the evaluation of the seed bank of weeds in the soil with a maximum temperature of 24°C and a minimum of 8°C. Maximum and minimum humidity of soil were 73% and 32%, respectively. The weed species were then observed, identified, and quantified. A first destructive sampling (S1) was carried out using 10 pots when achieving 100% coverage to identify species that stopped growing due to competition with others until 30 d after seeding (DAS). Subsequently, all weeds were removed from the pots. A second destructive sampling (S2) was carried out 60 DAS in the same pots to observe the species of the bank that were more competitive and established based on the Cardenal Rubio *et al.* (2016) methodology. Finally, Equation 1 for Relative representation (Rr) was utilized to calculate the importance of each weed species in the ecosystem, where the Species value represents the assessment of a species, and Total density of all species is the total number of species found in the sample (Moreno-Preciado *et al.*, 2021):

$$\text{(Rr) Relative representation} = \frac{\text{Species value}}{\text{Total density of all species}} \times 100 \qquad (1)$$

Finally, the weed identification process was carried out through morphological characterization of seedlings both in a controlled environment and in the field. We used the reference materials "Seedlings of common weed species in the central zone of Colombia" (Fuentes *et al.*, 2006) and the "Illustrated guide to weedy plants of the Marengo agricultural center" (Gámez *et al.*, 2018).

Results and discussion

Limitations associated with soil poor structure and texture

The clay content was predominantly higher in the studied soil. These clays can be defined as low-activity clays based on the observations in the field that evidenced deficiencies as a result of the lack of exchangeable elements available for the plant (Jaramillo, 2002). Additionally, the absence of soil structure prevents the breakdown of inorganic materials, which in turn inhibits the production of elements that plants can metabolize (Tab. 2).

Also, the soil exhibited small pores related to fine textures and poor structure without sand soil. Jaramillo (2002) attributed these soil features to compaction. The soil had clayey clods of moderate resistance and larger than 80 mm throughout the intervened area. This is the product of anthropogenic actions associated with the material in the area, which is poor in weatherable materials and sometimes contains rubble of different sizes and plastic debris linked to the low soil evolution degree. Del Valle Neder *et al.* (2010) describe the anthropic effect as a cause of loss of productivity in soils, stating that human intervention acts as a modifying factor of the environment, forming soils of anthropogenic origin. This garden is a clear example of such an effect.

These characteristics make the establishment of cultivated plants even more difficult, affecting the optimum physical properties of the soil for the root growth, such as pore space, air capacity, moisture retention, actual and bulk density, and resistance to compaction (Antúnez *et al.*, 2015).

Therefore, soils with anthropic influence that are typical of urban spaces must be renovated and conditioned to be

TABLE 2. Physical and chemical properties of the soil studied.

Physical properties						Chemical properties					
Clay	Loam	Sand	Textural class	BD	RD	pH	EC	ECEC	BS	OM	OC
%				g cm^{-3}			dS m^{-1}	cmol$^{(+)}$ kg^{-1}		%	
52	28	20	Ar	1.3	2.65	5.15	9.69	9.69	8.85	5.35	3.1

BD – bulk density, RD – real density, EC – electrical conductivity, ECEC – effective cation exchange capacity, BS – base saturation, OM – organic matter, and OC – organic carbon (Agrosoil laboratory, Bogotá). RD taken from FAO (2022).

TABLE 3. Chemical composition of the soil.

N-Total	N-Available	P-Available	K^+	Ca^{2+}	Mg^{2+}	Na^+	Al^{3+}	S^{-2}	Fe^{2+}	Mn^{2+}	Cu^+	Zn^{2+}	B^{3+}
%	mg kg^{-1}		cmol$^{(+)}$ kg^{-1}										
0.27	34.78	73.51	0.88	6.38	1.49	0.10	0.84	11.27	366.13	11.48	2.44	6.03	0.42

used in urban gardens. It is important to define the ideal soil practices that can help to transform low-fertility soils into areas with the desired fertility and the ability to sustain plant growth. An ideal scenario is described by Torres Sanabria and Cuartas Ricaurte (2013), who mention that the pre-Columbian cultures of the Amazon transformed low-fertility soils into highly productive anthropic soils called *Tierras prietas*. One of the numerous examples of soil conditioning is the use of aromatic plants that improve soil conditions such as pH and organic carbon availability (Dikr, 2022).

Alternatives to soil limitations

While the addition of organic matter to the studied soil improved its structural characteristics, such as porosity, texture and friability, various authors propose alternatives that expand the options for soil enrichment and which may be considered in the future. For instance, Pozza *et al*. (2020) state that the use of cover crops and the incorporation of organic matter not only maintain soil structure and prevent soil exposure, but also promote diversity within the system. They also suggest that the addition of organic matter to soil should go hand in hand with the cultivation of resilient crop varieties and the incorporation of nitrogen-fixing legumes to reduce the use of fertilizers.

The product Lombritenjo® was applied using vermicomposting, in which earthworms convert organic materials into humus. It enhances soil fertility, provides more nutrients to plants, and adds more porosity, density, aeration, and water retention to the soil (Lim *et al*., 2015). The biochar Solidblend® improves the structure of compacted soil. Allohverdi *et al*. (2021) mentioned that compost mixed with biochar produces higher biomass degradation that provides nutrients to plants rapidly. Thus, using biochar's porosity improves soil aeration and increases porosity.

Fosfobiol®, which contains *Penicillium janthinellum* isolates as part of the *Penicillium* species, was also used. Hao *et al*. (2020) identified its capacity to solubilize inorganic P, making it available for the plant. Fitotripen®, which contains *Trichoderma* spp., was used to increase the soil health. Zin and Badaluddin (2020) stated that it works as a plant growth promoter and increases the decomposition of organic matter to enhance the availability of nutrients in the soil.

Finally, the utilization of arbuscular mycorrhizae frequently establishes beneficial associations that enhance nutrient uptake by plants through a symbiotic relationship, ultimately ameliorating the fitness and growth of the plants integrated within the system (Alyokhin *et al*., 2020).

Limitations associated with the presence and abundance of invasive species

Thirteen weed species were found in the soil of the UNAL Garden (Tab. 4). These species corresponded to 10 families that were recorded throughout the experiment, but only 8 remained until the end. Of these weed species, 84.6% were broad-leaved and 15.4% were narrow-leaved (Tab. 4). The most represented species calculated with the Equation 1 of relative representation (Rr) in the first sampling was *Veronica* spp. (43.6%) (Fig. 3E), followed by *Lolium temulentum* (21.6%) and *Oxalis corniculata* (11.7%) (Figs. 2 and 3G).

TABLE 4. Main weeds found in the soil of the UNAL Garden.

Species	Family	Leaf type
Cenchrus clandestinus	Poaceae	Narrow
Veronica spp.	Scrophulariaceae	Broad
Oxalis corniculata	Oxalidaceae	Broad
Polygonum segetum	Polygonaceae	Broad
Trifolium spp.	Fabaceae	Broad
Lolium temulentum	Poaceae	Narrow
Spergula arvensis	Caryophyllaceae	Broad
Galinsoga quadriradiata	Asteraceae	Broad
Sonchus oleraceus	Asteraceae	Broad
Euphorbia peplus	Euphorbiaceae	Broad
Chenopodium petiolare	Amaranthaceae	Broad
Cardamine hirsuta	Brassicaceae	Broad
Medicago spp.	Fabaceae	Broad

In the second sampling, the most relative representative species was also *Veronica* spp. (33.3%), followed by *Lolium temulentum* (21.6%) and *Cenchrus clandestinus* (17.7%). All the species representations tended to decrease, except *Spergula arvensis* (Fig. 3D) and *C. clandestinus* (Fig. 3H). In addition, in the first sampling, *C. clandestinus* represented only 2.7% of the number of individuals found in the garden but was the most difficult to manage. Although the other species were more represented in the samplings, they were easily controlled manually (Fig. 3A).

The characteristics of *Veronica* spp. as a highly relative representation are explained by Bond *et al*. (2007) who observed that this species grew on calcareous and acid soils. These features were found in the soil during the experiment, which could explain the predominance in the relative representation. The authors claimed that *Veronica* spp. makes up a persistent seed bank which could explain its major predominance in the soil bank of weeds.

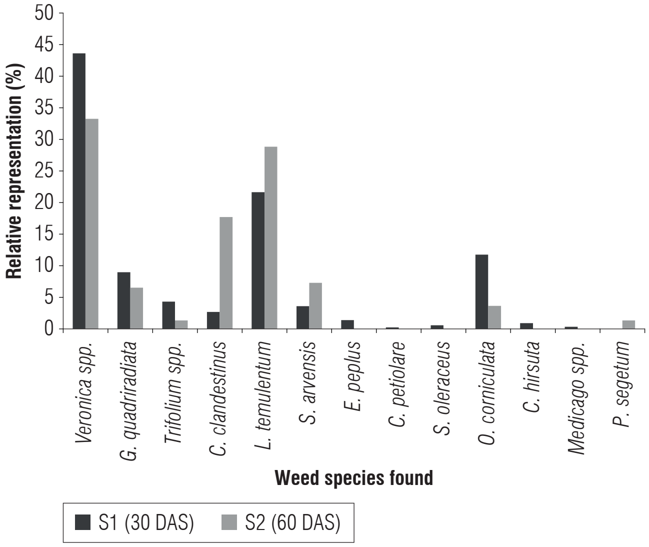

FIGURE 2. Weed species found in the UNAL Garden (Bogota). Samples "S1" and "S2" were collected up to 30 and 60 d after seeding (DAS), respectively. The x-axis shows the different weed species and the y-axis shows the number of individuals per number of analyzed samples, with n = 10.

The results of the bank of weeds in the soil test contrasted with what was observed in the study area. During the establishment of the garden, the weed *C. clandestinus* (Kikuyu grass) became a major problem since it was rooted up to 30 cm deep and showed an abundance of rhizomes (Fig. 3H) (Cordero Rodríguez *et al*., 2021). These characteristics make *C. clandestinus* a species with excellent reproductive potential which, added to its ecology (a perennial species with a wide range of adaptability to different environments), results in a very invasive grass species. It reproduces by rhizomes and stolons, allowing it to cover the entire area where it is found (Contexto Ganadero, 2022). This behavior negatively affects the biosystem and diversity which is of utmost importance for the maintenance and conservation of agroecosystems (Camacho-Ballesteros, 2018; Rodríguez, 2021).

Although competition and existing allelopathy were considered for the cultivable species, an in-depth diagnosis of the bank of weeds in the soil was not performed, which would have prevented competition and drastic invasion

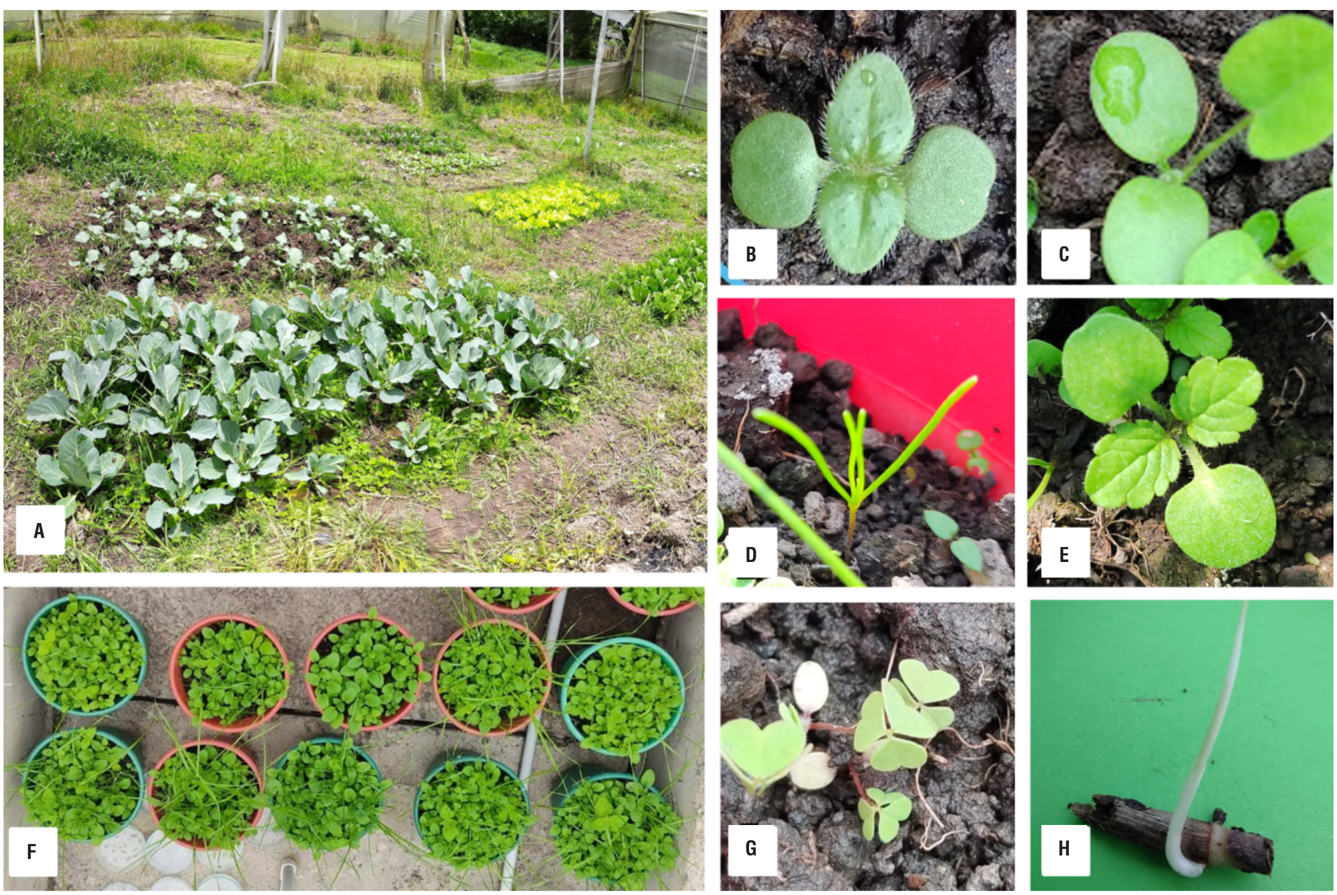

FIGURE 3. Photographic record of the presence of weeds in the UNAL Garden. A) *Cenchrus clandestinus* growing around cabbage, chard and lettuce sections in the UNAL Garden, B) *Galinsoga quadriradiata*, C) *Trifolium* spp., D) *Spergula arvensis*, E) *Veronica* spp., F) pots of the soil bank of weeds, G) *Oxalis corniculata*, and H) *Cenchrus clandestinus* rhizome found during the trial.

by *C. clandestinus* (Fig. 3A). Camacho-Ballesteros (2018) pointed out that this species of grass competes with cultivated plants for water, light, and space. The use of water resources is the most critical problem, not only because of competition but also because this species prevents water infiltration, seriously affecting water availability in reservoirs and the soil.

The relative representation by *Veronica* spp. during the experiment does not relate with the establishment of the different species of crops over the field. Since the biology of *C. clandestinus* depends on the competition of water and nutrients, it might have a higher impact on the production system. The opposite occurred with *Veronica* spp., which had a low persistence in the field, although it was the most representative in the experiment in pots. This shows the importance of knowing the biology and weather response of these different weeds in the production system.

Although the problems of managing and maintaining a biointensive garden can affect the continuity of urban agriculture projects, there are relevant factors that are rarely considered. For instance, compacted soil can be improved by adding various materials, such as organic matter from diverse sources, to enhance the soil structural integrity and, in some instances, supply essential mineral elements for plant growth.

Additionally, soil conditioning techniques can be implemented and the bank of weeds managed by selecting beneficial weed species, creating the possibility to use the qualities of distinct plants in a way that allows soil improvement and the establishment of different crops. Finally, plant growth-promoting rhizobacteria can be used along with the addition of vegetal material and mycorrhizae to create a symbiosis with plants.

Conclusions

Despite the limitations imposed by poor soil conditions, this project was able to establish a successful garden with improved soil quality, which supported the growth of various vegetables, even when the soil presented many challenges. This project demonstrated the potential of urban gardens as a sustainable and viable solution to address food insecurity and promote healthy eating habits in communities, even in areas with suboptimal soil conditions, allowing them to be replicated in different scenarios of the city and accomplish their mission.

Adding root type and growth form characteristics to the methodology of weed evaluation will improve future studies by providing a better understanding of the behavior of weeds and their competitive ability. This will allow for more accurate predictions of their impact on crops, aid in the selection of appropriate control measures, and promote sustainable agriculture while reducing negative impacts on the urban gardens.

Finally, knowing the relative representation and the biology characteristic of the weeds allows control and study of different weeds during the first crop stages, when they still have a low relative representation, to avoid losing the garden profit to competition.

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Conflict of interest statement

The authors declare that there is no conflict of interests regarding the publication of this article.

Author's contributions

MPQ, JPC, and CC formulated the research goals. MPQ supervised and directed the planning and execution of the research activities. KPG, JPC, and CC developed the methodology and carried out the research and investigation process with the collaboration of AB, JS, IN, and ODG, particularly in the field trials and data collection process. KPG, CC, IN, and JPC applied statistical techniques, discussed the results, and performed a critical review of the manuscript. MPQ revised the initial version of the manuscript and translated the initial draft. All authors reviewed the final version of the manuscript.

Literature cited

Allohverdi, T., Mohanty, A. K., Roy, P., & Misra, M. (2021). A review on current status of biochar uses in agriculture. *Molecules*, *26*(18), Article 5584. https://doi.org/10.3390/molecules26185584

Alyokhin, A., Nault, B., & Brown, B. (2020). Soil conservation practices for insect pest management in highly disturbed agroecosystems – a review. *Entomologia Experimentalis et Applicata, 168*(1), 7–27. https://doi.org/10.1111/eea.12863

Antúnez, A., Felmer, S., Vidal, M., Morales, R., Coz, E., & Fuentes, F. (2015). *Propiedades físico-hídricas del suelo en el cultivo del maíz grano (Boletín INIA No. 312).* Instituto de Investigaciones Agropecuarias. https://hdl.handle.net/20.500.14001/7894

Blake, G. R., & Hartge, K. H. (1986). Bulk density. In A. Klute (Ed.), *Methods of soil analysis, Part 1, Physical and mineralogical* *methods* (2nd ed., pp. 363–382), Agronomy Monograph 9, American Society of Agronomy. Soil Science Society of America, Madison.

Bond, W., Davies, G., & Turner, R. (2007). *The biology and non-chemical control of Wall Speedwell (Veronica arvensis L.)*. HDRA, Ryton Organic Gardens. https://gardenorganic-assets.s3.eu-west-2.amazonaws.com/documents/veronica-arvensis.pdf

Bouyoucos, G. J. (1936). Directions for making mechanical analyses of soils by the hydrometer method. *Soil Science, 42*(3), 225–228.

Camacho-Ballesteros, S. E. (2018). La especie *Pennisetum clandestinus* en la restauración ecológica. *Amazonia Investiga, 7*(14), 265–273. https://amazoniainvestiga.info/index.php/amazonia/article/view/514

Cardenal Rubio, Z. C.., Torres Hernández, D. F., Dotor Robayo, M. Y., & Morillo Coronado, A. C. (2016). Caracterización del banco activo de semillas en cultivos de zanahoria del municipio de Villa Pinzón (Cundinamarca). *Revista U.D.C.A Actualidad & Divulgación Científica*, *19*(2), 297–306. https://doi.org/10.31910/rudca.v19.n2.2016.83

Centro Agroecológico las Cañadas. (2009). *Producción de hortalizas orgánicas. Manual del cultivo biointensivo de alimentos.* https://botanicoalcala.es/wp-content/uploads/ManualHuertoBiointensivo-Las-Ca%C3%B1adas-M%C3%A9xico.pdf

Contexto Ganadero. (2022). *Por estas razones el pasto kikuyo es recomendado para producción de leche en trópico alto.* Servicio informativo de ganadería. https://www.contextoganadero.com/ganaderia-sostenible/por-estas-razones-el-pasto-kikuyo-es-recomendado-para-produccion-de-leche-en

Cordero Rodríguez, J. P., Galindez Labrador, K. P., Peñuela Mojica, L. J., & Guzmán Sánchez, O. D. (2022). Proceso de implementación de tres huertas comunitarias ubicadas en Bogotá, Pitalito (Huila) y Viotá (Cundinamarca). *INNAGRI*, *1*, 32–57. http://bienestar.bogota.unal.edu.co/pgp/Publicaciones/innagri/innagri_1.pdf

Degenhart, B. (2016). La agricultura urbana: un fenómeno global. *Nueva Sociedad, 262*, 1–11.

Del Valle Neder, L., Busnelli, J., & Sampietro Vattuone, M. M. (2010). Incremento de erosión y suelos degradados por acciones antropogénicas y variaciones climáticas, Tucumán. *Revista de la Asociación Geológica Argentina*, *66*(4), 499–504. http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S0004-48222010000300007

Dikr, W. (2022). Role of intercropping some aromatic and medicinal plants with fruit vegetables crops, a review. *Global Academic Journal of Agriculture and Biosciences*, *4*(2), 22–30. https://doi.org/10.36348/gajab.2022.v04i02.002

FAO. (2022, August 25). *Portal de suelos de la FAO*. Food and Agriculture Organization of the United Nations. https://www.fao.org/soils-portal/soil-survey/propiedades-del-suelo/propiedades-fisicas/es/

FAO., Rikolto., & RUAF. (2022). *Urban and peri-urban agriculture sourcebook - from production to food systems*. Food and Agriculture Organization of the United Nations and Rikolto. https://doi.org/10.4060/cb9722en

Fuentes, C., Fúquene, A., Perdomo, E., & Pinto, S. (2006). *Plántulas de especies arvenses frecuentes en la zona centro de Colombia*. Universidad Nacional de Colombia, Bogotá, Colombia.

Gámez, A., Cruz, C., Plaza, G., Cepeda, J., Rojas, L., Jaramillo, M., & Hoyos, V. (2018). *Guía ilustrada de plantas arvenses del Centro Agropecuario Marengo (CAM)*. Universidad Nacional de Colombia, Bogotá, Colombia.

Gómez, J. N. (2014). *Agricultura urbana en América Latina y Colombia: perspectivas y elementos agronómicos diferenciadores* [Undegraduate thesis, Universidad Nacional Abierta y a Distancia]. UNAD repository. https://repository.unad.edu.co/handle/10596/2749

Hao, X., Zhu, Y. G., Nybroe, O., & Nicolaisen, M. H. (2020). The composition and phosphorus cycling potential of bacterial communities associated with hyphae of *Penicillium* in soil are strongly affected by soil origin. *Frontiers in Microbiology*, *10*, Article 2951. https://doi.org/10.3389/fmicb.2019.02951

Hernández, L. (2006). La agricultura urbana y caracterización de sus sistemas productivos y sociales, como vía para la seguridad alimentaria en nuestras ciudades. *Cultivos Tropicales*, *27*(2), 13–25. https://www.redalyc.org/pdf/1932/193215872002.pdf

IGAC. (2021). *Recomendaciones para la toma de muestras para análisis del laboratorio nacional de suelos. Version 1.* https://www.igac.gov.co/sites/default/files/listadomaestro/in-agr-pc01-13_recomendaciones_para_la_toma_de_muestras_para_analisis_en_el_lns1_0.pdf

ILO. (2020, August 25). *COVID-19 and the impact on agriculture and food security*. ILO Sectoral Brief. https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/briefingnote/wcms_742023.pdf

Islam, A. K. M., Suttiyut, T., Anwar, M. P., Juraimi, A. S., & Kato-Noguchi, H. (2022). Allelopathic properties of Lamiaceae species: Prospects and challenges to use in agriculture. *Plants*, *11*(11), Article 1478. https://doi.org/10.3390/plants11111478

Jaramillo, D. F. (2002). *Introducción a la ciencia del suelo*. Universidad Nacional de Colombia. https://repositorio.unal.edu.co/bitstream/handle/unal/70085/70060838.2002.pdf?sequence=1&isAllowed=y

Jeavons, J. C. (2001). Biointensive sustainable mini-farming: II. Perspective, principles, techniques and history. *Journal of Sustainable Agriculture*, *19*(2), 65–76. https://doi.org/10.1300/J064v19n02_07

Lim, S. L., Wu, T. Y., Lim, P. N., & Shak, K. P. Y. (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. *Journal of the Science of Food and Agriculture*, *95*(6), 1143–1156. https://doi.org/10.1002/jsfa.6849

López, R. (2014, March 13–15). *Beneficios ambientales de la agricultura ecológica urbana y periurbana* [Conference presentation]. Segundo congreso de agricultura urbana y periurbana. Huertos urbanos, autoconsumo y participación social. Utrera, Sevilla. https://digital.csic.es/bitstream/10261/116301/3/Beneficios_ambientales_agricultura_ecol%C3%B3gica_urbana_periurbana_2014_Com_Congr..pdf

Martínez-Toro, P. M., Betancurth-Loaiza, D. P., & Velásquez-Arias, M. (2022). Huerta urbana comunitaria, más que lechugas entre cemento. Producción social de territorios saludables. *El Ágora USB, 22*(1), 409–425.

Moreno-Preciado, O. E., & Balaguera-López, H. E. (2021). Caracterización de la comunidad de malezas y su diversidad en una modelación estadística en un cultivo de duraznero (*Prunus persica* (L.) Batsch.). *Revista UDCA Actualidad & Divulgación*

Científica, *24*(1), Article e1734. https://doi.org/10.31910/rudca.v24.n1.2021.1734

Orsini, F., Kahane, R., Nono-Womdim, R., & Gianquinto, G. (2013). Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development, 33*, 695–720. https://doi.org/10.1007/s13593-013-0143-z

Pentón Fernández, G., Milera Rodríguez, M. C., & Schmidt, H. P. (2021). *Manual para la elaboración de biochar y microorganismos eficientes IHPLUS®BF*. Editorial Estación Experimental de Pastos y Forrajes Indio Hatuey. https://www.researchgate.net/publication/356873494_Manual_para_la_elaboracion_de_biochar_y_microorganismos_eficientes_IHPLUS_R_BF

Pérez-Somarriba, E. B., & Hernández-Fernández, G. M. (2022). Efecto de densidades de siembra en el desarrollo fenológico-productivo del cultivo de maíz (*Zea mays*) en camas biointensivas. *Revista Iberoamericana de Bioeconomia y Cambio Climático*, *8*(15), 1876–1885. https://doi.org/10.5377/ribcc.v8i15.14332

Pozza, L. E., & Field, D. J. (2020). The science of Soil Security and Food Security. *Soil Security, 1*, Article 100002. https://doi.org/10.1016/j.soisec.2020.100002

Rodríguez, B. (2021). *Análisis de la diversidad y abundancia de arvenses asociadas a producciones agrícolas familiares para fomentar el desarrollo de estrategias de conservación agroecológica* [Master thesis, Universidad de Cundinamarca]. Repositorio Universidad de Cundinamarca. http://hdl.handle.net/20.500.12558/3440

Román, P., Martínez, M. P., & Pantoja, A. (2013). *Manual de compostaje del agricultor*. Experiencias en América Latina.

Ruiz, B. (2013). *El huerto familiar biointensivo - introducción al método de cultivo biointensivo, alternativa para cultivar más alimentos en poco espacio y mejorar el suelo*. Secretaría de Medio Ambiente y Recursos Naturales. https://biblioteca.semarnat.gob.mx/janium/Documentos/Ciga/Libros2013/CD001599.pdf

Schonwald, J., & Pescio, F. (2015). *Mi casa, mi huerta: técnicas de agricultura urbana*. Ediciones INTA. https://www.magyp.gob.ar/sitio/areas/nuestra-huerta/pdf/mi-casa-mi-huerta.pdf

Torres Sanabria, C., & Cuartas Ricaurte, J. A. (2013). Uso de los suelos antropogénicos amazónicos: comparación entre comunidades Caboclas e indígenas Tikunas. *Gestión y Ambiente*, *16*(2), 5–17. https://revistas.unal.edu.co/index.php/gestion/article/view/39559

UFISAMO. (2018). *Urban gaps: good agricultural practice for urban agriculture - Cape Town edition*. Humboldt-Universität zu Berlin. https://www.sle-berlin.de/files/sle/FORSCHUNG/UFISAMO-urbanGAPs-guidelines-Cape%20Town.pdf

Walkley, A. J., & Black, I. A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Science, 37*, 29–38.

Zin, N. A., & Badaluddin, N. A. (2020). Biological functions of *Trichoderma* spp. for agriculture applications. *Annals of Agricultural Sciences*, *65*(2), 168–178. https://doi.org/10.1016/j.aoas.2020.09.003