# Horticultural Interventions may Reduce Adults' Depressive Symptoms: A Systematic Review of Randomized Controlled Trials

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**Abstract**

We conducted a systematic review to examine the effect of horticultural interventions (e.g., planting or taking care of plants) on people's depressive symptoms as assessed by depression outcome measures. On January 19 of 2022, the databases MEDLINE (PubMed), PsycArticles (APA), SCOPUS (Elsevier), Google Scholar, and ClinicalTrails.gov were searched from inception. The decision to include or exclude studies in the full text, the data extraction, and the risk of bias assessment were performed by two researchers. We identified 20 randomized controlled trials (RCTs) ($n$ = 998 participants; all adults), from nine different countries. Overall, we found evidence that some horticultural interventions plus usual care (i.e., continuing normal routine for healthy people or treatment for unhealthy ones) may reduce depressive symptoms more than usual care alone, with most studies suggesting a moderate (Hedges' $g \geq 0.5$) or large effect ($g \geq 0.8$). The percentage of participants who dropped out from any of the horticultural interventions ranged from 0% to 40% and only one study reported adverse events (i.e., fatigue and tiredness) related to the intervention. Except for one study, all studies had some risk of bias due to design limitations, such as lack of participants' blinding and/or a prespecified analysis plan. Our findings suggest that some horticultural interventions are effective and safe to use as a complementary strategy to reduce adults' depressive symptoms. More RCTs are needed to understand how specific participants and intervention characteristics can alter the effect of horticultural interventions on depressive symptoms.

*Keywords*: depressed, gardening, horticulture, mental health

# Horticultural Interventions may Reduce Adults' Depressive Symptoms: A Systematic Review of Randomized Controlled Trials

Depression is one of the most serious global health challenges (A. Cipriani et al., 2018). Before the COVID-19 pandemic, it was estimated that 322 million people in the world dealt with this disorder, which can harm different dimensions of people's lives including affective relationships, professional achievement, and overall health and well-being (World Health Organization, 2017). Unfortunately, this prevalence may now be higher since a 27.6% increase in depression was associated with the COVID-19 pandemic (World Health Organization, 2022). The use of antidepressants and psychotherapy are two of the most well-known and recommended treatments for depression (Lopresti, 2019). Nonetheless, even the combination of these treatments commonly produces small improvements in depressive symptoms (Cuijpers et al., 2020; Lopresti, 2019; McCormack & Korownyk, 2018). Thus, efforts have been directed towards complementary interventions that may help to provide greater reductions in depressive symptoms, such as physical exercise (Catalan-Matamoros et al., 2016), diet changes (Berk & Jacka, 2019), and contact with nature (Rosa et al., 2021). The use of nature-based activities to reduce people's depressive symptoms seems especially promising when compared to physical exercise and diet changes (Rosa et al., 2021). For example, Rosa et al. (2021) found that, compared to usual care, participants in forest therapy groups were 17 times as likely to achieve remission and three times as likely to have at least a 50% reduction on depressive symptoms.

Several theories and frameworks have been used to explain the health benefits associated with activities in nature (Fernee et al., 2017; Houge Mackenzie et al., 2021; Kaplan, 1995; Reese & Gosling, 2020; Russell & Farnum, 2004; Ulrich et al., 1991; Wilson, 1984). Among these, Attention Restoration Theory (ART, Kaplan, 1995) and Stress Recovery

Theory (SRT, Ulrich et al., 1991) have emerged as the most popular theoretical explanations (Berto, 2014; Crossan & Salmoni, 2021; Frost et al., 2022; Hartig, 2021; Jiang et al., 2021; Moll et al., 2022; Ohly et al., 2016). Taken together ART and SRT posit that positive experiences in nature can be pleasurable, reduce anxiety and stress, and improve concentration and mood, all of which are related to lower depressive symptomatology (Fried, 2017; Kaplan, 1995; Owens & Bunce, 2022; Rosa et al., 2021; Ulrich et al., 1991). In accordance with these theories, research suggests that some activities involving contact with nature may improve people's depressive symptoms such as sad mood (Soga et al., 2017), difficulty in concentrating (Clatworthy et al., 2013), sleep problems (Shin et al., 2012), and hopelessness (Sturm et al., 2012). Despite the potential benefits of nature-based activities, systematic reviews on the effect of nature-based interventions on depression are scarce, hindering our knowledge about what types of nature-based activities (if any) are best to improve depressive symptoms.

Three different types of nature-based interventions are often described in the academic literature: forest therapy (e.g., W. Kim et al., 2009), nature-based adventure (e.g., Sturm et al., 2012), and horticultural activities (e.g., Kam & Siu, 2010). Systematic reviews were already done to investigate the effect of the first two types of nature-based interventions on depression (Rosa et al., 2021; Rosa, Chaves, Collado, Larson, et al., 2023) but, to our knowledge, the effect of horticultural activities on depressive symptoms has not been systematically reviewed. We use horticultural interventions as a broad term encompassing both horticultural therapy and therapeutic horticulture. According to the American Horticultural Therapy Association (AHTA, 2017, p.2), "horticultural therapy is the participation in horticultural activities facilitated by a registered horticultural therapist to achieve specific goals within an established treatment, rehabilitation, or vocational plan" while therapeutic horticulture is "the participation in horticultural activities facilitated by a registered horticultural therapist or

other professionals with training in the use of horticulture as a therapeutic modality to support program goals". Thus, we use the term horticultural intervention to refer to any horticultural activity facilitated by a horticultural therapist or other trained professional to achieve health benefits (AHTA, 2017). Examples of horticultural interventions include planting and taking care of plants with the support of a therapist or other trained professional (Soga et al., 2017).

Although many reviews have assessed the effect of horticulture on health-related outcomes (J. Cipriani et al., 2017; Clatworthy et al., 2013; Kamioka et al., 2014; Liu et al., 2014; Murroni et al., 2021; Nicholas et al., 2019; Soga et al., 2017; Tu, 2022; D. Wang & MacMillan, 2013; Z. Wang et al., 2022), no studies have conducted a systematic review of the effect of horticultural interventions on people's depressive symptoms. For instance, Nicholas et al. (2019) conducted a systematic review to assess the effect of horticultural therapy on older adults, but their review identified only four primary studies evaluating the effect of horticultural therapy on depressive symptoms as assessed by depression outcome measures. This small number of identified studies can be partially explained by the authors' eligibility criteria that excluded studies with younger adults, adolescents, and children, studies not published in English, and those published before January 2008. Importantly, this small pool of research (i.e., only four studies) constitutes a fraction of the existing empirical evidence on the effect of horticultural interventions on people's depressive symptoms. The lack of a systematic synthesis of previous research hinders practitioners to develop guidelines and effective intervention programs that can prevent or treat depression (Owens & Bunce, 2022; Rosa et al., 2021). We therefore present a systematic review summarizing the effect of horticultural interventions on depressive symptoms. Our broad eligibility criteria (e.g., including studies in any language and from any period of time), together with a search strategy focused on depression, allowed us to identify more studies assessing the effect of horticultural interventions on depression than any previous systematic review. We also

collected information about dropouts and adverse events. Our systematic synthesis is expected to deepen the understanding of the potential utility of horticultural interventions in reducing depressive symptoms. The overarching research question guiding our review was: "What is the effect of horticultural interventions on depressive symptoms as compared to alternative interventions (or no intervention)?"

## Method

### Eligibility Criteria

The criteria for inclusion in our review are summarized in Table 1, and a detailed description of these criteria can be found in our registered protocol (Supplementary File 1), which was built based on the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement (Shamseer et al., 2015). We did not exclude studies based on language, date, or because they were not published in a peer-reviewed journal. Although the aim of our study was not restricted to adults, we were only able to identify eligible randomized controlled trials (RCTs) conducted with this age group.

<Table 1 about here>

In this study, we focus on RCTs. We did this because randomization ensures that any differences between groups in prognostic/confounding variables at the baseline are due to chance (Sterne et al., 2016, 2019).

### Search Strategy

We used previous systematic reviews on related topics (e.g., the effects of horticultural therapy on older adults' health) as an informative source to identify eligible primary studies (e.g., Murroni et al., 2021; Nicholas et al., 2019), and we searched for primary studies that were not included in these systematic reviews. On January 19 of 2022 the databases MEDLINE (PubMed), PsycArticles (APA), SCOPUS (Elsevier), Google Scholar, and ClinicalTrails.gov were searched from inception. Additionally, we checked the references of

included studies and our personal files (e.g., computer archives), which could provide access to additional studies. Our exact search strategy is described in our registered protocol (Supplementary File 1).

**Selection, Data Extraction, and Risk of Bias Assessment**

The first author performed the title and abstract screening, selection based on full-text, data extraction, and risk of bias assessment. Another researcher checked whether the eligibility criteria were applied appropriately, and also examined the data extraction and the risk of bias assessment. Specifically, the second researcher read through the decisions made by the first researcher and approved/disapproved them. The few disagreements between the first author and the other researcher were resolved through discussion. From each study, we collected information regarding participants' sociodemographic variables, the setting where the interventions took place, the horticultural activities conducted, and the depression score at baseline and after the intervention (see Table 2 in Supplementary File 1). The studies' risk of bias was assessed with the RoB 2 tool (Sterne et al., 2019).

**Data Synthesis**

To estimate the effect of horticultural interventions on depressive symptoms, we extracted data from the pre-test closest to the start of the intervention and the post-test closest to the end of the intervention. When studies used more than one depression outcome measure, we selected just one measure based on pre-specified criteria (see "Dealing with Multiple Effect Estimates" in Supplementary File 1). When possible, we calculated Hedges'*g* using each group's mean change in depression scores from pre to post-intervention and its standard deviation. Otherwise, we calculated *g* by using the post-test scores and its standard deviation (Higgins et al., 2019). Although depression outcome measures varied, we were able to calculate the percentage of change in depressive symptoms from baseline to post-intervention and the standardized mean change (as described by Morris, 2008) in the majority of studies.

Focusing on change in depressive symptoms is more appropriate than the difference between groups following treatment when group scores differ substantially at baseline (Vickers, 2001).

Another relevant outcome was the number of participants who demonstrated substantial improvement following the intervention. We operationalized response to the intervention as a $\geq 50\%$ decrease in depressive symptoms from baseline (Riedel et al., 2010). Research shows that a $\geq 50\%$ decrease is a good proxy for clinically relevant improvement in depression as assessed by three depression scales: Hamilton Depression Rating Scale (HDRS), Beck Depression Inventory (BDI), and Montgomery Asberg Depression Rating Scale (MADRS) (Riedel et al., 2010). Accordingly, we calculated the number of participants reporting a $\geq 50\%$ decrease in depressive symptoms when the studies used one of these three scales. This number was calculated using the formula described by Furukawa et al. (2005). For all studies with available data, we report the number of participants who dropped out and the adverse events that occurred. When feasible, we calculated risk ratios for dichotomous outcomes because these are easier to understand than odds ratios (Higgins et al., 2019).

We conducted a fixed-effects meta-analysis to avoid an overestimation of the intervention effect due to a huge effect observed by one study, and we ran sensitivity analyses to check the robustness of our findings (Higgins et al., 2019). In this meta-analysis, we also assessed whether the results from studies that offered other interventions (co-interventions) in addition to horticulture revealed greater improvements in people's depressive symptoms than studies that just involved horticulture.

Because no study reported having substituted participants' usual treatment with horticultural activities, we assumed that the horticultural interventions were used as a complementary intervention for unhealthy participants or as the only intervention for healthy ones. We used the term "usual care" to represent individuals' keeping their normal routine; this normal routine means that unhealthy participants continued their usual treatment (e.g.,

psychotherapy), and the healthy ones received no intervention. To clarify the distinction between usual care and co-interventions, we use Kim et al.'s (2016) study as an example. This study was conducted with patients with Alzheimer at Seongdong-gu Center for Dementia. Usual care in this case is the normal care offered to patients at this center and co-interventions are the additional interventions (e.g., exercise and music therapy), other than horticulture, provided to the study's participants.

To facilitate the interpretation of the findings from the RCTs included in this systematic review, we report estimates of effects and, when feasible, 95% confidence intervals (CI) for these estimates. Hedges'*g* and risk ratios were calculated using RevMan (*Review Manager (RevMan) [Computer Program]*, 2020), and figures illustrating the risk of bias of RCTs were created using robvis (McGuinness, 2019). All data utilized in our analyses that are not reported in the manuscript are available in Supplementary File 2. This file also contains the references for all randomized studies included in our systematic review.

## Results

Our database searches produced 223 records, from which 62 were deemed eligible after the full-text assessment. An example of a study excluded after the full-text assessment is Shao et al. (2020), who did not assess people's depression using a depression outcome measure. An additional 20 studies were identified through supplementary search strategies such as checking the reference list of all eligible studies and previous systematic reviews on related topics (e.g., Nicholas et al., 2019; Soga et al., 2017). Thus, a total of 82 studies were deemed eligible based on our eligibility criteria (Table 1). From these 82 eligible studies, 20 were RCTs that were considered in the present study (see Figure 1 for a flow diagram). These 20 RCTs took place in nine different countries and involved a total of 998 adults (Table 2). Sixteen studies were conducted in Asia, three in Europe, and one in the United States of America. All studies were published in peer-reviewed scientific journals from 2003 to 2021,

with more than half published in the last five years (2017 to 2021). These studies included older and middle-aged adults, psychiatric and stroke patients, and university students. No study included children or adolescents.

<Table 2 about here>

<Figure 1 about here>

Horticultural interventions involved a variety of activities, such as sowing, potting, planting, making bouquets, making a terrarium, watering plants, and harvesting (Table 3). Also variable was the length, frequency, and duration of these interventions. Intervention length varied from two to 26 weeks. The frequency of horticultural interventions ranged from weekly to daily sessions, and duration from one to four hours. Some horticultural interventions were associated with co-interventions such as physical activities, cognitive occupational therapy, art therapy, stress management lessons, and physiotherapy. The effects of horticultural interventions were most often compared with usual care but they were also compared with other interventions like educational sessions, exercise therapy, social activities, other occupational activities, and stress management sessions. Seven different measures were used to assess depression. The short form of the Geriatric Depression Scale was the one most frequently used (Table 2). We were able to evaluate the risk of bias of 19 RCTs, from which we deemed 18 as at a “high” risk of bias and one at “low” risk of bias (Figure 2). One study was not evaluated because we only had access to its abstract (Moshfeghi et al., 2014).

<Table 3 and Figure 2 about here>

**Horticultural Intervention versus Usual Care Alone**

Overall, 15 RCTs compared horticultural interventions plus usual care with usual care only. Of the 15 RCTs providing data for this comparison, 13 suggest that horticultural interventions plus usual care may reduce depressive symptoms more than usual care alone,

including 12 studies that provided data for a fixed-effects meta-analysis (Hedges'$g$ = -1.26, 95% *CI* [-1.47, -1.05], $p < .001$, $I^2 = 91.9\%$). Eleven of these 12 studies reported a moderate ($g \geq 0.5$) or large ($g \geq 0.8$) effect size (Figure 3a).

<Figure 3 about here>

Studies in which participants took part in horticultural interventions plus additional interventions (i.e., co-interventions) like physiotherapy resulted in a smaller combined estimate than the one obtained from studies in which a horticultural intervention was the only reported intervention (Figure 3a). We conducted two sensitivity analyses to understand the robustness of these findings. First, we ran a random-effects meta-analysis to check the impact of statistical heterogeneity in our results. This analysis produced similar results to the ones observed in Figure 3 with an even larger combined estimate because the random effects meta-analysis gave more weight to a single study that found a very large estimate of effect (Chu et al., 2019). Second, after removing this single study from the meta-analysis, the effect remained large and in the same direction. In other words, regardless of method, we observed a large effect favoring horticultural interventions, suggesting these findings are robust.

Only three studies reported data necessary to estimate the number of participants who had a ≥ 50% reduction in their depressive symptoms from baseline to post-intervention (Figure 3b). The combined estimate from a fixed-effects meta-analysis of these studies suggests that participants in the horticultural interventions were twice as likely to have a ≥ 50% reduction in their depressive symptoms from baseline to post-intervention than participants only receiving usual care (Risk Ratio = 2.03 [1.38, 2.98], $p = .002$, $I^2 = 84\%$). Similar to the previous meta-analysis (Figure 3a), we ran additional tests to check the robustness of these findings. First, a random-effects meta-analysis suggested an even larger estimate, but the 95% CI was much larger due to statistical heterogeneity (Risk Ratio = 2.77, [0.36, 21.03], $p = .32$, $I^2 = 84\%$). Second, after removing a study that found a very large

estimate of effect (Ghanbari et al., 2015) from these meta-analyses, the combined estimate of effect became smaller and statistical heterogeneity disappeared (Risk Ratio = 1.28 [0.93, 1.72], $p = .11$, $I^2 = 0$), suggesting these findings are not robust.

Among the RCT studies that compared horticultural interventions plus usual care to usual care only but did not report data to be included in the meta-analysis, Moshfegui et al. (2014) reported that their horticultural intervention group had a statistically significant larger reduction in the mean depression score than their control group ($p < .01$). In addition, two studies found non-statistically significant differences in depressive symptoms between the horticultural interventions and the usual care groups (Ng et al., 2018; Pálsdóttir et al., 2020).

Ten studies reported the number of participants who dropped out from horticultural interventions and the number of participants who dropped out from the usual care groups (Table 4). In eight studies, no dropout occurred. The two studies that reported dropouts pointed in opposite directions: one study found that more participants dropped out from the horticultural intervention group (Risk Ratio = 5.00 [0.27, 94.34], $p = .28$), and the other found that fewer participants dropped out from the horticultural intervention group (Risk Ratio = 0.14 [0.02, 1.10], $p = .06$). Overall, dropouts from horticultural interventions ranged from zero to 40%. Only one study reported an adverse event related to the horticultural intervention. Some participants in Kam and Siu's (2010) study felt fatigued and tired during and after participating in horticultural activities.

<Please insert Table 4 about here>

**Horticultural Interventions compared to other Interventions**

Five studies found small differences in changes in mean depression scores from baseline to post-intervention between horticultural interventions and other interventions. For example, Makizako et al. (2020) compared their horticultural intervention to a group of people who received classes about traffic safety and disaster prevention (i.e., the educational

group) and to a group of people who received an intervention based on physical exercises (i.e., the exercise group). The results from these comparisons were similar, with the horticultural intervention group having a slightly larger reduction in mean depression score from baseline to after the intervention than the two comparison groups ($g$ = -0.34 [-0.87, 0.20], $p$ = .22 for the comparison with the educational group, and $g$ = -0.19 [-0.73, 0.35], $p$ = .49 for the comparison with the exercise group). In a previous study, Lai et al. (2018) compared their horticultural intervention to a similar intervention (i.e., group size, intervention length, frequency, and duration) involving social activities without using living plants. The authors reported a non-statistically significant difference between the two groups' mean reduction in depressive symptoms (-0.25 [-1.12, 0.63], $p > 0.05$), and the direction of this effect is unclear. Similar results were found by Vujčić et al. (2017). The authors compared a horticultural intervention to art therapy plus usual care. The authors reported a non-statistically significant difference in mean reduction of depressive symptoms, from pre to post-intervention, between the two groups (eta squared = .04, $p$ = .31); again, the direction of this effect is unclear. In another study, Detweiler et al. (2015) compared their horticultural intervention to other occupational activities (e.g., ceramic painting and assembling of leather belts or models in plastic or wood). The horticulture group held a smaller mean depression score after the intervention but the difference with the comparison group was not statistically significant (effect size = .37, $p$ = .13). Finally, Kotozaki et al. (2015) compared their horticultural intervention to the provision of stress management sessions and found that the horticulture group held a slightly smaller mean depression score after the intervention ($g$ = -0.11 [-0.64, 0.42], $p$ = .69) compared to the alternative intervention group.

Differences in dropout rates between horticultural interventions and other types of interventions were also small, and none of these five studies reported any adverse events related to horticultural interventions. In Makizako et al.'s (2020) study, a few more

participants dropped out from the horticultural intervention as compared to the educational group (Risk Ratio = 3.87 [0.46, 32.57], $p$ = .21) and to the exercise group (Risk Ratio = 1.33 [0.33, 5.45], $p$ = .69). Similarly, Lai et al. (2018) reported that a few more participants dropped out of the horticultural intervention as compared to the group in the non-horticultural intervention (Risk Ratio = 2.46 [0.50, 12.13], $p$ = 27), and Detweiler et al. (2015) found that nine participants dropped out in the comparison group and eight in the horticulture group (Risk Ratio = 0.80 [0.39, 1.62], $p$ = .54). In Kotozaki et al. (2015), there were no dropouts.

## Discussion

In this study, we report evidence from 20 RCTs that assessed the effect of horticultural interventions on adults' depressive symptoms. Unfortunately, we were unable to identify any eligible RCT conducted with children or adolescents through our search strategy. Findings suggest that some horticultural interventions plus usual care may, on average, reduce adults' depressive symptoms more than usual care alone (Figure 3a). Thirteen of the 15 RCTs assessing this comparison suggested that the addition of horticultural activities to participants' normal daily routines may promote a reduction in their depressive symptoms, and most studies found a moderate or large effect. Two of the 15 RCTs found non-statistically significant differences, on average, in the depressive symptoms of the participants who engaged in horticultural activities and in those who continued their normal routines. These findings are in line with a recent meta-analysis indicating that forest therapy plus usual care may reduce adults' depressive symptoms more than usual care alone (Rosa et al., 2021). Moreover, both studies suggest that people may adhere well to these nature-based interventions (i.e., low dropout rates) and that adverse events are rare.

Several mechanisms could explain why some horticultural interventions reduce adults' depressive symptoms. ART (Kaplan, 1995) and SRT (Ulrich et al., 1991) articulate that positive experiences with nature may reduce people's stress and anxiety and improve mood

and attention, all of which are closely related to depression (Fried, 2017; Slavich & Irwin, 2014). For example, higher levels of stress and anxiety have been associated with stronger depressive symptoms (Slavich & Irwin, 2014), and sad mood and concentration problems are both symptoms of major depression (American Psychiatric Association, 2014). Thus, horticulture may reduce people's depressive symptoms by reducing stress and anxiety, and improving mood and concentration. The opportunity to restore one's psychological resources might be linked to the fact that some horticultural interventions are organized outdoors, and likely conducted when weather conditions are favorable. Bad weather conditions limit people's outdoor time, constrain restorative activities, and are linked to more frequent use of antidepressants (Hartig et al., 2007). Related to this, research suggests that sun exposure during nature-based activities may reduce depressive symptoms by improving sleep (Lopresti, 2019; Moreton et al., 2021). Horticultural interventions promote exposure to biodiversity and increase accessibility to plant-based diets, which are also associated with positive health outcomes (Aerts et al., 2018; Leri et al., 2020; Marselle et al., 2021)

Horticultural intervention also involves the practice of physical activity and (typically) some form of socialization, which are both linked to reductions in depressive symptoms (Chu et al., 2019; Clatworthy et al., 2013; Ng et al., 2018; Soga et al., 2017). In line with this, some RCTs that compared engagement in horticultural interventions to physical exercise (Makizako et al., 2020) or to getting involved in social activities (Lai et al., 2018) found small and imprecise (i.e., confidence intervals overlapping zero) differences between these interventions, in terms of reduction in depressive symptoms. This suggests that horticultural interventions are one of several effective, and potentially complementary approaches (e.g., physical activity and socialization), to improve adults' depressive symptoms. In fact, horticultural interventions were not found to be largely superior to engagement in other

occupational activities (Detweiler et al., 2015), art therapy (Vujcic et al., 2017), or stress management sessions (Kotozaki et al., 2015).

**Study Limitations**

Our findings should be considered in light of several limitations. First, all except one RCT included in our systematic review presented design limitations that might have biased their results (Figure 2). One limitation presented in all included studies was the inability of keeping the participants unaware of the intervention they were receiving (i.e., blinding). In other words, participants knew when they were receiving the horticultural intervention. This lack of blinding might influence adults' decision to search for additional care if they are not satisfied with the group they were allocated to, or it might bias their reporting of depressive symptoms (Rosa & Delabrida, 2021; Sterne et al., 2016, 2019). Another limitation of many of the included studies was the lack of a registered analysis plan matching the analyses performed in the paper, which would ensure that reporting of results was not selective. Some RCTs did not report enough information to prove that the strategy used to allocate participants to groups was random and concealed (see Rosa, Chaves, Collado, & Harper, 2023; Sterne et al., 2019). Additionally, some RCTs had a considerable amount of missing data from baseline to post-intervention, which can bias the interpretation of an intervention's effect on depressive symptoms under some conditions (Sterne et al., 2016, 2019).

Whereas most included studies may have been affected by some kind of bias, it is unknown how much those biases explain the estimates of horticultural intervention effects that we observed. When considering RCTs with a similar risk of bias, researchers may have more confidence in the efficacy of interventions reported in studies with larger samples and larger estimates than in studies with fewer participants and smaller estimates (Higgins et al., 2019). On average, RCTs included in our review involved about 54 participants, with sample sizes ranging from 12 to 150. To illustrate, both Buru et al. (2021) and Chu et al. (2019) have

a high risk of bias, but the latter study included many more participants (N = 150) than the first one (N = 16) and found a larger estimate of effect (g = -15.21 vs. -1.06). Thus, one can be more confident about the efficacy of the intervention reported by Chu et al. (2019) than the one reported by Buru et al. (2021). It is also relevant to note that while a high risk of bias occurs due to limitations in study design, it does not always imply biased estimates (Moustgaard et al., 2020). Future research is essential to understand how study design may influence results. Additionally, adherence to relevant Consolidated Standards of Reporting Trials (CONSORT) would improve the interpretation of the results for horticultural intervention studies (Moher et al., 2010).

In addition to these limitations, a systematic review comprises many decisions that influence the interpretation of findings (Higgins et al., 2019). Here we point out how some of our decisions impact the findings' interpretation. First, we did not limit this review to specific populations (e.g., older adults), intervention characteristics (e.g., weekly sessions), and comparison groups (e.g., usual care). Hence, the included RCTs are different in important characteristics that somewhat preclude a comprehensive quantitative synthesis of all results (i.e., meta-analysis). We, therefore, chose to present a forest plot with effect estimates from the RCTs comparing horticultural interventions plus usual care with just usual care (Figure 3a). Nonetheless, we recommend that readers do not focus on the combined estimate from these studies. Instead, they may consider how different kinds of horticultural interventions (including the kind of activities provided, their length, frequency, and duration) may improve the depressive symptoms of specific groups (e.g., older adults) as compared to the alternative interventions (i.e., usual care). More randomized studies that isolate the impacts of specific variables are needed to improve the understanding of how participants' and interventions' characteristics may influence the study results.

Also linked to our broad criteria of eligibility, we included studies independent of whether or not their participants had a diagnosis of depression. We did this because every individual can experience depressive symptoms (e.g., sad mood) to a certain degree. Some studies included participants diagnosed with mental health problems related to but not necessarily involving just depression, such as adults with psychiatric illnesses (Kam & Siu, 2010; Vujcic et al., 2017). In fact, only one (Najjar et al., 2018) out of the 20 RCTs included exclusively adults' diagnosed with depression. Thus, more RCTs with individuals exclusively diagnosed with depression are needed.

Finally, concerning our methodology, one researcher conducted the title and abstract screening. This approach was efficient, but the risk of unintentionally excluding a potentially relevant study might have been reduced if two researchers were involved in this process. Unfortunately, this was a necessary decision to facilitate the execution of this systematic review. Additionally, no systematic review is expected to include all studies relevant to the research question since no search strategy is perfectly effective (Higgins et al., 2019).

## Conclusion and Next Steps

To date, our systematic review is the most comprehensive summary of studies estimating the effect of horticultural interventions on adults' depressive symptoms. We found relatively consistent results indicating that horticultural interventions plus usual care may reduce adults' depressive symptoms more than usual care alone. Overall, we observed some variability in the magnitude of the effect estimates across the included RCTs, which might be due to variability in participants, interventions, and the outcome measures used. We were unable to determine which specific characteristics of the participants, interventions, or outcome measures are associated with a stronger impact of horticultural interventions on depressive symptoms. Thus, we encourage researchers to conduct RCTs aimed at exploring the potential influence these characteristics have on the effect of horticultural interventions on

depression. A randomized study could provide a similar intervention to two different groups of individuals or a slightly different intervention to the same participants. For instance, future RCTs could assess the relevance of sun exposure for improvement in depressive symptoms during horticultural interventions by comparing groups randomly allocated to indoor versus outdoor settings. As another example, future RCTs could compare whether group-based horticultural interventions are more effective than participation in one-on-one, or solo horticultural activities. Such an investigation could provide extra support to the evidence that social interactions play a role in reducing depressive symptoms during horticultural interventions (Chu et al., 2019; Clatworthy et al., 2013; Lin et al., 2020; Ng et al., 2018; Soga et al., 2017).

Our findings also suggest that people may adhere well to horticultural interventions (i.e., low dropout rates) and that adverse events like fatigue and tiredness (Kam & Siu, 2010) during and after these interventions are likely rare. Nonetheless, we highlight that other complementary interventions, such as the practice of physical exercise (Makizako et al., 2020) and social activities without direct interaction with plants (Lai et al., 2018), might provide similar, but maybe slightly smaller reductions in adults' depressive symptoms. Given the design limitations of virtually all studies, more rigorous RCTs are needed. It may be worth conducting RCTs in places where the effect of horticultural interventions has been scarcely examined, like Latin America, Africa, and Oceania. It may also be prudent to focus RCTs on people diagnosed with depression, as well as young people, especially because we did not find any RCTs (eligible for our systematic review) involving children or adolescents.

Future systematic reviews could also explore other outcomes relevant to understanding the potential value of horticultural interventions, including the possible effects of these activities on other mental (e.g., anxiety, loneliness, and anger) and physical outcomes (e.g., weight loss). Systematic reviews that directly assess the effect of horticultural interventions

447 on specific symptoms of depression (e.g., sad mood and anhedonia) are also warranted since
448 our review focused on aggregate scores from depression outcome measures, not on specific
449 symptoms. Finally, studies should consider the financial cost, and relative benefits, of
450 implementing horticultural interventions compared to other more conventional strategies
451 commonly employed to prevent or treat depression and other mental health disorders.

452 **Declaration of Interest Statement**

453 The authors declare they have no conflict of interest.

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**Table 1**

*Eligibility criteria for our review based on population (P), intervention (I), comparison groups of interest (C), outcomes (O), and study designs (S).*

| PICOS | Description |
|---|---|
| Population | Studies with humans at any age, healthy or unhealthy |
| Intervention | Any horticultural activity facilitated by a horticultural therapist or other trained professional to achieve health benefits. |
| Comparison groups of interest | Studies with any comparison/control group and studies without a control group. |
| Outcomes | Studies that assess depression using a measure designed to measure depression. At least one study (i.e., a validation study) should exist describing how the content of the measure matches the construct's content (i.e., depression). |
| Study design[a] | Randomized and non-randomized studies of interventions. |

*Note.* [a]It was part of our eligibility criteria to include both randomized and non-randomized studies of interventions. In this manuscript, we focus on randomized controlled trials (RCTs). The findings from non-randomized studies will be reported in a separate study.

742 **Table 2**

743 *Main characteristics of the randomized controlled trials (RCTs) included in this systematic*

744 *review of studies investigating the effects of horticultural interventions on depressive*

745 *symptoms*

| First author (year) | Participants | Mean age or age range | Women % | Time (T) in which data was collected[b] | Depression measure | Country | Setting where the horticultural intervention took place |
|---|---|---|---|---|---|---|---|
| Buru (2021) | University students | 20.2 | Unclear | T1: Before the intervention T2: After the intervention | Beck Depression Inventory | Romania | University of Agricultural Sciences and Veterinary Medicine |
| Pálsdóttir (2020) | Stroke survivors | 67 | 60 | T1: Before the intervention T2: Eight months after randomization | Hospital Anxiety and Depression Scale | Sweden | Alnarp Rehabilitation Garden |
| Kim (2020a) | Elderly living in a homeless living facility | 73.2 | 33.3 | T1: Before the intervention T2: After the intervention | Geriatric Depression Scale-Short Form | South Korea | In some parts of the garden |
| Kim (2020b) | Caregivers of elderly with dementia | 60.0 | 100 | T1: Before the intervention T2: After the intervention | Center for Epidemiological Studies Depression Scale | South Korea | At a health center |
| Makizako (2020) | Older adults with depressive symptoms and memory problems | 73.1 | 50.6 | T1: Before the intervention T2: Immediately after the intervention | Geriatric Depression Scale-Short Form | Japan | Public garden |
| Chu (2019) | Older residents of nursing homes | 78.6 | 62.7 | T1: Before the intervention T2: At the end of the intervention | Geriatric Depression Scale-Short Form | China | Indoors at a table where residents could sit |
| Najjar (2018) | Chronic depressed male outpatients | Unclear | 0.0 | T1: Before the intervention T2: After the intervention | Depression, Anxiety, and Stress Scale-44 | Iran | Noor-Almahdi Mental Hospital |
| Kim (2018) | Middle-aged women | 40 to 59 | 100 | T1: Before the intervention T2: After the intervention | Zung Self-rating Depression Scale | South Korea | At a culture center in Incheon |
| Lai (2018) | Frail and prefrail nursing home residents | 84.6 | 65.6 | T1: Before the intervention T2: Immediately after the intervention | Geriatric Depression Scale-Short Form | China | Indoor and outdoors |
| Ng (2018) | Older adults | 67.7 | 78.0 | T1: At the start of the study T2: Three months after the intervention | Zung Self-rating Depression Scale | Singapore | Indoor and outdoor activities at parks, gardens, and a nature reserve |
| Vujčić (2017) | Psychiatric patients | 45.4 | 70.0 | T1: Before the intervention T2: Directly after the intervention | Depression Anxiety Stress Scale-21 | Serbia | The Jevremovac Botanical Garden |
| Kim (2016) | Patients with Alzheimer | 78.5 | 69.8 | T1: Before the intervention T2: After the intervention | Geriatric Depression Scale-Short Form | South Korea | Seongdong-gu Center for Dementia |

| First author (year) | Participants | Mean age or age range | Women % | Time (T) in which data was collected[b] | Depression measure | Country | Setting where the horticultural intervention took place |
|---|---|---|---|---|---|---|---|
| Detweiler (2015) | War veterans | 46.4 | 4.2 | T1: Before the intervention T2: After the intervention | Center for Epidemiological Studies Depression Scale | United States of America | Veterans Affairs Medical Center in Salem, Virginia |
| Ghanbari (2015) | Female students of Golestan dormitory | 20.6 | 100 | T1: Before the intervention T2: After the intervention | Beck Depression Inventory | Iran | Dormitory yard |
| Kotozaki (2015) | Women victims of an earthquake | 43.4 | 100 | T1: Before the intervention T2: After the intervention | Center for Epidemiologic Studies Depression Scale | Japan | At a university lab and at participants' homes |
| Kotozaki (2014) | Women victims of an earthquake | 46.5 | 100 | T1: First day of the intervention T2: After the intervention | Center for Epidemiologic Studies Depression Scale | Japan | At a community center and at participants' homes |
| Moshfeghi (2014)[a] | Older adults in nursing homes | Unclear | Unclear | T1: Before the intervention T2: After the intervention | Depression, Anxiety, and Stress Scale-44 | Iran | Unclear |
| Tse (2013) | Older persons living in nursing homes | 60 to 89 | 62.2 | T1: Before the intervention T2: After the intervention | Geriatric Depression Scale-Short Form | China | Nursing home |
| Kam (2010) | People with psychiatric illness | 44.3 | 29.7 | T1: Before the intervention T2: After the intervention | Depression Anxiety Stress Scale-21 | China | New Life Farm |
| Kim (2003) | Poststroke hemiplegic patients | 56.0 | 30.95 | T1: Before the intervention T2: After the intervention | Beck Depression Inventory | South Korea | An indoor setting at a rehabilitation hospital |

*Note*. [a] We were unable to translate the full text of this study. [b] Only the time relevant for the data analyses was considered.

## Table 3

*Description of horticultural activities, comparison group activities, and co-interventions of the randomized controlled trials (RCTs) included in the systematic review*

| First author (year) | Horticultural interventions[a] and comparison group activities | Co-interventions | Intervention length in weeks[b] | Intervention frequency[c] | Session duration in hours[d] | Group N |
|---|---|---|---|---|---|---|
| Buru (2021) | **Horticultural intervention**: Specific gardening activities such as sowing, potting, and planting | No co-intervention was reported | 2 | Daily | 4 | 8 |
| | **Usual care:** No intervention | Not applicable | Not applicable | Not applicable | Not applicable | 8 |
| Pálsdóttir (2020) | **Horticultural intervention**: Horticulture activities | Physical activities and enjoying the garden | 10 | Two days a week | 3.5 | 48 |
| | **Usual care** for stroke survivors | Not applicable | Not applicable | Not applicable | Not applicable | 44 |
| Kim (2020a) | **Horticultural intervention**: Activities included transplanting, making bouquets, and harvesting. | Walking at the arboretum, reflecting on what changed after the program, and setting goals to live an active and planned life | 16 | Weekly | 1 to 1.5 | 6 |
| | **Usual care** for elderly living in a homeless living facility | Not applicable | Not applicable | Not applicable | Not applicable | 6 |
| Kim (2020b) | **Horticultural intervention**: Activities included sowing flower seeds, making a terrarium, and making a scandiamoss tree | Conversations about dementia and therapeutic activities | 4 | Twice a week | 1.5 to 2 | 10 |
| | **Usual care**: No intervention | Not applicable | Not applicable | Not applicable | Not applicable | 9 |
| Makizako (2020) | **Horticultural intervention**: The program included crop-related activities such as cultivating, growing, and harvesting. | No co-intervention was reported | 20 | Weekly | 1 to 1.5 | 26 |
| | **Educational group**: The classes included topics such as traffic safety and disaster prevention that experts considered less likely to influence study outcomes | Not applicable | 26.1 | Two times | 1.5 | 28 |
| | **Exercise group**: Each session began with a warm-up period with stretching exercises followed by muscle strength exercises and postural balance re-training. | Not applicable | 20 | Weekly | 1.5 | 27 |
| Chu (2019) | **Horticultural intervention**: Activities included planting seeds, watering plants, and decorating with flowers. | A co-intervention was reported but we do not believe it has the potential to reduce participants' depressive symptoms. | 8 | Weekly | 1.5 to 2 | 75 |
| | **Usual care** for older residents of nursing homes | Not applicable | Not applicable | Not applicable | Not applicable | 75 |
| Najjar (2018 | **Horticultural intervention**: Activities included planting, watering, and weeding. | A co-intervention was reported but we do not believe it has the potential to reduce participants' depressive symptoms. | 5 | Twice a week | 2 | 15 |
| | **Usual care** for chronically depressed male outpatients | Not applicable | Not applicable | Not applicable | Not applicable | 15 |
| Kim (2018) | **Horticultural intervention**: The intervention included planting, making crafts with plants, and flower arrangements | No co-intervention was reported | 6 | Twice a week | 1 | 18 |
| | **Usual care:** No intervention | Not applicable | Not applicable | Not applicable | Not applicable | 18 |

| First author (year) | Horticultural interventions[a] and comparison group activities | Co-interventions | Intervention length in weeks[b] | Intervention frequency[c] | Session duration in hours[d] | Group N |
|---|---|---|---|---|---|---|
| Lai (2018) | **Horticultural intervention**: The intervention included fertilizing, re-potting plants, watering, trimming, propagation, species introduction, and seeding. | No co-intervention was reported | 8 | Weekly | 1 | 46 |
| | **Social activities group**: All aspects of this group were equivalent to the horticulture group except for the use of living plants. | Not applicable | 8 | Weekly | 1 | 50 |
| Ng (2018) | **Horticultural intervention**: The intervention included gardening, growing, maintaining, and harvesting vegetables and herbs | Guided walking in various parks | 26.1 | Weekly during 13 weeks then monthly | 1 | 29 |
| | **Usual care:** No intervention | Not applicable | Not applicable | Not applicable | Not applicable | 30 |
| Vujčić (2017) | **Horticultural intervention**: The intervention included plot weeding, potting collecting autumn fruits, and working with plants. | Other activities in contact with nature such as meditation, social support group, and art therapy. | 4 | Three days a week | 1 | 16 |
| | **Art therapy plus usual care:** The control group was included in the occupational and art therapy while continuing to receive conventional therapy, in conditions without plants. | Not applicable | 4 | Three days a week | 1 | 14 |
| Kim (2016 | **Horticultural intervention**: Planting rattan or other plants and creating flower-based decorations | Exercise therapy, cognitive occupational therapy, recollection therapy, art therapy, music therapy, and pharmacological treatment. | 26.1 | Five times a week | 1 | 32 |
| | **Usual care** for patients with Alzheimer | Not applicable | Not applicable | Not applicable | Not applicable | 21 |
| Detweiler (2015) | **Horticultural intervention**: The intervention included adding soil to garden boxes; planning the types of seeds to plant (e.g., flowers, vegetables, and herbs); planting the seeds; and watering, weeding, and harvesting the vegetables and flowers. | No co-intervention was reported | 3 | Five days per week | 1 | 12 |
| | **Other occupational activities:** The group was able to choose from a large variety of crafts, such as ceramic painting, flower arranging, and assembling leather belts or models in plastic or wood. | Not applicable | Unclear | Unclear | Unclear | 9 |
| Ghanbari (2015) | **Horticultural intervention**: Plowing land, planting, picking up, and harvesting. | No co-intervention was reported | 8.7 | Three days a week | 1 | 25 |
| | **Usual care:** No intervention | Not applicable | Not applicable | Not applicable | Not applicable | 25 |
| Kotozaki (2015) | **Horticultural intervention**: The intervention included planting, seeding, watering, weeding, and picking flowers | Introductory psychology and stress management lessons | 8 | Weekly | 1 | 27 |
| | **Stress management sessions**: These consisted of video lectures regarding stress education | Not applicable | 8 | Weekly | 1 | 27 |
| Kotozaki (2014 | **Horticultural intervention**: The intervention included designing a garden planter, seeding, watering, weeding, and picking flowers. | No co-intervention was reported | 16 | Weekly | 2 | 22 |
| | **Usual care** for women victims of an earthquake | Not applicable | Not applicable | Not applicable | Not applicable | 23 |
| Moshfeghi (2014)[e] | **Horticultural intervention**: Planting, maintaining, and harvesting fruits and vegetables | Unclear whether any co-intervention was reported because we were unable to translate the full text to another language. | 13 | Unclear | Unclear | Unclear |
| | **Control group** | Not applicable | Not applicable | Not applicable | Not applicable | Unclear |

| First author (year) | Horticultural interventions[a] and comparison group activities | Co-interventions | Intervention length in weeks[b] | Intervention frequency[c] | Session duration in hours[d] | Group N |
|---|---|---|---|---|---|---|
| Tse (2013) | **Horticultural intervention**: Each participant was responsible for his or her planting, while the research team facilitated and discussed the proper care of the plant, preparing the soils, watering, and adding fertilizers. | Physiotherapy | 8 | Not reported | Not reported | 48 |
| | **Usual care** for older persons living in a nursing home | Not applicable | Not applicable | Not applicable | Not applicable | 42 |
| Kam (2010) | **Horticultural intervention:** The intervention included watering, fertilizing plants, weeds removal, and loosening soil. | No co-intervention was reported | 2 | Daily | 1 | 10 |
| | **Usual care:** Participants were receiving workshop training that included a garden tour, and sharing experiences about coping with life events and stress. | Not applicable | Unclear | Unclear | Unclear | 12 |
| Kim (2003) | **Horticultural intervention:** The intervention included planting, transplanting, making flower baskets, and cutting herbs. | No co-intervention was reported | 6 | Five times a week | 1 | 21 |
| | **Usual care** for poststroke hemiplegic patients | Not applicable | Not applicable | Not applicable | Not applicable | 21 |

*Note*. [a] Unhealthy participants probably continued their usual treatment while participating in the horticultural interventions. [b] Intervention length refers to the duration of the full intervention. [c] Intervention frequency refers to the frequency of the horticultural activities or comparison group activities. [d] Session duration refers to the duration of the horticultural activities or comparison group activities provided during each session. [e] We were unable to translate the full text of this study.

**Table 4**

*Percentage of change from baseline in depression scores, standardized mean change, number of participants who had a ≥ 50% reduction on depression scores from baseline to post-intervention (i.e., responders), and dropouts in the horticultural interventions and comparison groups of the randomized controlled trials (RCTs) included in this systematic review*

| First author (year) | Group | Percentage of change from baseline [a] | Standardized mean change [b] | Responders [c] | Dropouts |
|---|---|---|---|---|---|
| Buru (2021) | Horticultural intervention | -43.8 | -1.63 | 3/8 | Unclear |
| | Usual care | -10.8 | -1.18 | 2/8 | 18/32 |
| Pálsdóttir (2020) | Horticultural intervention | -19.4 | NR | NR | 1/51 |
| | Usual care | -20.1 | NR | NR | 7/50 |
| Kim (2020a) | Horticultural intervention | -17.2 | -0.32 | NR | 0/6 |
| | Usual care | 7.3 | 0.13 | NR | 0/6 |
| Kim (2020b) | Horticultural intervention | -6.8 | -0.22 | NR | Unclear |
| | Usual care | 11.1 | 0.51 | NR | Unclear |
| Makizako (2020) | Horticultural intervention | -31.9 | -0.47 | NR | 4/30 |
| | Exercise group | -25.4 | -0.72 | NR | 3/30 |
| | Educational group | -20.3 | -0.52 | NR | 1/29 |
| Chu (2019) | Horticultural intervention | -62.9 | -12.43 | NR | 0/75 |
| | Usual care | 48.5 | 6.95 | NR | 0/75 |
| Najjar (2018 | Horticultural intervention | -25.2 | -1.05 | NR | 0/15 |
| | Usual care | 1.7 | 0.06 | NR | 0/15 |
| Kim (2018) | Horticultural intervention | -25.3 | -1.31 | NR | 0/18 |
| | Usual care | 0.7 | 0.69 | NR | 0/18 |
| Lai (2018) | Horticultural intervention | NR | NR | NR | 5/56 |
| | Social activities | NR | NR | NR | 2/55 |
| Ng (2018) | Horticultural intervention | NR | NR | NR | 0/29 |
| | Usual care | NR | NR | NR | 0/30 |
| Vujčić (2017) | Horticultural intervention | NR | NR | NR | NR |
| | Art therapy plus usual care | NR | NR | NR | NR |

| First author (year) | Group | Percentage of change from baseline [a] | Standardized mean change [b] | Responders [c] | Dropouts |
|---|---|---|---|---|---|
| Kim (2016) | Horticultural intervention | -8.8 | -0.19 | NR | 0/32 |
| | Usual care | -0.7 | -0.02 | NR | Unclear |
| Detweiler (2015) | Horticultural intervention | NR | NR | NR | 8/20 |
| | Other occupational activities | NR | NR | NR | 9/18 |
| Ghanbari (2015) | Horticultural intervention | -51.5 | -1.35 | 13/25 | 0/25 |
| | Usual care | -13.7 | -0.58 | 0/25 | 0/25 |
| Kotozaki (2015) | Horticultural intervention | -12.1 | -0.23 | NR | 0/27 |
| | Stress management sessions | -14.0 | -0.30 | NR | 0/27 |
| Kotozaki (2014) | Horticultural intervention | -41.9 | -0.69 | NR | 0/22 |
| | Usual care | -15.2 | -0.22 | NR | 0/23 |
| Moshfeghi (2014) [d] | Horticultural intervention | Unclear | Unclear | Unclear | Unclear |
| | Control group | Unclear | Unclear | Unclear | Unclear |
| Tse (2013) | Horticultural intervention | -29.6 | -0.63 | NR | NR |
| | Usual care | 7.0 | 0.12 | NR | NR |
| Kam (2010) | Horticultural intervention | -63.0 | -1.01 | NR | 2/12 |
| | Usual care | -12.6 | -0.13 | NR | 0/12 |
| Kim (2003) | Horticultural intervention | -62.7 | -4.89 | 19/21 | 0/21 |
| | Usual care | -58.8 | -3.57 | 15/21 | 0/21 |

*Note*. Negative values for change from baseline and standardized mean change signify reductions in depressive symptoms.

[a] Change in score divided by baseline score times 100. [b] Change in score divided by the baseline standard deviation. [c] Having a ≥ 50% reduction in depressive symptoms from baseline to post-intervention; estimated using the formulae described by Furukawa et al. (2005). [d] We were unable to translate the full text of this study. NR = Not reported.

**Figure 1**

*Flowchart illustrating the process of identifying and selecting studies*

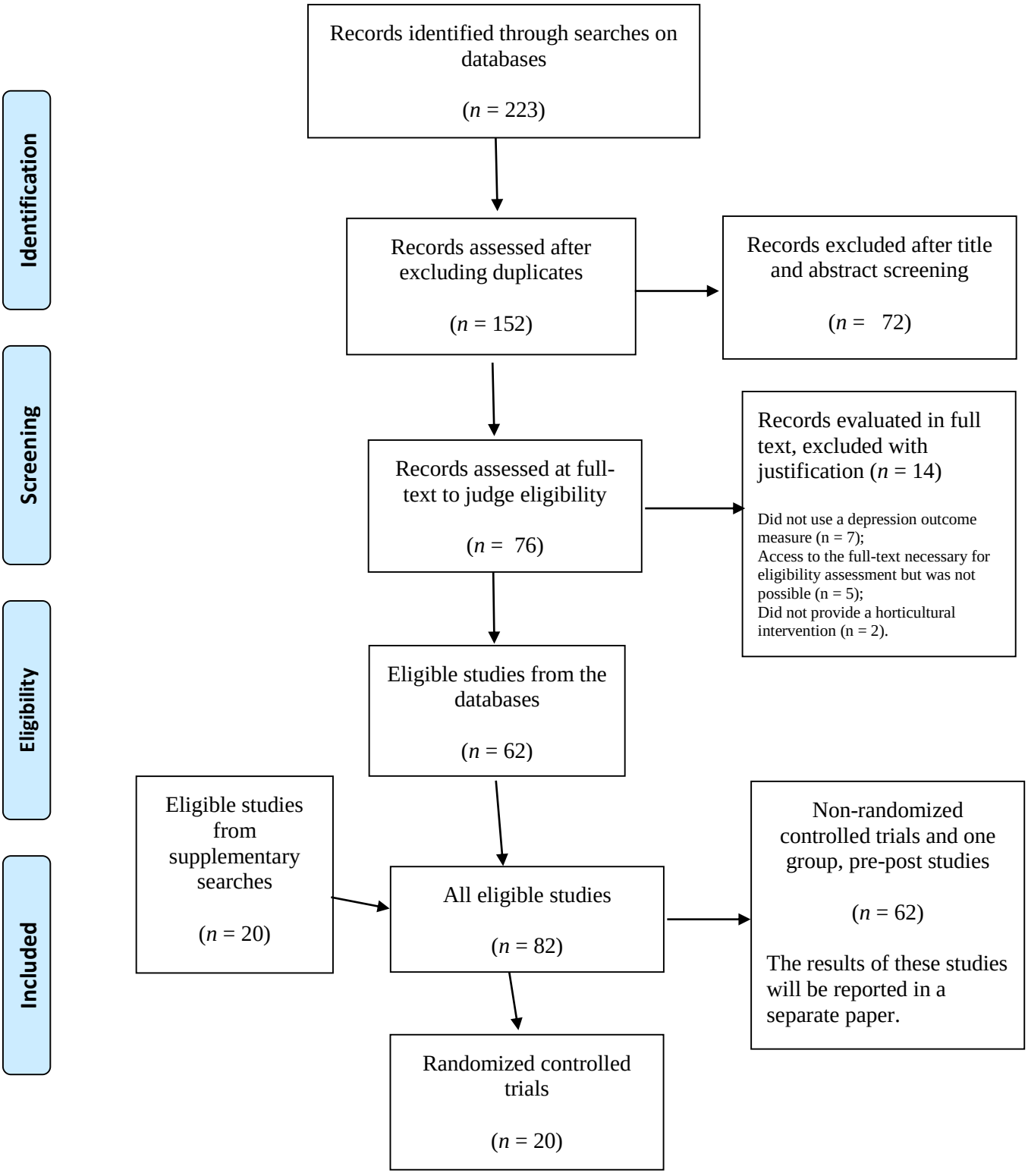

**Figure 2**

*Risk of bias of the 19 randomized controlled trials that provided enough data for risk of bias assessment*

**Figure 3**

*(a) Comparison of the post-intervention mean score or mean change from baseline of horticulture groups versus usual care only using the inverse variance fixed-effect meta-analysis. (b) Comparison of the risk of response to treatment (i.e. ≥ 50 % reduction in depressive symptoms) between horticulture groups and usual care groups, using the Mantel-Haenszel fixed-effect meta-analysis. Events refer to the number of participants who responded to treatment. Green squares refer to standardized mean differences and blues squares to risk ratios. Bigger squares indicated more participants in a study or more events and a bigger diamond indicates greater uncertainty in the combined estimate*