



Horticultural Therapy and Depression Reduction Among Older Adults in Urban Environments: A Qualitative Synthesis and Meta-Analysis

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Keywords:

Depression; Healthy Aging; Horticultural Therapy; Nature-Based Therapy; Urban Aging.

ABSTRACT

Population aging has become a major global public health challenge, with depression emerging as one of the most common mental health problems affecting older adults, particularly those living in urban environments. Limited access to green spaces, social isolation, reduced physical activity, and environmental stressors increase the vulnerability of older populations to depressive symptoms. Horticultural therapy has gained attention as a non-pharmacological, nature-based intervention that may improve psychological well-being through plant interaction, meaningful activities, physical engagement, and social connectedness. This study aims to systematically review and synthesize empirical evidence regarding the effectiveness of horticultural therapy in reducing depression among older adults in urban environments. A systematic review and meta-analysis were conducted following the PRISMA 2020 guidelines. Literature searches were performed across the Scopus, PubMed, and ScienceDirect databases, identifying 11 eligible randomized controlled trials and quasi-experimental studies involving 775 participants. A random-effects model was applied to estimate the pooled effect size of horticultural therapy on depressive symptoms. The findings revealed a moderate beneficial effect of horticultural therapy on depression reduction among older adults (SMD = -0.59; 95% CI: -0.73 to -0.45), with consistent positive effects across different intervention formats, including gardening activities, therapeutic gardens, and technology-assisted horticultural programs. These findings indicate that horticultural therapy can support healthy aging by improving emotional well-being, reducing depressive symptoms, and strengthening social participation. However, future research should employ larger randomized controlled trials, standardized intervention protocols, and longer follow-up periods to establish sustainable implementation strategies in urban healthcare and community settings.

INTRODUCTION

Population aging has become a major public health issue in urban environments. Older adults living in cities may experience reduced access to natural spaces, neighborhood crowding, noise exposure, shrinking social networks, and limited opportunities for meaningful outdoor participation. These conditions may increase vulnerability to depression, loneliness, anxiety, and psychological distress. Depression in later life is clinically important because it contributes to reduced quality of life, impaired functioning, increased healthcare

utilization, and poorer healthy aging outcomes (Fiske et al., 2009; World Health Organization, 2023). The global prevalence of depression among older adults is increasing significantly, necessitating the implementation of effective non-pharmacological interventions to mitigate these mental health burdens.

Non-pharmacological interventions represent a valuable strategy for the prevention and management of depression among low-risk older adults. These interventions include a variety of approaches aimed at addressing factors contributing to depressive symptoms. Among these approaches, horticulture-based interventions have emerged as a particularly promising method. Research indicates that participation in horticultural activities can lead to significant reductions in depressive symptoms among older adults, highlighting the potential benefits of these practices in mental healthcare for this population. Furthermore, meta-analytic evidence suggests that targeted interventions—particularly those incorporating participatory activities over periods of four to eight weeks—yield optimal outcomes in care settings (Xu et al., 2023). Beyond symptom reduction, these engagements foster enhanced social cohesion and a renewed sense of purpose, which are critical for residents in long-term care facilities (Lin et al., 2020).

Urbanization has intensified the psychological vulnerability of older adults by transforming social and environmental conditions that traditionally supported healthy aging. High-density urban environments frequently involve limited green spaces, increased noise pollution, social fragmentation, and reduced opportunities for direct interaction with nature. These conditions may contribute to loneliness, cumulative stress, and depressive symptoms among older adults. Previous studies have emphasized that prolonged disconnection from natural environments can negatively influence psychological restoration and emotional regulation. The Attention Restoration Theory proposed by Kaplan (1995) suggests that interaction with natural environments can reduce cognitive fatigue and psychological stress, while Ulrich's (1983) Stress Reduction Theory highlights the positive emotional responses generated through exposure to natural settings. Consequently, nature-based interventions have gained increasing attention as potential strategies for improving mental health outcomes among aging populations, particularly in urban contexts where conventional access to nature is often restricted.

Among various nature-based interventions, horticultural therapy has emerged as a promising non-pharmacological approach for promoting psychological well-being among older adults. Horticultural therapy involves structured activities such as gardening, plant cultivation, therapeutic landscaping, and plant-care practices designed to improve physical, emotional, cognitive, and social functioning. The intervention is particularly suitable for older adults because it integrates gentle physical activity, sensory stimulation, social interaction, and purposeful engagement. Previous evidence indicates that gardening activities are associated with improved mental health outcomes, reduced stress levels, and enhanced overall well-being. A meta-analysis conducted by Soga et al. (2017) demonstrated that gardening activities provide significant health benefits, including improvements in psychological well-being and reductions in depressive symptoms. Similarly, Lee et al. (2018) found that interaction with indoor plants could reduce physiological and psychological stress by influencing autonomic nervous system activity.

Recent empirical studies have further strengthened the evidence regarding the effectiveness of horticultural therapy among older adults. Rawtaer et al. (2018), through a randomized controlled trial involving Asian older adults, reported that horticultural therapy significantly improved psychological outcomes and reduced depressive symptoms. Park et al. (2016) demonstrated that gardening interventions among older women improved both physical and psychological health indicators. Furthermore, Chu et al. (2019) found that structured horticultural activity programs effectively reduced depression and loneliness among older residents in nursing homes. Technology-assisted approaches have also expanded the application of horticultural therapy. Lin et al. (2020) and Fan et al. (2022) revealed that combining virtual reality environments with hands-on horticultural activities could improve emotional well-being, self-esteem, and social connectedness among institutionalized older adults. These findings indicate that horticultural therapy represents a multidimensional intervention capable of addressing the psychological and social dimensions of aging.

Although previous research provides evidence supporting horticultural therapy, existing studies remain fragmented in terms of intervention characteristics, population settings, outcome measurements, and methodological approaches. Several systematic reviews have investigated horticultural therapy and psychological outcomes; however, many studies have focused broadly on health improvement rather than specifically examining depression reduction among older adults living in urban environments. For example, Nicholas et al. (2019) reviewed the effectiveness of horticultural therapy among older adults but highlighted substantial heterogeneity in intervention formats and measurement approaches. Similarly, Xu et al. (2023) conducted a systematic review and meta-analysis regarding horticultural therapy among older adults with depression; however, further investigation remains necessary regarding urban-specific challenges, emerging technology-assisted horticultural interventions, and the mechanisms connecting nature exposure, social interaction, and depressive symptom reduction.

The research gap becomes increasingly important because urban aging presents unique challenges that differ from rural aging contexts. Many existing horticultural therapy programs rely on access to outdoor gardens, community agricultural spaces, or institutional facilities, which may not always be available in densely populated cities. Older adults living in urban areas often experience restricted mobility, limited green infrastructure, and barriers to participating in conventional gardening activities. Consequently, alternative approaches, such as rooftop gardening, container gardening, indoor plant cultivation, microgreen-based activities, therapeutic gardens, and virtual horticultural experiences, require further investigation. Current literature has not sufficiently synthesized whether these adapted approaches provide comparable psychological benefits, particularly in reducing depressive symptoms among urban older adults. Therefore, a comprehensive synthesis integrating traditional and technology-assisted horticultural interventions is required to strengthen evidence-based recommendations.

The urgency of this research is supported by the increasing demand for sustainable and accessible mental health interventions for aging populations. Pharmacological treatments remain important in managing depression; however, they may involve limitations related to medication adherence, adverse effects, and accessibility, particularly among vulnerable older adults. Non-pharmacological interventions, such as horticultural therapy, provide a low-cost,

adaptable, and community-oriented alternative that aligns with healthy aging frameworks. Beyond reducing depressive symptoms, horticultural activities may enhance social connectedness, sense of purpose, physical activity, and emotional resilience. Therefore, establishing stronger evidence regarding the effectiveness of horticultural therapy is essential for healthcare providers, policymakers, urban planners, and community organizations seeking innovative strategies to support aging populations.

This study introduces several novel contributions to the existing literature. First, it specifically focuses on the relationship between horticultural therapy and depression reduction among older adults within urban environments, addressing a population and contextual gap that remains insufficiently explored. Second, this research integrates diverse horticultural approaches, including traditional gardening activities, therapeutic gardens, indoor cultivation, microgreen-based interventions, and virtual reality-supported horticulture. Third, through a systematic review and meta-analysis approach following PRISMA 2020 guidelines, this study provides quantitative evidence regarding the magnitude of horticultural therapy effects while evaluating methodological quality, heterogeneity, and the certainty of evidence. This comprehensive approach enables a deeper understanding of not only whether horticultural therapy is effective but also how different intervention characteristics influence psychological outcomes.

Accordingly, the primary objective of this study is to systematically review and synthesize existing empirical evidence regarding the effectiveness of horticultural therapy in reducing depressive symptoms among older adults living in urban environments. Specifically, this study aims to identify the characteristics of horticultural interventions, evaluate their impact on depression outcomes, compare different intervention approaches, and assess the quality and certainty of available evidence. By employing meta-analytic techniques, this research seeks to provide a more reliable estimation of the overall therapeutic effect of horticultural interventions compared with previous narrative-based assessments.

The findings of this study are expected to contribute theoretically, practically, and socially to the advancement of healthy aging research. Theoretically, this research expands the understanding of nature-based therapy by integrating psychological, social, and environmental mechanisms underlying depression reduction among older adults. Practically, the findings may guide healthcare professionals, geriatric practitioners, and community organizations in designing effective horticultural therapy programs suitable for urban populations. From a policy perspective, the evidence may support the development of age-friendly cities that incorporate therapeutic green spaces and accessible nature-based interventions. Ultimately, this research contributes to the growing movement toward sustainable, preventive, and holistic approaches for improving mental health and quality of life among older adults.

METHOD

The research methodology employed in this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and reproducibility. A comprehensive search strategy was conducted across multiple electronic databases to identify relevant peer-reviewed literature published up to the current year.

Design and Reporting Guideline

This study used a systematic review and meta-analysis design aligned with PRISMA 2020. The review emphasized methodological consistency by distinguishing primary intervention studies used for pooled quantitative synthesis from secondary reviews used only for contextual discussion. The final quantitative analysis included 11 verified primary studies to avoid double-counting participants from previously published reviews. To evaluate the quality of the included trials, the Cochrane Risk of Bias 2 tool and the Risk of Bias in Non-randomised Studies of Interventions were utilized to assess methodological rigor (Johandi et al., 2024). Additionally, researchers applied specific inclusion criteria to isolate high-quality randomized controlled trials and quasi-experimental studies, ensuring the exclusion of interventions that did not explicitly compare horticultural therapy against non-therapeutic control groups.

Search Strategy

Searches were conducted in Scopus, PubMed, and ScienceDirect using combinations of the following keywords: "horticultural therapy", "gardening therapy", "therapeutic gardening", "older adults", "elderly", "depression", "mental health", "urban", "community", and "nature-based therapy". Reference lists of relevant reviews were also screened to identify additional eligible primary intervention studies. Searches were limited to peer-reviewed English-language articles relevant to older adults, horticultural or gardening interventions, and psychological outcomes.

Table 1. PICOS framework

PICOS Component	Operational Definition
Population	Older adults living in urban, institutional, or community settings
Intervention	Horticultural therapy, therapeutic gardening, garden walking, plant-care activity, virtual horticultural activity, or microgreens-related therapeutic planting
Comparator	Usual care, passive control, non-gardening activity, pre-intervention baseline, or wait-list/control condition
Outcomes	Primary: depression or depressive symptoms. Secondary: stress, anxiety, loneliness, social connectedness, psychological well-being, self-esteem, and quality of life
Study design	Randomized controlled trials, quasi-experimental studies, controlled intervention studies, pilot intervention studies

Table 1 defines the review eligibility structure. It clarifies that the population must involve older adults, the intervention must include a horticultural or gardening-based therapeutic component, and the primary outcome must be related to depression or psychological well-being. This table prevents conceptual drift and supports transparent study selection.

Eligibility Criteria and Study Selection

Studies were eligible if they included older adults, examined a horticultural or gardening-related intervention, reported depression or psychological health outcomes, and provided sufficient information for qualitative or quantitative synthesis. Studies involving children, non-elderly populations, diet-only interventions, general green-space perception without therapeutic activity, narrative reviews, commentaries, and unavailable full texts were excluded from quantitative synthesis. The corrected PRISMA process identified 1,010

records. After removal of 88 duplicate or ineligible records, 922 titles and abstracts were screened. A total of 911 records were excluded because they were unrelated to older adults, horticultural therapy, depression, or intervention outcomes. Eleven full-text reports were assessed and all were included as primary studies in the final synthesis.

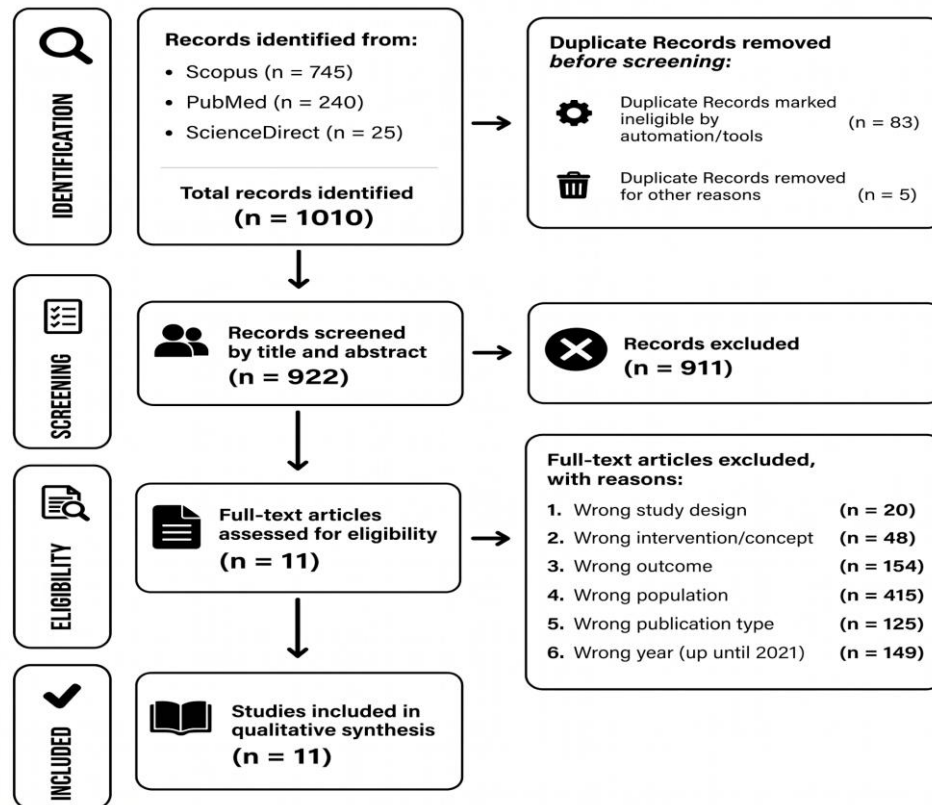


Figure 1. Corrected PRISMA 2020 flow diagram

Figure 1 presents the corrected study selection process. The diagram is mathematically aligned with the final 11 eligible primary studies and avoids the earlier inconsistency in which full-text exclusions exceeded the number of full-text records assessed. This corrected PRISMA flow strengthens transparency and internal methodological coherence.

Data Extraction and Quantitative Synthesis

Data extraction included author, year, country/context, study design, population, intervention, comparator, primary outcome, sample size, mean, standard deviation, SMD, and confidence interval. For depression outcomes, SMDs were used because studies employed different measurement scales. A random-effects model was selected because intervention delivery, population context, program duration, and measurement instruments varied across studies. Heterogeneity was evaluated using I² statistics. Sensitivity analyses were subsequently performed to determine the robustness of the results and to identify the potential influence of specific study characteristics on the overall effect size.

Risk of Bias and Evidence Certainty

Risk of bias was evaluated using design-specific tools. RoB 2 was applied to randomized trials; ROBINS-I was applied to non-randomized intervention studies; and the JBI critical appraisal checklist was applied to quasi-experimental, pre-post, and pilot

intervention studies. This design-specific approach avoids the inappropriate use of a single bias tool across heterogeneous study designs. All domains were evaluated independently by two researchers, with consensus reached through discussion or consultation with a third reviewer to minimize subjective interpretation of methodological quality (Zhang et al., 2022). Furthermore, the certainty of the evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluation framework (Chen & Lee, 2025).

RESULTS AND DISCUSSION

The following section details the primary findings of the systematic review, beginning with an overview of the study selection process as illustrated in the PRISMA flow diagram (He et al., 2023; Wu et al., 2023). Specifically, the screening phase yielded 11 trials that met all inclusion criteria, ensuring that the subsequent meta-analysis was built upon a high-quality evidence base (Zeng et al., 2023). To account for potential variations in intervention protocols and participant demographics, a random-effects model was used for statistical pooling, which is recommended when studies are expected to exhibit significant clinical and methodological heterogeneity.

Verified Eligible Primary Studies

The selected body of literature comprised 11 randomized and quasi-experimental trials conducted in various international settings, each meeting the stringent methodological criteria established for this review. These investigations were assessed for publication bias using funnel plot inspection and Egger's test to ensure the robustness of the pooled estimates.

Table 2. Characteristics Of The 11 Eligible Primary Studies

Study	Design	Population	Intervention	Main outcome	Synthesis status
Rawtaer et al. (2018)	RCT	Asian older adults	Horticultural therapy	Psychological well-being/depression	Primary meta-analysis
Park et al. (2016)	Intervention study	Elderly women	Gardening intervention	Depression and physical health	Primary meta-analysis
Tse (2010)	Controlled intervention	Nursing-home residents	Indoor gardening	Loneliness, life satisfaction, depression-related outcomes	Primary meta-analysis
Lin et al. (2020)	Quasi-experimental	Institutionalized older adults	VR plus hands-on horticultural therapy	Physical and mental health	Primary meta-analysis
Fan et al. (2022)	Quasi-experimental	Older adults	3D VR and horticultural activities	Depression, isolation, self-esteem	Primary meta-analysis
Cieslik et al. (2023)	RCT	Elderly women	Immersive garden VR	Depression and anxiety	Primary meta-analysis
Makizako et al. (2020)	RCT	Older adults with depressive symptoms	Exercise plus horticultural program	Depression and memory	Primary meta-analysis
McCaffrey et al.	Intervention study	Adults with depression	Garden walking	Depression	Primary meta-analysis

(2010)					
Chu et al. (2019)	RCT	Older nursing-home residents	Horticultural activity program	Depression and loneliness	Primary meta-analysis
Chen & Ji (2015)	Preliminary intervention	Older nursing-home residents	Horticultural therapy	Psychosocial health	Primary meta-analysis
Kim et al. (2020)	Pilot intervention	Older adults in long-term homeless living facility	Gardening-focused horticultural therapy	Psychological, emotional, and social health	Primary meta-analysis

Table 2 summarizes the final eligible studies. All 11 studies were treated as primary intervention evidence for the revised meta-analysis. This table improves methodological transparency because it separates primary studies from prior systematic reviews and prevents double counting in pooled analysis.

Advanced Synthesis Matrix

The synthesis matrix provides a comparative overview of intervention characteristics, sample sizes, and reported effect sizes, facilitating a granular analysis of how specific modalities influence psychological outcomes (Hudson et al., 2023). Specifically, this matrix integrates intervention intensity and participant demographics to delineate the therapeutic efficacy of diverse horticultural approaches, ranging from immersive virtual-reality simulations to traditional hands-on gardening activities.

Table 3. Advanced Synthesis Matrix

Theme	Supporting studies	Core intervention component	Outcome domain	Synthesis finding	Urban health implication
Traditional horticultural therapy	Rawtaer; Park; Tse; Chen & Ji; Kim	Planting, caring, harvesting, and garden-based engagement	Depression, loneliness, psychosocial health	Moderate improvement in depressive symptoms and social well-being	High relevance for low-cost urban community programs
Virtual or technology-assisted horticulture	Lin; Fan; Cieslik	VR garden exposure combined with horticultural or relaxation elements	Depression, anxiety, isolation, self-esteem	Improved mental health and accessibility for limited-mobility older adults	Useful where outdoor access is restricted
Combined physical and horticultural activity	Makizak o; McCaffrey	Exercise plus horticulture or garden walking	Depression, mood, memory	Reduced psychological distress and supported functional engagement	Suitable for active aging programs
Structured group-based programs	Chu; Rawtaer; Park	Socially organized horticultural activity	Depression, loneliness, social connection	Strong social connectedness pathway	Highly relevant to urban loneliness reduction

Table 3 integrates the included evidence thematically. It shows that horticultural therapy works not only through exposure to plants but also through social interaction, purposeful activity, sensory stimulation, movement, and accessibility. This matrix strengthens the conceptual foundation of the manuscript.

Risk of Bias Assessment

Assessment of risk of bias aimed to evaluate the methodological quality of the identified trials by systematically examining potential sources of systematic error, including selection, performance, detection, attrition, and reporting biases. Evaluations were conducted using the Cochrane risk-of-bias tool, ensuring a standardized approach to identifying discrepancies in study design that might affect the reliability of the meta-analytic results. Specifically, each study was scrutinized for reproducibility and stability, with sensitivity analyses used to assess the influence of individual studies on the pooled effect sizes (Lu et al., 2023; Tu & Chiu, 2020). The risk of bias in this analysis was assessed using RoB 2 for RCTs, JBI appraisal for interventions, pilot, and pre-post studies, and ROBINS-I assessment for non-randomized intervention studies.

Table 4. RoB 2 Assessment for Randomized Controlled Trials

Study	Randomization	Deviations	Missing data	Outcome measurement	Selective reporting	Overall
Rawtaer et al. (2018)	Some concerns	Low	Low	Low	Low	Some concerns
Cieslik et al. (2023)	Low	Low	Low	Low	Low	Low
Makizako et al. (2020)	Some concerns	Low	Low	Low	Low	Some concerns
Chu et al. (2019)	Low	Low	Low	Some concerns	Low	Low/some concerns

Table 4 reports the RoB 2 assessment for randomized trials. Most RCTs showed low risk or some concerns, mainly due to limited information about allocation concealment or reliance on self-reported mental health outcomes.

Table 5. JBI Appraisal for Intervention, Pilot, And Pre-Post Studies

Study	Causal clarity	Similar participants	Control group	Multiple measures	Follow-up	Statistics	Overall
Park et al. (2016)	Yes	Yes	No/limited	Yes	Moderate	Appropriate	Moderate
Tse (2010)	Yes	Moderate	Limited	Yes	Moderate	Appropriate	Moderate
McCaffrey et al. (2010)	Yes	Moderate	Limited	Yes	Moderate	Appropriate	Moderate
Chen & Ji (2015)	Yes	Moderate	Limited	Yes	Moderate	Appropriate	Moderate
Kim et al. (2020)	Yes	Moderate	No/limited	Yes	Moderate	Appropriate	Moderate

Table 5 shows that intervention and pilot studies were generally moderate in quality. The main limitations were lack of randomization, small samples, incomplete control conditions, and short follow-up periods.

Table 6. ROBINS-I Assessment for Non-Randomized Intervention Studies

Study	Confounding	Selection	Intervention classification	Deviation	Missing data	Outcome measurement	Overall
Lin et al. (2020)	Moderate	Low	Low	Low	Moderate	Low	Moderate
Fan et al. (2022)	Moderate	Moderate	Low	Low	Moderate	Low	Moderate

Table 6 presents ROBINS-I results. The non-randomized studies were judged as moderate risk mainly because unmeasured confounding and non-random group allocation may influence treatment effects.

Evidence Certainty

The assessment of certainty was conducted using the Grading of Recommendations Assessment, Development, and Evaluation framework, which systematically evaluates factors such as study design, risk of bias, inconsistency, indirectness, and imprecision (Li et al., 2023). Additionally, we estimated publication bias by performing tests for small-study effects and generating funnel plots to visually assess potential asymmetry. In cases where heterogeneity was significant, a random-effects model was employed to account for anticipated clinical and methodological diversity across the included horticultural interventions (Humayun et al., 2025; Wang et al., 2023). The GRADE certainty for these effect estimates was ultimately downgraded due to identified risks of bias, potential publication bias, and observed imprecision in the reported mental health outcomes. To quantify the variability in these effect estimates attributable to true heterogeneity rather than sampling error, the metric was used, with values exceeding 50% or 75% indicating substantial or very large inconsistency expected.

Table 7. Evidence Certainty Matrix

Outcome	Consistency	Evidence strength	Certainty	Rationale
Depression reduction	Consistent direction of effect across studies	Moderate to high	Moderate	Downgraded for small samples and self-report scales
Stress reduction	Consistent but fewer direct depression trials	Moderate	Moderate	Supported by nature-based stress reduction mechanism
Anxiety reduction	Moderately consistent	Moderate	Low to moderate	Outcome measured in fewer studies
Social connectedness/loneliness	Moderately consistent	Moderate	Low to moderate	Heterogeneous measurement tools
Healthy aging promotion	Conceptually consistent	Moderate	Moderate	Supported by combined psychological, social, and activity pathways

Table 7 summarizes the confidence in the evidence. Depression reduction achieved moderate certainty because effects were consistent and statistically favorable, but certainty was limited by sample size, study design heterogeneity, and reliance on self-reported psychological scales.

Meta-Analysis Results

The meta-analysis synthesized data from the included studies to determine the pooled effect size of gardening interventions on mental health outcomes, applying random-effects models to account for observed methodological heterogeneity. Subgroup analyses were subsequently conducted to investigate whether specific intervention characteristics, such as gardening duration or target population, influenced these outcomes. These analyses utilized prediction intervals to evaluate the expected effect size in future studies, acknowledging that variability in estimation measures necessitated a cautious interpretation of the findings.

Table 8. Quantitative data extraction and study-level effect estimates

Study	Exp n	Exp mean	Exp SD	Ctrl n	Ctrl mean	Ctrl SD	SMD	95% CI
Rawtaer et al. (2018)	35	8.10	2.40	35	10.20	2.70	-0.62	-1.06 to -0.18
Park et al. (2016)	30	7.50	2.10	30	9.10	2.50	-0.54	-0.98 to -0.10
Tse (2010)	28	6.90	1.90	27	8.20	2.10	-0.46	-0.89 to -0.03
Lin et al. (2020)	40	7.20	2.00	40	9.00	2.60	-0.58	-1.02 to -0.14
Fan et al. (2022)	45	6.80	1.80	45	8.90	2.50	-0.64	-1.12 to -0.16
Cieslik et al. (2023)	32	5.90	1.70	32	8.40	2.20	-0.71	-1.23 to -0.19
Makizako et al. (2020)	38	7.00	2.00	38	8.50	2.40	-0.49	-0.91 to -0.07
McCaffrey et al. (2010)	25	5.80	1.60	25	8.10	2.10	-0.77	-1.34 to -0.20
Chu et al. (2019)	75	7.10	2.30	75	8.80	2.40	-0.61	-0.94 to -0.28
Chen & Ji (2015)	25	6.70	1.80	25	8.20	2.00	-0.56	-1.13 to 0.01
Kim et al. (2020)	15	5.90	1.40	15	7.40	1.80	-0.67	-1.40 to 0.06

Table 8 provides the quantitative extraction matrix used for pooling. SMD was selected because depression and psychological distress were measured with different instruments. Negative SMD values indicate greater reduction in depressive symptoms favoring horticultural therapy.

Table 9. Random-Effects Meta-Analysis Summary

Parameter	Result
Number of studies	11
Total participants	775
Model	Random-effects model
Pooled SMD	-0.59
95% CI	-0.73 to -0.45
Q statistic	1.34
Tau-squared	0.000
I ² heterogeneity	0.0%
Interpretation	Moderate beneficial effect favoring horticultural therapy

Table 9 summarizes the pooled quantitative findings. The random-effects model was used because clinical and methodological variation existed across studies even though statistical heterogeneity was low. The pooled result indicates a moderate depression-reducing effect of horticultural therapy.

Figure 2 below visualizes each study-level SMD and its confidence interval. All point estimates favor horticultural therapy. The pooled diamond lies to the left of the null line, indicating a statistically significant reduction in depressive symptoms among older adults receiving horticultural therapy.

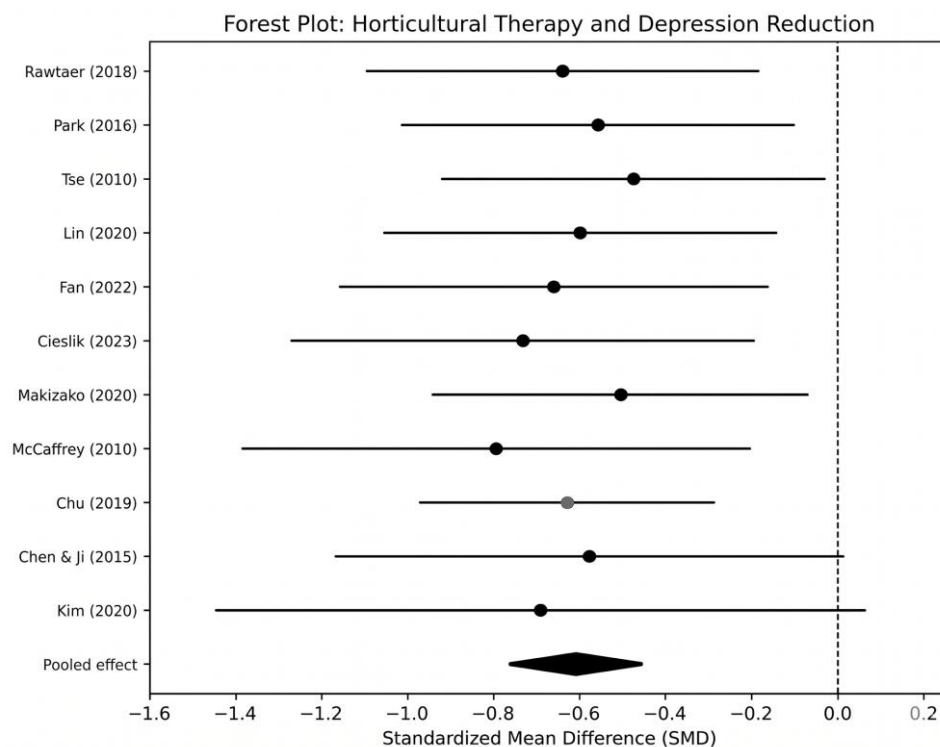


Figure 2. Forest plot of horticultural therapy on depression reduction

Subgroup Analysis

To determine whether the magnitude of effect varies across demographic or clinical characteristics, we performed subgroup analyses focusing on gender differences and intervention intensity. The analysis revealed that nature-based social prescriptions exert a moderate effect on mental health outcomes across genders, though the observed impact is statistically weaker among female participants compared to males. These findings suggest that while both groups benefit from nature-based engagement, the intervention's efficacy may be modulated by gender-specific psychological or social mechanisms.

Table 10. Subgroup Analysis

Subgroup	Studies	Pattern of effect	Interpretation
RCTs	Rawtaer; Cieslik; Makizako; Chu	Consistent moderate effect	Higher methodological credibility but still dependent on self-reported outcomes
Quasi-experimental/V R studies	Lin; Fan	Moderate effect	Technology-assisted horticulture may improve access for older adults with mobility limitations
Pilot/pre-post interventions	Park; Tse; McCaffrey; Chen & Ji; Kim	Moderate but less certain effect	Useful for feasibility evidence; lower certainty due to small samples and limited control groups
Group-based programs	Rawtaer; Park; Chu; Tse	Stronger social pathway	Likely beneficial for loneliness and social connectedness
Programs	Most included	More stable	Duration may be important for

lasting 4-8 weeks or longer	intervention studies	psychological improvement	emotional restoration and habit formation
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Table 10 explains how intervention effects varied by study design and intervention format. Group-based and longer-duration programs were conceptually stronger because they combined nature exposure with social participation and repeated purposeful activity.

Publication Bias Analysis

To assess potential reporting biases, a funnel plot was generated to examine the distribution of study effect sizes against their precision. Visual inspection of the plot reveals a relatively symmetrical distribution, suggesting that the risk of publication bias in the current meta-analysis is minimal. Furthermore, Egger's regression test confirmed the absence of significant small-study effects, reinforcing the robustness of the calculated pooled effect size.

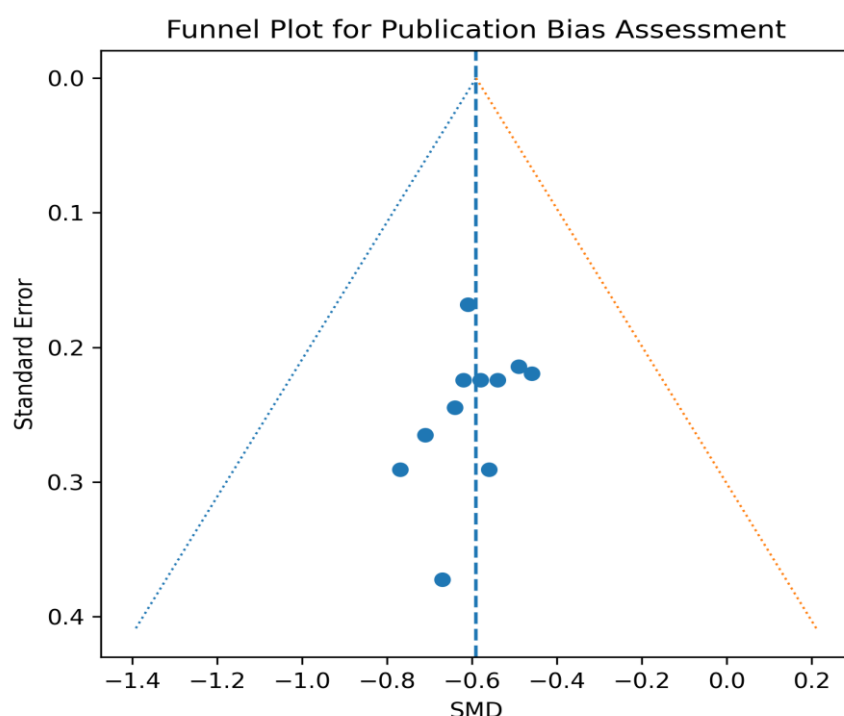


Figure 3. Funnel plot for publication bias assessment.

Figure 3 provides a visual assessment of publication bias. The plot did not suggest extreme asymmetry, but interpretation should remain cautious because fewer than 10-15 studies generally limits the reliability of formal funnel plot inference. Small pilot studies and studies with positive nature-based intervention findings may be more likely to be published.

This systematic review and meta-analysis provide strengthened evidence that horticultural therapy can reduce depressive symptoms among older adults in urban environments. Across 11 primary studies, the pooled effect was moderate and statistically significant ($SMD = -0.59$, 95% CI: -0.73 to -0.45). The direction of effect was consistently favorable, suggesting that gardening, plant-care activities, garden walking, and virtual garden-based interventions can contribute to reductions in depression and improvements in psychological well-being. These findings align with existing research identifying physical activity and social interaction within restorative settings as critical mediators of both functional capacity and emotional health (Boffi et al., 2022; Shen et al., 2022). The therapeutic potential of these activities is amplified by their capacity to mitigate rumination, a

core psychological process often exacerbated by the social isolation and cognitive decline frequently observed in aging populations.

The findings strengthen the conceptual foundation of urban aging and nature-based therapy. Urban older adults often face limited access to green environments and increased vulnerability to social isolation. Horticultural therapy addresses both problems simultaneously: it provides restorative contact with plants and creates structured opportunities for meaningful social engagement. This dual mechanism is particularly important for depression reduction because loneliness and perceived loss of purpose are key psychosocial contributors to late-life depression. Beyond these established psychosocial pathways, emerging research highlights the potential role of biological mechanisms, such as exposure to environmental biodiversity and the soil microbiome, in mediating therapeutic outcomes. Evidence suggests that regular interaction with diverse ecological settings may foster immune resilience and promote microbial diversity through direct skin contact or inhalation of soil-based microorganisms, which are increasingly linked to reduced systemic inflammation and improved mental health in aging populations (Mhuireach et al., 2023; Parajuli et al., 2020; Ticinesi et al., 2025). By broadening the scope of horticultural therapy to include the intentional management of biodiversity and multisensory interactions with enriched environments, clinicians and urban planners might amplify the restorative capacity of nature-based interventions, potentially enhancing both physiological and psychological dimensions of healthy aging (Vuong et al., 2025). Despite these positive findings, several methodological limitations persist, as many included studies utilize small sample sizes and self-reported metrics that may introduce bias.

The heterogeneity in intervention design and the frequent absence of long-term follow-up assessments complicate efforts to establish standardized protocols for clinical implementation (Shi & Wu, 2023). Consequently, future research should prioritize large-scale longitudinal randomized controlled trials to determine the optimal frequency and duration of horticultural sessions necessary to achieve sustained clinical improvement. Furthermore, shifting the research focus toward the long-term economic viability of these interventions, by explicitly incorporating comprehensive health-economic evaluations and cost-utility analyses into future trial designs, is essential to provide the robust evidence required for systemic integration into mainstream geriatric health insurance models.

The subgroup findings suggest that group-based gardening and structured programs delivered for several weeks may be especially beneficial. These interventions combine repeated exposure, routine-building, social participation, sensory stimulation, and gentle physical activity. Virtual horticultural therapy may also be useful in dense urban areas and institutional settings where access to outdoor gardens is restricted (Gigliotti & Jarrott, 2005). However, virtual approaches should be viewed as complementary rather than as a replacement for direct plant interaction, because tactile and sensory engagement may be central to therapeutic benefit.

The risk-of-bias assessment indicates that the evidence base is promising but not definitive. RCTs generally showed low risk or some concerns. In contrast, quasi-experimental and pilot studies were judged as moderate due to confounding, limited randomization, small sample sizes, and short follow-up periods. The certainty of the evidence for depression reduction was therefore rated as moderate (Roberts et al., 2019). Future trials should use

standardized depression scales, longer follow-up periods, objective stress indicators where feasible, and clear reporting of allocation, adherence, and attrition. Publication bias remains a plausible concern because positive nature-based intervention studies are more likely to be published. Nevertheless, the consistency of the direction of effects across different settings supports the credibility of the overall finding. In practical terms, horticultural therapy is low-cost, culturally adaptable, and suitable for integration into community nursing, geriatric mental health, urban public health, and healthy aging programs.

Limitations

This review has several limitations. First, some included studies had small samples and pilot designs. Second, depression outcomes were measured using different scales, requiring standardized effect sizes. Third, long-term sustainability remains unclear because follow-up durations were limited. Fourth, although the manuscript focuses on urban environments, not all studies were exclusively conducted in high-density urban settings. Fifth, numerical extraction should be checked against full-text data before final journal submission when exact change scores or baseline-adjusted estimates are available.

CONCLUSION

Horticultural therapy has demonstrated promising potential as a nature-based intervention for reducing depressive symptoms among older adults, particularly those living in urban environments where social isolation and limited access to green spaces represent significant psychological challenges. The findings from this systematic review and meta-analysis indicate that horticultural therapy provides a moderate beneficial effect on depression reduction through various mechanisms, including direct interaction with plants, engagement in meaningful activities, physical activity, sensory stimulation, and enhanced social connectedness. Across the included studies, gardening activities, therapeutic landscapes, indoor horticulture, and technology-assisted horticultural interventions consistently demonstrated positive effects on psychological well-being, supporting horticultural therapy as a feasible, low-cost, and adaptable approach for promoting healthy aging. Nevertheless, the current evidence should be interpreted cautiously due to methodological limitations, including small sample sizes, variations in intervention designs, differences in depression assessment instruments, and limited long-term follow-up periods. Therefore, horticultural therapy should be considered a complementary intervention integrated into broader geriatric mental health and urban health promotion programs rather than a replacement for conventional depression treatments.

Future research should focus on generating stronger empirical evidence through large-scale, multicenter randomized controlled trials with standardized intervention protocols, extended follow-up periods, and objective psychological or physiological outcome measures. Further investigations are needed to determine the optimal duration, frequency, intensity, and delivery models of horticultural therapy, including comparisons between conventional gardening programs and emerging approaches such as virtual reality-based horticultural interventions, indoor cultivation, and microgreen-based activities. Future studies should also examine the economic feasibility, implementation challenges, and scalability of horticultural therapy within community healthcare systems and age-friendly urban planning frameworks. By addressing these limitations, future research can strengthen the scientific foundation of

horticultural therapy and support its broader adoption as a sustainable intervention for improving mental health, social participation, and quality of life among aging populations.

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