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Article

The Urban Double-Crop: Can Fall Vegetables and a Warm-Season Lawn Co-Exist?

Ellen M. Bauske [1,*], Sheri Dorn [2], Freddie Clinton Waltz, Jr. [3] and Lauren Garcia Chance [4]

1 Department of Plant Pathology, Griffin Campus, University of Georgia, Griffin, GA 30223, USA
2 Department of Horticulture, Griffin Campus, University of Georgia, Griffin, GA 30223, USA; sdorn@uga.edu
3 Department of Crop and Soil Science, Griffin Campus, University of Georgia, Griffin, GA 30223, USA; cwaltz@uga.edu
4 American Public Gardens Association, Longwood Gardens, Kennett Square, PA 19348, USA; lchance@publicgardens.org
* Correspondence: ebauske@uga.edu

Abstract: A gardening methodology using double-cropped cool-season vegetables and warm-season turfgrass, thereby capitalizing on the ideal growing season for each, was developed in field trials and tested in volunteers' landscapes. Broccoli (*Brassica oleracea*), lettuce (*Lactuca sativa*), and Swiss chard (*Beta vulgaris* subsp. *Cicla*) were planted into an established hybrid bermudagrass lawn (*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy 'Tifsport') in September. The vegetables were planted into tilled strips, 5 cm × 10 cm holes and 10 cm × 10 cm holes in the turf. All treatments produced harvestable yield, though the yield of vegetables planted in the tilled treatments and larger holes was greater than in smaller holes. Efforts to reduce turfgrass competition with vegetables by the application of glyphosate or the use of the Veggie Lawn Pod (an easily installed plastic cover on the lawn) did not increase yield. Tilled treatments left depressions that discouraged spring turfgrass recovery. The double-crop was tested by seven volunteers on their lawns. Though lawn-planted vegetables did not produce as much yield as those planted in the volunteers' gardens, the volunteers were enthusiastic about this methodology. The volunteers reported that lawn vegetables were more difficult to plant but not more difficult to maintain, and they were easier to harvest than vegetables in their gardens. All volunteers reported satisfactory recovery of their lawns in the spring.

Keywords: gardening; master gardeners; consumer horticulture; citizen science

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1. Introduction

Enthusiasm for local food production, self-sufficiency, and food safety has generated interest in home vegetable gardens. However, many urban dwellers have small outdoor spaces, and often lawns occupy the only full-sun areas of the landscape.

Lawns can be replaced with food gardens. This approach has supporters [1,2], though many people enjoy their lawns and the physical and psychological benefits they provide [3,4]. While systems exist for fully replacing lawns with vegetable gardens or beds, no studies have assessed the possibility of double-cropping vegetables and turfgrass, growing them both in the same space in the same year, and capitalizing on the ideal growing season for each.

Some studies have explored the possibility of double-cropping forbs and bulbous species in warm-season lawns with the intent to maintain, rather than replace, the lawn [5–8]. These studies focused on flower production, the ability to withstand mowing, and the potential to provide an early season habitat and nectar source for beneficial insects.

Georgia, U.S. is in the transition zone between cool-season and warm-season turfgrasses, and both are used throughout the state. They vary considerably in their growth phases, with cool-season grasses growing most in spring and fall, and warm-season grasses experiencing peak growth in the summer [8]. In Georgia, warm-season turfgrasses experience low-temperature-induced dormancy for up to 6 months of the year [9]. This period of dormancy coincides with the production period of cool-season vegetables.

A pilot demonstration in the fall of 2013 explored the potential of a vegetable/turfgrass double-crop [10]. Several cool-season vegetable transplants were planted directly in holes of varying sizes and shapes dug into turfgrass. The plants produced harvestable yield. While none of the cultivation techniques in the demonstration were entirely satisfactory, the preliminary results indicated it may be possible to double-crop a warm-season lawn and fall vegetables. In addition, the pilot suggested several options for future study. Some of the vegetable planting techniques created shallow troughs in the turf that would be unacceptable in many lawns. It was also apparent that reducing competition between young seedlings and turf in early fall (i.e., increasing hole size, herbicide use, hand removal of grass) may increase vegetable production.

This small pilot demonstration received considerable interest from the public [11], turfgrass specialists, and industry representatives [12]. It was a unique project on a university research campus that sparked many questions about its application to personal garden spaces. The idea of growing vegetables in the same space as turf as a double-crop merited further exploration.

The first objective of this study was to evaluate planting techniques that would allow fall vegetables to be grown in dormant, warm-season grass and allow lawn recovery so the lawn could be enjoyed in the summer. This "lawn garden" would produce both fall vegetables and a satisfactory summer lawn in the same space. A two-year field trial was done to evaluate vegetable planting techniques, yield, and lawn recovery.

The second objective of the study was to test the most appropriate methodology in home lawns with the assistance of Extension Master Gardener (EMG) volunteers. These individuals are recruited and trained to assist with the public dissemination of information and research related to consumer horticulture that is generated by land-grant university scientists [13]. Extension is a public education system administered through land-grant universities in the U.S., offering programs addressing agriculture, youth development, and family and consumer sciences. Extension programs rely on EMG volunteers to meet consumer demand for horticulture information [14] and EMG volunteers answer questions from the public, give presentations, do hands-on training, and provide support to research endeavors in many capacities [15–17].

2. Materials and Methods

All field trials of the lawn garden were established at the University of Georgia Griffin Campus, Griffin, GA, U.S. (33.2642° N, 84.2841° W; USDA Zone 8a; avg. annual extreme min. temp. −12.2 to 9.4 °C; 91–120 days >30 °C). The soils were a Cecil series sandy clay loam. Plots were irrigated as needed from an inground irrigation system typical of home lawns in the Southeast U.S. An established hybrid bermudagrass (*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy 'Tifsport') plot was selected for the trial. Data were analyzed using PROC MIXED in SAS software (version 9.4; SAS Institute, 2013). Means were separated using Tukey's honestly significant difference test with $p \leq 0.05$ considered statistically significant.

Three cool-season vegetables were tested in lawn garden field trials. Broccoli (*Brassica oleracea* 'Packman'), lettuce (*Lactuca sativa* 'Simpson Elite'), and Swiss chard (*Beta vulgaris* subsp. *Cicla* 'Bright Lights') transplants were used in field trial experiments. Transplants were grown in 5.0 cm × 3.8 cm × 7.5 cm liners. Broccoli transplants were spaced 30 cm apart; chard and lettuce were planted 15 cm apart. Broadleaf weeds were controlled by hand and an insecticidal soap with 1% potassium salts of fatty acids (Garden Safe ™, St. Louis, MO, USA) was applied to control aphids on individual plants as needed. Plants were fertilized individually with granular 10-10-10 at the rate of 50 g/m^2 at planting and again at four weeks. Vegetables and turf were irrigated as needed throughout all experiments.

2014–2015 Trial. Treatments were arranged in a split-plot, randomized complete block design with four replications (total 16 plots). Whole plots consisted of combinations of planting treatment and glyphosate treatment in a factorial design. Subplots (randomized within whole plots) consisted of four plants of each vegetable (Figure 1).

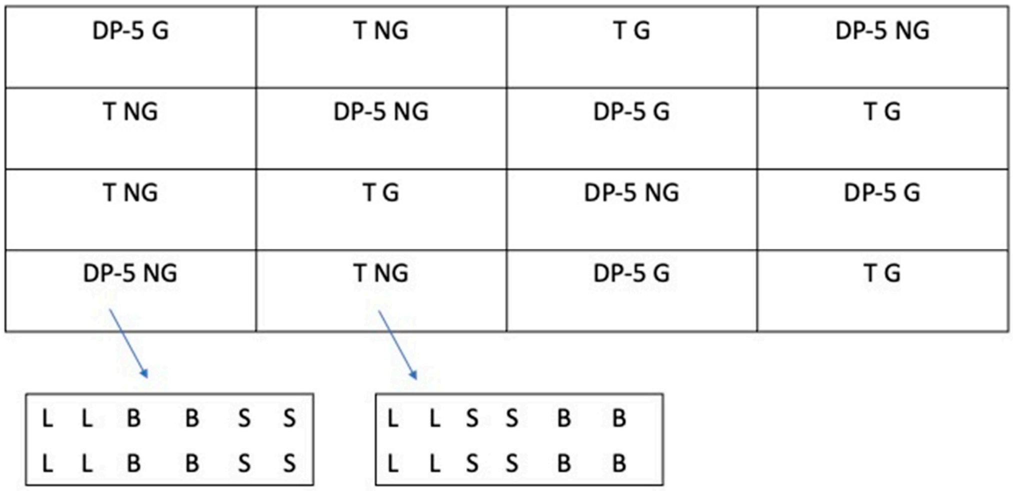

Figure 1. Experimental design of field trial 2014–2015. The whole plot treatments consisting of a planting treatment and glyphosate treatment were arranged in a 2 × 2 factorial and vegetable subplots were randomized within each whole plot. Abbreviations: DP-5 = Directly planted into a hole 5 cm wide × 10 cm deep; T = planted into a tilled strip 2 m long × 15 cm wide; NG = no glyphosate treatment; G = treated with glyphosate; L = lettuce; B = broccoli; S = swiss chard.

Two glyphosate treatments were applied one week prior to planting vegetables in mid-September 2014. Half of the whole plots were treated with glyphosate (G) at a rate of 8.9 g ae/l (2% mixed solution, Roundup Pro Concentrate^{TM}, Monsanto, St. Louis, MO, USA) using a sponge mop that applied glyphosate in 20 cm × 15 cm rectangles centered on the location of future transplants. The other half of the plots received no glyphosate treatment (NG) (Figure 2).

Two planting treatments were created. The direct-planted 5 cm planting treatment (DP-5) was created by planting transplants into test plots using a 5 cm drill bit on a portable drill to dig a hole 10 cm deep. Commercial potting soil (Evergreen^{TM}, Muscle Shoals, AL, USA) was added to the holes as needed. A Mantis^{TM} tiller (Schiller Grounds Care, Southampton, PA, USA) was used to create the tilled treatment (T). This treatment consisted of two tilled strips approximately 2 m × 15 cm within each of the tilled plots.

Subplots consisted of four transplants each of the three cool-season vegetables. Subplots were randomized within the whole plots (Figure 3). Transplants were installed in late September.

As with any home garden, plants were harvested weekly, removing mature leaves or florets, yet leaving the plant to recover and produce more yield. The plants were harvested over a period of 5 weeks that ended with the first frost. The weight of harvested material was recorded and the yield of the four plants of each vegetable within the whole plots treatments was totaled. The cumulative yield of the vegetables over the growing season is reported in all experiments.

Lawn recovery was evaluated in the spring of 2015. Lawn recovery from the four treatments (DP-5 G, DP-5 NG, T G, and T NG) was evaluated. In February, two additional treatments were created. One row in each tilled (T) treatment was top-dressed with sand to smooth the lawn surface, a common procedure for smoothing turf surfaces on golf courses. This created the treatments T G S (tilled, glyphosate-treated with sand) and T NG NS (tilled, no glyphosate, no sand), for a total of six lawn recovery treatments.

Observations of lawn recovery were made periodically from the initiation of green-up (late April) to mid-June. Recovery was measured by visually estimating the percentage of disturbed lawn covered by turf. Additionally, plots were rated for smoothness on the final evaluation data using a 4-point scale (0 = no visual depression, 1 = depression $\leq$ 2.5 cm, 2 = depression 2.6–5.0 cm, 3 = depression 5.1–7.5 cm, and 4 = depression $\geq$ 7.6 cm).

Figure 2. Glyphosate treated field ready to plant in 2014.

Figure 3. Vegetable field trial in November, 2014.

2015–2016 Trial. First-year trials were repeated in 2015. As in 2014, two herbicide treatments (G, NG) were established one week prior to planting in mid-September. Half the whole plots received glyphosate treatment as described above and half did not. An additional planting treatment was added. DP-10 was created by digging a larger hole (10 cm × 10 cm) as described above, using a 10 cm drill bit. Planting treatments consisted of T, DP-5, and DP-10 creating a 2 × 4 split-plot factorial with four replications (24 whole plots) and subplots consisted of vegetables. Transplants were planted in late September. Yield data were measured and reported as described above.

Vegetables were removed in December 2015 and lawn recovery was evaluated in Spring 2016. As in the previous trial, one randomly chosen tilled strip in each tilled treatment was top-dressed with sand in January, creating additional treatments (T S G and T S NG). Plots were evaluated as in the 2015 lawn recovery trial.

2017–2018 Volunteer Trial. To test the lawn garden methodology in a residential setting, Extension Master Gardener (EMG) volunteers were recruited in Georgia, U.S. (approved for human studies research by the University of Georgia #00003635). Volunteers were located in the cities of Athens, Columbus, Gainesville, Lawrenceville, Cumming, Canton, Decatur, McDonough, and Fayetteville in Georgia, USA. All reported having bermudagrass (*Cynodon* spp.) lawns and had active vegetable gardens. Two online training sessions were held to prepare volunteers to plant the tests, maintain the vegetables, harvest, and report yields. The first training provided an overview of the trial and outlined the requirements to participate in the trial (volunteers must have a bermudagrass lawn, be willing to dig holes in it, take weekly data, etc.). The second training focused on the methodology used in the trial.

A simplified protocol was developed for the EMG volunteer test gardens. The glyphosate treatment (G) was replaced by the Veggie Lawn POD (VLP), a prototype developed by My Lawn Garden (College Station, TX, USA). The VLP (Figure 4) is an easily installed plastic cover designed to reduce lawn competition with vegetables. It is mower-safe, durable, and easily stored due to its unique nested design. The plastic collar is held in place with metal pins. The T treatments and DP-5 treatments were also eliminated in lawn tests.

Figure 4. Volunteer trial with DP-10 treatment and the VLP treatment.

Volunteers were mailed planting kits in early September. The kits contained 12 VLPs with instructions for use and 36 plants (12 plants each of broccoli (*Brassica oleracea* 'Lieutenant'); lettuce (*Lactuca sativa* 'Butter Crunch'); and Swiss chard (*Beta vulgaris* subsp. *Cicla* 'Bright Lights'). The kits also contained a small bag of commercial potting soil (Evergreen ™, Muscle Shoals, AL, USA) and fertilizer (10-10-10). The volunteers were asked to provide a digging implement, the lawn mower for measuring the distance between in-lawn vegetables, a scale to measure yield, and water for plants throughout the project duration. Volunteers were asked to apply only pesticides labeled for both vegetables and turf.

Each volunteer was instructed to install three treatments in their yard using the provided plant material. A garden treatment (GARDEN) was created by planting four plants of each vegetable in their existing garden. A direct-planted treatment (DP-10) was created by planting four plants of each vegetable into 10 cm × 10 cm holes dug into their lawn. A direct-planted treatment with VLP (DP-10 VLP) was created by digging 10 cm × 10 cm holes, placing the VLP around the hole, pinning the VLP down, and planting the four plants of each vegetable into the holes. Volunteers used a post hole digger, sharpshooter shovel, trowel, or other suitable implements to make the 10 cm × 10 cm holes in their lawns and filled in holes after planting with the provided potting soil as needed. We suggested the plants be placed far enough apart to allow passage of their lawn mower should the grass require mowing. Volunteers fertilized and irrigated plants as needed.

As in field trials, plants were harvested weekly, removing mature leaves or florets, yet leaving the plant to recover and produce more yield. Volunteers were asked to enter yield data (g/plant) weekly into a data collection website until the first frost.

Each test location was treated as one block in a randomized complete block design. Cumulative yield data for each vegetable were analyzed with a mixed model with test location as a random effect (block). A log transformation was used to normalize the data.

Lawn recovery was also assessed. Participating EMG volunteers completed a monthly survey (the first week of April, May, June and July 2018) to assess perception of the impact of the previous year's fall treatments on their lawn.

After finishing the trials, the EMG volunteers were surveyed (Qualtrics, Provo, UT, USA) to compare their experiences with lawn vegetables and vegetables planted in their actual gardens. They periodically provided pictures of all three treatments.

3. Results

3.1. 2014–2015 Trial

There were no interactions among the main effects of planting technique and glyphosate treatment in whole plots in the fall of 2014; therefore, only comparisons within planting treatments and within glyphosate treatments are reported (Table 1). Glyphosate application did not affect the yield of any of the vegetables, while the planting technique did ($p \leq 0.05$). Lettuce and broccoli produced more yield when planted in tilled plots than when directly planted, with lettuce yields decreasing from 297.1 g in T plots to 238.9 g when planted in DP-5 plots. Similarly, broccoli decreased from 259.5 g to 71.8 g. Swiss chard also decreased slightly but not significantly.

Table 1. Cumulative yield of vegetables grown in a bermudagrass lawn in 2014.

Treatment ^{Y}	Lettuce (g)	Swiss Chard (g)	Broccoli (g)
DP-5	238.9 a ^{Z}	147.3 a	71.8 a
T	297.1 b	181.0 a	259.5 b
NG	257.5 a	128.3 a	172.3 a
G	278.6 a	199.9 a	158.9 a

^{Y} Abbreviations: DP-5 = Directly planted into a hole 5 cm wide × 10 cm deep; T = planted into a tilled strip 2 m long × 15 cm wide; NG = no glyphosate treatment; G = treated with glyphosate. ^{Z} Values followed by the same lowercase letter are significantly different at $p \leq 0.05$.

In the spring of 2015, as the lawn recovered from planting, there were interactions ($p \leq 0.01$) on all evaluation dates among the main effects of planting treatments and glyphosate treatments, therefore treatment means are reported (Table 2). The percentage of the cultivated area covered by turfgrass was lower in treatments that received glyphosate treatment ($p \leq 0.05$) when compared with the non-treated counterpart. For example, on 20 May 2015, DP-5 NG was 94.4% while DP-5 G was 50.6%. Bermudagrass in the DP-5 NG treatment covered 97.5% of the disturbed area by 5 June, whereas no other treatment had exceeded 70.0% by that date. By 19 June, the percentage of cultivated area covered by bermudagrass in both sand treatments was lower ($p \leq 0.05$) than all other treatments (T S NG = 63.7%, T S G = 53.7%). The application of the sand to the tilled treatments reduced the smoothness rating of the lawn surface from 3.75 in T NG and 2.75 in T G to 1.00 in TS NG and 0.75 in T S G.

Table 2. Lawn recovery and evaluation of smoothness in the 2015 Lawn Recovery trial.

Treatment ^{X}	Percentage of Cultivated Area Covered by Bermudagrass				Smoothness Rating ^{Y}
Date Evaluated	4/29/15	5/20/15	6/5/15	6/19/15	6/19/15
DP-5 NG	80.6 a ^{Z}	94.4 a	97.5 a	100.0 a	0.00 d
DP-5 G	36.2 b	50.6 b	68.1 b	82.5 b	0.50 cd
T NG	21.2 c	40.0 c	70.0 b	76.2 b	3.75 a
T G	13.7 c	21.2 d	63.7 bc	81.2 b	2.75 b
T S NG	22.5 c	31.2 c	57.5 cd	63.7 c	1.00 c
T S G	16.2 c	16.2 e	48.7 d	53.7 c	0.75 cd

^{X} Treatments: DP-5 = Directly planted into a hole 5 cm wide × 10 cm deep; T = Planted into a tilled strip 2 m long × 15 cm wide; G = Treated with glyphosate; NG = No glyphosate; S = sand added to depression. ^{Y} Smoothness rating: 0 = no visual depression, 1 = depression ≤ 2.5 cm, 2 = depression 2.6–5.0 cm, 3 = depression 5.1–7.5 cm, and 4 = depression > 7.6 cm. ^{Z} Values followed by the same lowercase letter are not significantly different at $p \leq 0.05$.

3.2. 2015–2016 Trials

There were no interactions ($p \leq 0.05$) among the main effects of planting treatments and glyphosate in whole plots in the fall of 2015 (Table 3). Both lettuce and broccoli yielded more (≤0.05) when planted in the larger 10 cm × 10 cm holes (289.4 g and 236.9 g, respectively) compared with the smaller holes (172.9 g and 103.5 g, respectively). Broccoli yield in treatment T (255.6 g) was also higher ($p \leq 0.05$) than in DP-5 (103.5 g). The application of glyphosate did not significantly affect the yield of any of the vegetables.

Table 3. Cumulative yield of vegetables grown in a bermudagrass lawn in 2015.

Treatment ^{Y}	Lettuce (g)	Swiss Chard (g)	Broccoli (g)
DP-5	172.9 b ^{Z}	200.6 a	103.5 a
DP-10	289.4 a	236.2 a	236.9 b
T	269.4 ab	252.5 a	255.6 b
NG	265.1 a	263.7 a	218.7 a
G	222.7 a	195.8 a	178.6 a

^{Y} Abbreviations: DP-5 = directly planted into a hole 5 cm wide × 10 cm deep; DP-10 = directly planted into a hole 10 cm wide × 10 cm deep; T = planted into a tilled strip 2 m long × 15 cm wide; NG = no glyphosate; G = treated with glyphosate. ^{Z} Values followed by the same lowercase letter are not significantly different at $p \leq 0.05$.

In the spring 2016 lawn recovery evaluation, there were interactions ($p \leq 0.03$) among the main effects of planting treatment and glyphosate treatment that affected the percentage of cultivated area covered by bermudagrass in the first four evaluation dates. Treatment means are reported (Table 4). As noted in 2015, glyphosate treatment reduced the percentage of area covered by bermudagrass on every evaluation date and within every planting treatment though the reduction was not always significant ($p \leq 0.05$). Both DP-5 and DP-10 had greater than 90% of the cultivated area covered by 13 May. The percentage of cultivated area covered by bermudagrass did not exceed 70% by the end of the trial in any of the four tilled treatments.

Table 4. Lawn recovery in the 2016 Lawn Recovery trial.

Treatment [Y]	Percentage of Cultivated Area Covered by Bermudagrass				
Date Evaluated	4/14/16	4/29/16	5/13/16	5/27/16	6/10/16
DP-5 NG	94.0 a [Z]	98.7 a	99.5 a	100.0 a	100 a
DP-5 G	52.0 c	61.0 c	63.2 b	75.7 b	81.5 abc
DP-10 NG	81.0 b	88.0 b	91.0 a	94.5 a	97.7 ab
DP-10 G	46.0 c	52.5 c	59.5 b	70.7 b	78.7 bc
T NG	28.0 d	37.5 d	42.0 c	62.2 bc	70.0 cd
T G	16.7 de	28.7 d	32.5 cd	43.2 ed	52.5 de
T S NG	13.5 e	30.0 d	43.75 c	53.2 cd	63.2 cde
T S G	5.5 e	17.5 e	21.5 d	33.2 e	48.2 e

[Y] Treatments: DP-5 = Directly planted into a hole 5 cm wide × 10 cm deep; DP-10 = Directly planted into a hole 10 cm wide × 10 cm deep; T = Planted into a tilled strip 2 m long × 15 cm wide; NG = no glyphosate; G = Treated with glyphosate; S = sand added to depression left by a tilled strip 2 m long × 15 cm wide. [Z] Values followed by the same lowercase letter are not significantly different at $p \leq 0.05$

The main effects of planting and glyphosate treatments affected the smoothness ratings ($p \leq 0.05$). The application of sand reduced the smoothness rating from 3.6 to 1.2, and glyphosate treatment increased the rating from 1.2 to 1.9 ($p \leq 0.05$) (Table 5).

Table 5. Evaluation of smoothness in the 2016 Lawn Recovery trial.

Treatment [X]	Smoothness Rating [Y]
DP-5	0.6 c [Z]
DP-10	0.9 bc
T	3.6 a
T S	1.2 b
G	1.9 a
NG	1.2 b

[X] Treatments: DP-5 = directly planted into a hole 5 cm wide × 10 cm deep; DP-10 = directly planted into a hole 10 cm wide × 10 cm deep; T = planted into a tilled strip 2 m long × 15 cm wide; NG = no glyphosate t; G = treated with glyphosate; T S = sand added to depression left by a tilled strip 2 m long × 15 cm wide. [Y] Smoothness rating: 0 = no visual depression, 1 = depression ≤ 2.5 cm, 2 = depression 2.6–5.0 cm, 3 = depression 5.1–7.5 cm, and 4 = depression ≥ 7.6 cm. [Z] Values followed by the same lowercase letter are not significantly different at $p \leq 0.05$.

3.3. 2017–2018 Volunteer Trial

Though 16 volunteers agreed to participate, not all were successful in establishing replications in their yards. Three volunteers never initiated the study for personal reasons. Two opted to work together and share a replication. Two did not adhere to the protocols and their test results were not included in the yield analyses. Animals, both domestic (dogs) and wild (rabbits and deer), destroyed three of the replications before completion. Therefore, seven replications were included in the statistical analysis, creating seven replications (blocks) of the three treatments.

Photos revealed considerable variation in GARDEN treatments. Volunteer home gardens included container, in-ground, and raised bed gardens. Some had extensive irrigation systems, fencing, and pathways, while others were far simpler.

Although the yields were higher in GARDEN, the only statistical difference in yield ($p \leq 0.05$) was observed for lettuce (GARDEN = 530.5 g, DP-10 = 339.0 g and DP-10 VLP = 302.0 g) (Table 6).

Table 6. Cumulative yield of vegetables grown in seven at-home trials in Georgia.

Treatment [Y]	Lettuce (g)	Swiss Chard (g)	Broccoli (g)
GARDEN	530.5 a [Z]	427.7 a	296.6 a
DP-10	239.0 b	227.5 a	154.3 a
DP-10 VLP	302.9 b	209.6 a	50.9 a

[Y] Abbreviations: Planted into an existing garden = GARDEN; Directly planted into a hole 10 cm wide × 10 cm deep = DP-10; Directly planted into a hole 10 cm wide × 10 cm deep and a VeggieLawnPod = DP-10 VLP. [Z] Values followed by the same lowercase letter are not significantly different at $p \leq 0.05$.

Participants were asked about the recovery of their lawns with a monthly survey. In April, respondents reported that they agreed or somewhat agreed with the statement, "I can clearly see the damage from the VLP (five out of six respondents) and DP-10 (four out of six respondents) in my lawn." By early May, six out of seven respondents reported being extremely or somewhat satisfied with the appearance of the lawn that had contained the VLP and the DP-10 treatments. They reported no challenges mowing the lawns.

EMG volunteers were asked to compare their planting, maintenance, and harvest experiences with lawn planting treatments to that of their personal vegetable gardens using a scale of 1 (much more difficult) to 100 (much easier) with 50 being of equal difficulty. They reported the DP-10 plantings ($\bar{x}$ = 37.7, s = 26.2, n = 9) and the DP-10 VLP lawn plantings ($\bar{x}$ = 42.6, s = 21.2, n = 9) were slightly more difficult to plant than their personal gardens. They reported it was neither easier nor more difficult to maintain either DP-10 ($\bar{x}$ = 53.4, s = 21.7, n = 7) or the GP-10 VLP treatments ($\bar{x}$ = 51.2, s = 24.66, n = 7) when compared to that of their personal garden. Harvesting DP-10 ($\bar{x}$ = 56.0, SD = 10.5, n = 5) and DP-10 VLP ($\bar{x}$ = 60.6, s = 12.6, n = 5) was slightly easier than their personal garden.

When asked how they felt about the treatments, the volunteers responded on a scale of 1 (disliked a great deal) to 100 (liked a great deal). Their personal gardens were favored ($\bar{x}$ = 86.3, s = 15.4, n = 8) over DP-10 ($\bar{x}$ = 55.7, s = 26.1, n = 9) and DP-10 VLP ($\bar{x}$ = 54.0, s = 27.0, n = 9) treatments. A similar result was apparent when participants were asked to rate their treatments aesthetically using a scale ranging from 1 (far below average) to 100 (far above). Their personal gardens ($\bar{x}$ = 91.0, s = 16.7, n = 7) rated well above either lawn treatment (DP-10: $\bar{x}$ = 54.1, s = 24.8, n = 9; VLP: $\bar{x}$ = 56.1, s = 22.1, n = 8). Interestingly, six out of nine respondents said they would consider planting vegetables in their lawn in the future.

The surveys offered opportunities for comments. The volunteers suggested other crops, techniques they felt would be more effective in lawns, and frustration at broccoli yields (a hard freeze occurred before broccoli matured, resulting in little or no yield for several gardeners). Two gardeners reported fire ants (*Solennopsis invicta* Buren, 1972) under the VLP. None of the volunteers used pesticides on their lawns, though some used insecticides on the vegetables.

4. Discussion

This study has established that an urban double-crop of cool-season vegetables followed by warm-season grass is possible. While yields in the volunteers' lawn gardens were lower than those achieved in their personal gardens, volunteers were able to produce vegetables and reported satisfactory summer lawns. This provides a gardening alternative for consumers with small yards.

The volunteers were inexperienced with lawn gardens and future yields may improve with practice. Some volunteer failures yielded useful data in this study. For example, because the initial experimentation was undertaken in a fenced university experiment facility, we did not realize the potential threat domestic and wild animals could present to the double-crop vegetables.

Neither glyphosate application nor the use of the VLP appeared to reduce the competition of the lawn with the vegetables. Furthermore, glyphosate application delayed recovery of the lawn in spring trials, reducing the percentage of the cultivated area covered by turfgrass in both years of field testing. The VLP used in the volunteer trials was ineffective at increasing vegetable yield and may provide an attractive habitat for fire ants.

The tillage treatment created 2 m $\times$ 15 cm depressions in lawns. The application of sand to these depressions was helpful in smoothing them out and reduced the smoothness rating in both field trials. However, it also appeared to slow the recovery of the lawn, delaying the growth of bermudagrass stolons and rhizomes in damaged areas and reducing the percentage of the cultivated area covered by bermudagrass. It seems unlikely that a consumer would find tilled treatments acceptable.

The direct-planted treatment that created a 10 $\times$ 10 cm hole (DP-10) appeared to be the most successful planting technique and was well tolerated by the EMG volunteers testing the system. The EMG volunteers in the trials expressed little concern about damage to their lawn. Admittedly, the nature of this study may have precluded participants who have a preference for a well-manicured lawn.

Despite the millions of consumers growing food in personal or community gardens, there is limited scientific exploration of growing methods suitable for small-scale residential production, especially in urban areas (personal communication, John Cruickshank, 2021). We were able to locate just one other study that attempted planting vegetables in lawns [18]. In this study, lettuce was planted in lawns to create an edible, ornamental carpet. The study noted that the plantings were very successful from an ornamental perspective and that the lettuce "behaved very well" from the vegetable point of view. No attempt to double-crop was made in this study. The lettuces were grown in beds in the lawn and were concurrent with the lawn.

This study helps address consumer horticulture research gaps by uniquely focusing on gardening methodology designed to meet the specific needs of consumers (gardeners) rather than commercial producers. Research in consumer horticulture (the cultivation, use and enjoyment of plants, gardens, landscapes, and related horticultural items to the benefit of individuals, communities, and the environment [19]) tends to focus on human and community health, well-being, and economics [20–22], rather than gardening methodology. There is a startling paucity of rigorous research on garden techniques suitable for consumers. Gardening methodology tends to be extrapolated from commercial production techniques. Though rigorously tested, commercial production may not be easily applied in home gardens.

5. Conclusions

Fall vegetables and a warm-season lawn can co-exist. It is possible to double-crop the cool-season vegetables lettuce, broccoli, and Swiss chard with a warm-season bermudagrass lawn. Volunteers were able to implement this gardening methodology. They were able to harvest fall vegetables and expressed satisfaction with their summer lawns. Our research suggests that DP-10 was the most successful planting technique tested and that neither glyphosate nor the use of the VLP increased the yield of the vegetables tested. Future studies should focus on other grasses and vegetables and explore additional planting techniques (e.g., larger holes, soil amendments).

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