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Article

Undergraduate Writing Promotes Student's Understanding of International Sustainable Development in Horticulture

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Abstract: Promotion of undergraduate student thinking and learning in the realm of sustainable production is a new focus for horticulture curricula. In a writing intensive course, Greenhouse Management (Hort 3002W; University of Minnesota), students focus their learning of sustainability by writing peer-reviewed, 3-phase 'Worldwide Sustainable Horticultural Crop Production Papers' on past, present, and future prospects for sustainability. The USA is used as an in-class example throughout the semester while each student focuses their writing on a specific country of their choosing. Their papers focus on eight goals for each country across the three Phases: I—their choice of a country, definition of sustainability, identification of historical production practices, current production statistics; II—current production practices and integration of historical/current practices (ranked strategies); III—finalized sustainable development strategy, design of a future sustainable, controlled-environment production facility. The last two goals (Phase III) provide plant breeders with potential breeding objectives for country-specific cultivar development within a sustainable production framework. Completed papers are web-published for global availability to enable each country's researchers and policy makers to access sustainable ideas for future development. In 2009–2010, 'Worldwide Sustainable Horticultural Crop Production Papers' were published for 41 countries which were downloaded 3900 times in 19 months through April 2011. This large readership indicates such an assignment can generate interest in either undergraduate writing about developing sustainable horticulture and/or the topic area itself, although the exact purpose of the downloads or the location of the users could not be determined.

Keywords: sustainability; horticultural crop production; writing intensive learning; plant breeding

1. Introduction

Horticultural crop production has deep origins in sustainable production following the historic 'hunter and gatherer' period [1,2]. These sustainable production roots shifted post-WWII with the advent of fossil-fuel-based production, long-distance shipping and economic globalization [3]. The post-1980s resurgent interest in sustainable horticulture production practices fostered implementation of older home horticulture and small farm production methods [4] for the modern producer and their consumers [5]. International symposia on sustainable horticultural practices have been convened [6,7] and sustainable practices, such as biodynamic farming, locavore, and organic production [8-10] have been reinvented for small and large producers and are gaining in widespread acceptance. Textbooks are also starting to be generated, e.g., [2], although they are still in their infancy and devote only a small proportion of text to actual sustainable horticultural practices.

Despite these advances, commercial modern horticulture remains the world's most intensive form of agriculture for energy usage and labor requirements [4]. The lowest energy ratio (output/input) and highest Gigajoules (GJ)/ha^{-1}-year input occurs in the production of heated glasshouse crops in northern latitudes [11-13]. Such protected crop culture systems rely on high-cost, increasingly unsustainable fossil fuel inputs [4,11,13]. Consumer-driven sustainable and/or organic products [14] have spawned changes to existing production systems [15-17], although considerable educational, research, and production challenges to their implementation remain [18].

In the past few decades within N. American and European higher education institutions, students have moved from agriculture and horticulture majors into more 'trendy' fields such as biotechnology and environmental sciences [4]. Academic programs have recently adapted their course offerings to include a suite of new courses on sustainable horticultural production or modifications to existing coursework [4]. The emergence of sustainable production has begun repopulating horticulture majors with students seeking new competencies that such a production shift entails. Fein identified that sustainable education programs should focus on understanding and an awareness of the issues before commitment and action can be implemented [19]. Keith and Dwyer identified sustainability initiatives as models for educational programs in Australia [20]. An educational program for high school students in the United Kingdom uses demonstrative low input techniques [21].

Since implementation of a 'new' system of sustainable horticulture production involves every participant in the horticultural distribution chain [22], an important first step towards its implementation requires system-wide education based on the ignorance-knowledge-action model of active learning [4,23]. Educators have changed their knowledge delivery approaches to student-centered life-long learning [24,25]. An important component of sustainable horticulture education is the contextual definition of the science within each country across the globe. While universal definitions have been created, each country may find the need to redefine these to accommodate their particular requirements. The evolution of sustainable horticultural education has benefited from the analogy that plant breeders use genetic diversity as the basis for selection and, thus, the attraction of a diverse population of students will aid in the success of this new era of sustainable production [4].

The objective of this study is to incorporate sustainable production education into a writing intensive assignment within the context of an existing course in the Environmental Horticulture major at the University of Minnesota. This objective is designed to promote student understanding of this complex issue. A secondary objective is for students to provide plant breeders with potential breeding crops for country-specific cultivar development within a sustainable production framework.

In a writing intensive course, Greenhouse Management (Hort 3002W; University of Minnesota), students focus their understanding of sustainability by writing peer-reviewed, 3-phase 'Worldwide Sustainable Horticultural Crop Production Papers' on past, present, and future prospects for sustainability. The US is used as an in-class example throughout the semester while each student focuses their writing on a specific country of their choosing. Their papers focus on eight goals for each country across the three Phases: I—their choice of a country, their country's definition of sustainability, identification of historical production practices, current production statistics; II—current production practices and integration of historical/current practices (ranked strategies); III—finalized sustainable development strategy, design of a future sustainable, controlled-environment production facility. The last two goals (Phase III) provide plant breeders with potential breeding objectives for country-specific cultivar development within a sustainable production framework. Completed papers are web-published for global availability to enable each country's researchers and policy makers to access sustainable ideas for future development.

2. Results and Discussion

Fifty-eight students enrolled in Hort 3002W during 2009 (n = 20) and 2010 (n = 38). All students completed the Worldwide Sustainable Horticultural Crop Production Paper assignment, although after the end of Phase III several papers were incomplete or scored below a passing grade (70%). As a result, only 41 papers (70.69%; Table 1) were published online at the University of Minnesota Library's Digital Conservancy website [26] using the DSpace Software [27]. During the period of 13 July 2009–15 January 2011, 'Worldwide Sustainable Horticultural Crop Production' papers were downloaded ~3000 times (Figure 1). Three months later (April 2011), an additional 1000 downloads occurred (n = 3900 total downloads; Table 1). Summary information from all 58 student's papers for the eight goals in the assignment is discussed as follows;

Table 1. Descriptive statistics (country, no. of downloads for the period of July 2009–April 2011, no. of sustainability definitions, gross domestic product, organic production, no. of historical sustainable production practices, no. of strategic rankings for sustainable production, strategic crop for future sustainability testing, and potential plant breeding contributions to future sustainability research) for the 41 'Worldwide Sustainable Horticultural Crop Production' online papers.

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Afghanistan	7	0	$800/capita (~80% of licit GDP)	10 (n/a)	n/a	*Malus domestica*, *Pistacia vera*, *Prunus amygdala*, *Punica granitum*	Adaptation to production facilities (greenhouses), techniques (permaculture) and compost nutrient sources
Argentina	35	2	$585B (9.2%)	1 (9)	3	*Helianthus annuus*	Cultivar development
Australia	4	1	n/a (3.8% of capital)	2 (n/a)	n/a	*Macadamia integrifolia, M. tetraphylla*	Cultivar adaptation to new pruning and harvesting techniques, and intercropping
Bahamas	24	2	$9.086B (3%)	1 (n/a)	n/a	*Capsicum annuum*, *Solanum lycopersicum*	Breeding cultivars adapted to high temperature greenhouse production
Belgium	4	2	n/a	4 (n/a)	n/a	*Solanum lycopersicum*	Cultivar adaptation to high tunnels using different energy sources, crop rotation

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Belize	3	2	n/a	n/a	3	*Citrus spp.* (export), *Solanum lycopersicum* (local use)	Cultivar adaptation to use of shrimp waste; high tunnels, crop rotation, polyculture production
Brazil	4	1	$1,314B in 2007 (n/a)	4 (n/a)	n/a	*Coffea arabica*	Cultivars bred for high yield in alley cropping and silvopastoral methods of agroforestry
Canada	3	4	$1,319B (2%)	2 (n/a)	n/a	*Solanum lycopersicum*	Cultivar development for Winter Efficiency Research Greenhouses in northern latitudes
Columbia	3	2	$400.3B (9.1%)	2 (n/a)	n/a	*Coffea arabica*	Maintaining high yield with alternative fertilizers and soilless substrates
Costa Rica	3	2	$48.19B (6.5%)	4 (n/a)	n/a	*Coffea arabica*	Increase yield of shade-cropping cultivars, selection of canopy tree types to maximize production potential

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Cuba	14	0	$144.6B in 2008 (n/a)	3 (n/a)	5	*Capsicum annuum*, *Lactuca sativa*, *Solanum lycopersicum*	Disease resistant or tolerant cultivars for high tunnel production
Czech Republic	2	2	$256.7B (2.8%)	2 (n/a)	1	*Malus domestica*	Develop disease (scab) and growth-defect resistant varieties
Denmark	4	2	$57,260 per capita (n/a)	2 (n/a)	5	*Kalanchoe blossfeldiana*—potted plant	Comparative solar, non-solar heated greenhouses
Egypt	52	0	$158.3B in 2008, (13.4%)	1 (n/a)	3	*Solanum lycopersicum*	Change high tunnel conditions, including coverings or misting, to increase fruit production
France	590	1	$2,856B in 2008 (2.2%)	3 (n/a)	4	*Pelargonium* spp.	Test effectiveness of raised beds in improved height, blossoms, bloom period and foliage
Germany	29	1	$3,673B in 2008 (1%)	3 (n/a)	4	*Valerianella locusta* (corn salad)	Solar heating of greenhouses and other energy-related issues

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Greenland	24	0	n/a	n/a	n/a	*Cucumis sativus*, *Solanum lycopersicum* (glasshouses), *Brassica rapa var. rapa*, *Solanum tuberosum* (field)	Solar heating, more greenhouse construction
Iceland	4	2	n/a (5% in 2006)	2 (n/a)	3	*Capsicum annuum, Cucumis sativus*, *Solanum lycopersicum* (fish farming)	Test energy inputs, substrates, planting times
India	3	1	n/a (17.5%)	2 (n/a)	4	*Mangifera indica*	High altitude tolerance, IPM practices
Iran	208	1	n/a (10.5%)	2 (n/a)	3	*Pistacia vera*	Irrigation methods; drought tolerant genotypes
Ireland	2	4	n/a (5% in 2002)	4 (n/a)	5	*Fragaria vesca*, *Cucumis sativus*, *Solanum lycopersicum*	Compare sensory evaluation, growth rate, weight, plant fresh weight in open fields *vs.* polytunnels

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Israel	531	1	$254.699B in 2008 (n/a)	1 (n/a)	2	*Rosa xhybrida*	Hydroponics and desalination; breed for salt tolerance
Italy	2	2	$1,756B (2.1%)	4 (n/a)	n/a	*Vitis vinifera*	Test grape and wine quality against changes in irrigation, soil conservation and lower machinery use
Japan	3	1	n/a (5% in 2000)	4 (n/a)	5	*Solanum lycopersicum*	Develop cultivars with low N requirements, mechanize to lower fertilizer use and imports, use renewable energy, develop cultivars better suited to Japanese climates
Madagascar	2	2	n/a (~33.3%)	n/a	4	*Oryza sativa*, *Vanilla planifolia*	Crop yield and quality in high/low tunnels *vs.* open-field growth
Nepal	1	4	n/a/ (35%)	1 (n/a)	n/a	*Dianthus caryophyllus*, *Gerbera jamesonii*, *Gladiolus xhybrida*, *Rosa xhybrida*, *Zantedeschia aethiopica*	Irrigation, fertilizers, soil-based and soilless substrates, cultivars able to withstand harsh water stress, mechanized planting/harvesting, post-harvest storage

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Netherlands	462	2	GDP (OER) $909.5B (2%)	n/a	3	*Solanum lycopersicum*	Test feasibility of solar-only greenhouse; select or breed genotypes more suited for this environment
New Zealand	1	2	$127B (4.78%)	1 (n/a)	6	*Cymbidium* spp.	Compare light and humidity levels between the glass and plastic greenhouse systems; bred for these environments
Norway	1	2	$276.5B (2.2%)	1+ (n/a)	n/a	n/a	Artificial light as photoperiod manipulation to induce flowering, climate-controlled greenhouse using Combined Heat and Power (CHP)
Panama	4	1	n/a (6.2% in 2008)	1 (n/a)	3	*Musa acuminata*, *M. balbisiana*, *Saccharum* spp.	Cultivar development for small scale organic production; develop best practices, pit planting and nursery use for sugar cane
People's Republic of China	461	1	$3,425.3B (n/a)	5 (n/a)	6	*Cucumis sativus*, *Solanum lycopersicum*	Cultivar adaptation to and yield in solar greenhouse production, using soilless sustainable media

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Peru	459	1	n/a (8.5%)	6 (n/a)	n/a	*Amaranthus caudatus, Arracacia xanthorrhiza*, *Daucus carota*, *Triticum* spp.	Revitalize native crops, develop IPM methods, degree-days, and damage thresholds specific to these crops
Poland	21	1	$686.2B (n/a)	1 (n/a)	n/a	cut flowers (*Dianthus caryophyllus*, *Helianthus annuus*, *Rosa xhybrida*)	High-yielding cultivars for sustainable greenhouse production
South Africa	2	2	$277B in 2002 (2.5%)	4 (n/a)	3	*Cucumis sativus*, *Solanum lycopersicum*	Experiment with heirloom tomatoes for feasibility and assess disease and insect risks
Spain	1	4	$1,556B (2.4%)	4 (n/a)	2	*Solanum lycopersicum*	Research on re-use of wastewater systems; breed cultivars for this type of nutrient cycling
Sweden	4	4	$333.2B (1.6%)	n/a	n/a	*Vaccinium vitis-idaea*	Cultivar development for sustainable production

Table 1. *Cont.*

Country	No. of downloads	No. of sustainability definitions	2009 or 2010 Gross domestic product (GSP) in US$ (% agriculture/ horticulture)	No. of historical sustainable production practices (crops)	No. of strategic rankings for sustainable production	Strategic crop(s) for future sustainability testing	Potential plant breeding contributions to future sustainability research
Switzerland	9	1	$316B (1.5%)	1 (n/a)	4	*Brassica napus*, *Cannabis sativus* (industrial), *Glycine max*	Crop rotation effects; select best cultivars
Tanzania	745	none found, but several that are related	n/a (48%)	n/a	3	*Dendrobium*, *Phalaenopsis*, *Oncidium, Rosa xhybrida*	Establishing farms in new regions, studying cost-effectiveness of sustainable methods in plastic bags
Turkey	23	none found, but several that are related	n/a	2 (n/a)	7	*Citrullus lanatus*	Compare soilless substrate production facility and outdoor orchard farm
United Kingdom	137	3	$2.788B (0.9%)	5 (n/a)	10	*Narcissus pseudonarcissus*	Using sustainable heating, cooling, water, and energy inputs, test fertilizers, soils
Vietnam	9	1	$91.76B (21.4%)	5 (n/a)	n/a	multiple crops	Crop diversification, compare integrated systems of aquaculture/agriculture farming to monoculture farms
Mean	**95.1**	**1.7**	**$1,128.67B (9.85%)**	**2.8 (9)**	**4.04**	**-**	**-**

Note: n/a = no information or data was available.

2.1. Goal 1. Choose the Country for Your Research

Students chose a wide range of countries, based on their personal interests. Several students reported being interested in doing an international internship in their chosen country; internships are required for students majoring in the Environmental Horticulture degree at the University of Minnesota.

The number of downloads for each country's paper ranges from n = 2 (Czech Republic) to n = 745 (Tanzania; Figure 1). In addition to Tanzania, at least seven other countries have the highest frequency of downloads (>100): France (n = 590), Iran (n = 208), Israel (n = 531), The Netherlands (n = 462), People's Republic of China (n = 461), Peru (n = 459) and The United Kingdom (n = 137; Figure 1). Statistics for the source country of each download request could not be gathered and displayed with the version of AWStats Software used for this site. Thus, it could not be determined where these downloads were being used nor the purpose for downloading the documents.

2.2. Goal 2. Definition of 'Sustainability'

Each country's sustainability definition ranges from none (Afghanistan, Cuba, Greenland; Table 1) to as many as four (Canada, Nepal, Ireland, Spain, Sweden) in each country. While it was impossible to determine the exact year in which each country may have commenced discussions and regulations for sustainable production, those with a longer history in the field have greater numbers of definitions. To the best of our students' knowledge, at least two countries did not have any specific definitions for sustainability (Tanzania, Turkey) but have terminology or definitions that were similar in nature. The average number of definitions per country is 1.7 (Table 1).

2.3. Goal 3. Identify Historical Production Practices

Sixteen countries did not have accessible published information on historical horticultural practices (Table 1) whereas for the rest there was a range of one (Argentina, Bahamas, Egypt, Israel, Nepal, New Zealand, Panama, Poland, and Switzerland) to ten (Afghanistan) reported with an overall mean number of 2.8/country. A similar range in values (from one—Argentina to ten—Afghanistan) is reported for the number of crops historically grown sustainably, although the average was 9.0 (Table 1).

Historical horticultural production practices in sample papers ranged from crop rotation (Belgium, United Kingdom); protected culture in orangeries with solar, wood heating (United Kingdom, Ireland) [28]; small family farms (Poland, Czech Republic, Argentina); organic fertilizers (Poland) to container culture (United Kingdom) [28]. Important production practice changes, which benefit from plant breeding improvements, include new and exotic crops (Belgium, United Kingdom) [28], higher yielding cultivars [29], adaptation to nutrient feeding (Belgium), and enhanced flavors (Argentina).

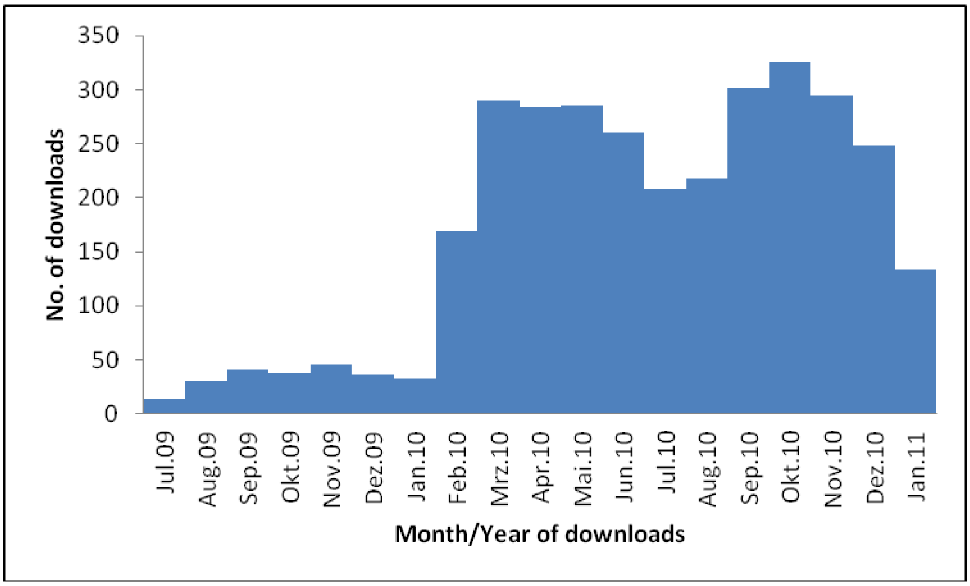
2.4. Goal 4. Current Production Statistics

Gross domestic product (GDP) data are not available for all countries for the years 2009–2010 or earlier. Additionally, GDP is on a per capita basis rather than a total amount per country, e.g., Afghanistan [30] or Denmark [31]. In countries such as Afghanistan, the GDP reported [30] is for licit crops, rather than including illicit drug crops such as the poppy (*Papaver* *somniferum*)—which is also an ornamental (horticultural) and edible crop. For those countries with GDP data, the overall mean was US $1,128.67B (Table 1). The amount of agricultural and/or horticultural crops, as a percentage of GDP, is not available for Belgium, Belize, and Brazil (Table 1) but ranges from 1% (Germany) to 80% (Afghanistan; Table 1). In many instances, it is impossible to delineate horticultural crops from the agricultural grouping as most countries do not distinguish differences when reporting such statistics. The overall mean for agricultural/horticultural crops for all reporting countries is 9.85% of the GDP (Table 1).

2.5. Goal 5. Current Production Practices

Current production practices vary widely, from countries like the Netherlands where state-of-the-art techniques are widespread and new techniques are constantly being tested, to those such as Panama where less sustainable methods from the last century are still regularly used. A few countries such as Belize and Madagascar are beginning to move toward more sustainable practices by emphasizing education. Plant breeders in private/public sector breeding programs could provide important educational opportunities in such countries, as well as attracting potential students into the profession. For example, the U.S. Plant Breeding Coordinating Committee coordinates plant breeders in a nation-wide effort to raise awareness of plant breeding and how to contribute for its future in a unified way [32].

Figure 1. Number of downloads per month (13 July 2009–15 January 2011) of Worldwide Sustainable Horticultural Crop Production papers from the website [33].



A number of countries have serious water issues that impact their practices, e.g., Afghanistan, Australia, and Egypt. Others have legacies of non-sustainable practices that may be difficult to change due to economics, both involving lack of funding and dependency on current funding models (e.g., Peru, Belize). Several countries seem to have a mix of progress in the area of sustainability alongside continued dependence on petroleum products and other less sustainable practices. Technology, especially in greenhouse design and function, is embraced by some more affluent nations (United Kingdom, The

Netherlands, Costa Rica), while those with less money may focus on water conservation, biofertilizers, and renewable energy sources (e.g., Nepal, Panama).

2.6. Goal 6. Integration of Historical and Current Production Practices; Ranked Strategies

The number of strategic rankings for sustainable horticulture production averages 4.04, although only 60.97% (25/41) of countries are ranked (Table 1). The Czech Republic has one strategic ranking while as many as ten are reported for the United Kingdom (Table 1).

Strategic crop(s) for future sustainability testing total 42, the majority of which (30/42 or 71.4%) are edible crops (fruits, grains, or vegetables) while 12 (28.6%) are ornamental flowers (Table 1). In many cases, more than one crop is prioritized for each specific country. The most commonly proposed strategic crop is *Solanum lycopersicum* (tomato)—identified for 15 countries, followed by *Cucumis sativus* (cucumber; 5 countries), *Capsicum annuum* (pepper; 3), *Coffea arabica* (coffee; 3), *Malus domestica* (apple; 2), *Pistacia vera* (pistachio; 2), *Macadamia integrifolia* and *M. tetraphylla* (macadamia nuts; 2), and *Musa acuminata* and *M. balbisiana* (banana; 2) (Table 1). All of the remaining edible crops are prioritized for only one country each (*Amaranthus*, *Arracacia*, *Brassica*, *Cannabis*, *Citrus*, *Citrullus*, *Daucus*, *Fragaria*, *Glycine*, *Helianthus*, *Lactuca*, *Mangifera*, *Oryza*, *Prunus*, *Punica*, *Saccharum*, *Solanum tuberosum*, *Triticum*, *Vaccinium*, *Valerianella*, *Vanilla*, *Vitis*). Among the twelve ornamental crops, *Rosa xhybrida* (cut rose) is prioritized for four countries along with cut or potted orchids (*Cymbidium*, *Dendrobium*, *Oncidium*, *Phalaenopsis*), followed by *Dianthus caryophyllus* (cut carnations), and all others had one country each assigned (*Gerbera*, *Gladiolus*, *Kalanchoe*, *Narcissus*, *Pelargonium*, *Zantedeschia*) (Table 1).

Ranked strategies are rarely numeric in nature for the 41 countries, although exceptions occurred. For instance, strategic rankings of each sustainable method for the countries of Cuba and France include a 1–5 numeric scale (with 1 = not at all sustainable to 5 = very sustainable) across environmental, economic, social and overall aspects (Cuba) or sustainability, implementation potential and total score (France). Supportive reasoning is used to provide additional insight into the assigned scoring. The majority of strategic rankings are not quantitative in nature but rely on qualitative functions.

2.7. Goal 7. Finalized Sustainable Development Strategy

Students identify a wide range of Finalized Sustainable Development Strategies, depending on the historic and current production practices in use. For instance, if protected culture in heated greenhouses located in northern latitudes is a predominant production environment, energy conservation is an important strategy (e.g., Belgium). A focus on harnessing wind energy is likewise important in tropical areas such as the Bahamas. In this country, geothermal heating as well as wind energy are proposed as new solutions to high cost and non-sustainable heating during winter periods.

The movement of crops from fields to protected structures (low tunnels, high tunnels, glasshouses) predominates in less developed countries, such as Argentina. In some instances, even though greenhouse production of flowering crops occurs predominantly in greenhouses, the movement of other crops from field to greenhouses (coffee in Colombia) is proposed by the student writer. Crop rotation for field production remains an important factor across developed and less-developed countries alike. Alternative production methods, such as pruning techniques in woody nut crops (macadamia in Australia) or harvesting methods are also important. In several countries, the focus is on higher yielding crops, particularly through the creation and testing of new cultivars (Australia).

Most locations for the 'Finalized Sustainable Development Strategies' to be tested are carefully considered, based on the identified crops' (Table 1) cultural requirements, availability of required production inputs, and the presence of researchers. Many, but not all, are proposed to be established on-site at, or in close proximity to, educational institutions (Argentina, for example). The opportunity for public and private sector plant breeders to spearhead and capitalize on these future research options worldwide is immense.

2.8. Goal 8. Design a Future Sustainable, Controlled-Environment Production Facility

Students produce a design for a future, sustainable, controlled-environment production facility depending on the 'Finalized Sustainable Development Strategies' (Goal 7), identified crop(s) (Goal 6, Table 1), and environmental factors. Innovative approaches surface such as a 'Winter Efficiency Research Greenhouse' for Canada, integrated production by restaurants and the eco-tourism industry in Belize, urban production systems in Cuba, or use of historic techniques in a country (The Marais or French Intensive Gardening Method for France). In some cases, historic sustainable methods used in field production need to be tested in controlled environments. For instance, The Marais method has not been tested in comparative trials within high tunnels.

Most authors pose specific questions or hypotheses to be answered by the initial experimentations. This helped guide the specific experimental designs and germplasm to be incorporated therein. The important role of plant breeding programs to aid in breeding lines and market standards for comparison are tantamount for the future success of any of these proposals.

3. Experimental Section

3.1. Greenhouse Management: Sustainable Horticulture Crop Production

The undergraduate course, 'Greenhouse Management: Sustainable Horticulture Crop Production' (Hort 3002W), is a writing-intensive (WI) course, as part of an innovative curricular approach to writing called the 'Writing-Enriched Curriculum Project' (WEC). WEC supports departments and colleges—including Horticultural Science and the Environmental Horticulture undergraduate major—in writing instruction throughout all undergraduate curricula [34]. WI and other writing initiatives result in wider integration of writing for the profession and scientific community throughout the Environmental Horticulture curriculum [35,36].

The 3-credit Greenhouse Management course is designed to enhance students' understanding of crop production in controlled environments. This course focuses on building a technical knowledge base and providing opportunities for students to apply this foundational knowledge to practical situations [3]. Since 2009, Hort 3002W emphasizes sustainable horticulture crop production, rather than just greenhouse management [34]. As a core of WI and in-class learning strategies, students focus their integrative learning of sustainability by writing peer-reviewed, 3-phase 'Worldwide Sustainable Horticultural Crop Production Papers' on past, present, and future prospects for sustainability.

Anderson and Flash [34] delineate the mechanistic structure of the peer review, editing, and rewriting processes.

In 2009–2010 spring semesters, a total of 58 undergraduate, MAST (Minnesota Agricultural Student Trainee), graduate (M.S.) and professional (M.Ag.) students enrolled in Hort 3002W (20 students in 2009; 38 in 2010). All students participate in the WI assignment and the peer review process, whereas only papers deemed professionally acceptable are published online.

3.2. Writing Intensive (WI) Assignment

In this assignment, students study the sustainable horticultural crop production practices around the world. The *WI Assignment* consists of three phases (Phases I, II, III), each building on the previous one(s), with different foci. As the semester progresses, students move progressively through the three Phases (I, II, III) of this *WI Assignment,* each building an ever-increasing Review Paper. At the end of Phases I and II, in-class Peer Review Sessions are conducted to enable feedback from colleagues, to foster community building and to provide networking opportunities [34]. The writing format adheres to the established standards for submission of a manuscript to the serial publication, *Horticultural Reviews* (ISSN 0163-7851; John Wiley & Sons [37]. Back issues of *Horticultural Reviews* were available for online reference purposes and a recent hardcopy was placed on reserve. Specifics of writing style, literature citations, presentation of supporting and evidentiary documents (tables, figures, *etc*.) are to follow those for the latest volumes published. Students are instructed to adhere to the universal terminology for uniform understanding by their international audience, including the International Units of measurement for all parameters (temperature in °C, area in hectares [ha], distance [kilometers, km], weight [grams, g; kilograms, kg], and scalar [meters, m; centimeters, cm]. Likewise, when referring to specific plant taxa, scientific nomenclature (binomial nomenclature—genus, species, and authority, e.g., *Dendranthema xgrandiflora* Tzvelv.) is required. Common names, regionalized in their meaning and recognition, can only be used for supplemental reference purposes but not to supplant the scientific name.

This assignment has several objectives to supplement student-learning objectives in the course:

- Exposure to the world community and varying viewpoints on sustainability, as it relates to the production of horticultural crops. By choosing a country of interest, this may enable students to foster contacts within their respective country for future professional contacts and interactions, such as an International Internship, post-graduate research or educational opportunities, future job prospects, *etc*.
- Exposé of the historical and current horticultural practices that are completely sustainable or that contain sustainable elements.
- Create an assemblage of sustainability definitions (covering the range of terminology from ‘green’, ‘sustainable’, to ‘organic’), learn about their derivations, modifications through time, enforcements, and means of implementation.
- Discover the challenges (opportunities), rewards (profitability), cost-effectiveness, and frustrations (lack of standards, legislative challenges, enforcement, *etc*.) connected with modern-day implementation of various sustainability practices identified in each country of study.

- Learn or identify where the opportunities are for increasing sustainable production.
- Formulate research questions that need to be answered before specific sustainable production practices can be implemented.
- Design a horticultural controlled-environment production facility (greenhouse, low tunnel, high tunnel) for each study country with the specific sustainability components, which can be plausibly and economically implemented for a crop(s) of choice.
- Identify specific sustainability practices for horticultural crop production that may be implemented in U.S. production.
- Determine a suite of sustainability practices that could be used in the U.S. (across northern and southern latitudinal, coastal differences) for each commodity group and production environment.

3.3. Phase I, WI Assignment

After choosing their respective country for the WI Assignment, students attend an in-lab session at the University of Minnesota Magrath Library to learn about search engines, use of RefWorks for citations, and possible sources for background and statistics about their chosen country. Since their previous searching experience may not have had an international focus, exercises include general indexes such as Google Scholar as well as more specialized tools like Agris, from the United Nations Food and Agriculture Organization. Government documents and other exceptional literature may contain much of the needed information, so locating country-specific material of that type is part of the session.

All writing for Phases I-III of this *Writing Intensive Assignment* require appropriate supporting evidence (tables, figures) and literature citations. Requirements include writing to specifications using Microsoft Word and saved as a document file (.doc or .docx). For ease in reading and editing, the entire papers are double-spaced with 1” margins, and 12 pt. Times New Roman font.

Phase I of this *Writing Intensive Assignment* has several goals to accomplish:

Goal 1. Choose The Country for Your Research. First, select a country for study. This will create the historical and modern-day geographical, socio-political, economic, and commodity- and crop-specific production opportunity framework for the paper. This framework will have to be researched and summarized in written form as an exposé to build the setting with all aspects inherent within your chosen country.

<u>The study country selection process</u>. Each student selects three countries as possible choices for study, in case a colleague has selected the same country. Choosing countries for this assignment occurs during the laboratory period in the second week of class; students must come to lab with a prioritized list of three countries. The U.S. could not be chosen since this country serves as an example throughout the lectures and laboratories this semester to help guide in formulation of each paper. In 2010, students were referred to the University of Minnesota Magrath Library’s Digital Conservancy website for previously published papers from this class [26]. All countries (13) for which a paper had been written and posted onto this website in 2009 could not be chosen for 2010.

The complete listing of 192 world countries, from Afghanistan to Zimbabwe, is available at the United Nations website [38]. Students are warned that the choice of a small country with limited production would not make this assignment any easier. In fact, it could make it more difficult to pursue any potential informational sources. Also, language challenges that might arise should be considered. While most countries publish and converse in one or more languages—which may include English—students might want to prioritize their choices in which English may be the primary, secondary, or tertiary language. Usually all scientific publications from a country will at least have an English summary if the manuscript is not in an English journal. Likewise, the popular press, governmental/agency, or extension publications may have English editions available.

A lottery system (during the second week's laboratory period) is used to determine student order in selecting their country to research to avoid more than one student studying the same country. Everyone's name is drawn from a production container by an objective party (either the T.A. or Instructor) to determine the order in which each student may choose their study country. The first person's name drawn has the first choice and so forth until all students have their choices determined.

Once the country choice has been determined, students began writing their paper with an informative description of the country and why this was their choice. A 1–3 page description of the salient features of the country, its location (hemisphere, continent/island, latitude, altitude, *etc.*), topography, ecosystems, environments, population and demographics, horticultural crops produced, and other important facts has to be presented along with any supporting documentation.

Goal 2. Definition of 'Sustainability'. Second, students were required to research and identify one or more definitions of 'sustainability' (covering the range of terminology from 'green', 'sustainable', to 'organic') in their study country. This occurs after students each write their own definition of 'sustainability' and following a lecture presentation, discussion of the definition of sustainability [39] with presentation of established U.S. definitions from the 1990 Farm Bill [40], the President's Council on Sustainable Development [41] which established the USDA Proposed Standards for Organic Food Production, the USDA Sustainable Agriculture Research & Education (SARE) program, and the US Food Quality Protection Act. Additional definitions are derived from the National Agricultural Library [42], the Leonardo Academy Sustainability Experts [43], and other sources [44,45]. Sustainability definitions may be clearly defined by a governmental agency and adopted countrywide, may be more obscure (only embraced by a select grower organization) or, perhaps, not even yet clarified. It is more likely that several definitions may exist from several organizations or spokespersons. When this is the case, students present all of these in their writing of this section. If no definition exists to the best of their knowledge, then this is stated and an appropriate definition is formulated (which could change and be edited, as appropriate, from Phase I through Phase III). Students are also directed to the United Nations organization devoted to sustainability,and the Dept. of Economic and Social Affairs, Division of Sustainable Development [46], which may offer substantive help in finding definitions or links to a country's agencies. For the definition(s) of sustainability in each country of study, students discuss the derivation(s) of the definition, any historical modifications, advantages (clarity, concise description, ability for the workable definition to be readily understood and implemented), disadvantages (such as vagueness), potential limitations, means of implementation, enforcements, or any other inherent factors important for this assignment.

Goal 3. Identify Historical Production Practices. Third, students specify the historical horticultural practices that are used for horticultural crop production as far back in time as they could find written records, delineating the pertinent information for each practice as necessary to highlight important aspects. Lengthy dissertations on each practice are to be avoided. Rather, students distill each practice in a single paragraph, along with supporting illustrations, as appropriate. Particular attention is devoted to unique crops, how cropping systems evolved, the use of controlled environment structures (shade houses, low tunnels, high tunnels, greenhouses, bioreactors), location of production sites within the country, transportation accessibility, and post-harvest systems and infrastructures. As each aspect is examined, students note exactly how each production procedure or growing structure is built, components used, all inputs required to grow crops (the five factors of plant growth), and where the harvestable units are shipped. This is facilitated by asking the question, "Are these components or factors 'sustainable' according to the country's definition? Students identify which historical practices or parts thereof are 'sustainable' and discuss their pertinence to their definition described in Goal 2.

Goal 4. Current Production Statistics. In this goal, the students 'set the stage' for current production information to gauge their country's productivity and its potential within the context of a sustainable framework. Horticultural production statistics include overall crop values (in the local currency and US $), ranking within the country's gross domestic product (GDP) output, commodities produced (fruit, nut, nursery, floriculture, turf, vegetable, mushroom) along with their ranked value, commodity-specific categories (e.g., floricultural—cut flowers, cut foliage, potted flowering plants, potted foliage plants, bedding plants, herbaceous perennials; seed *vs.* vegetative) and/or crops (specific listings, e.g., lilies, asparagus fern, chrysanthemums), commodity or crop area (ha) in production (for all possible production types—field, greenhouses, shade houses, low tunnels, high tunnels), number of commercial growers, production locations, and any other pertinent statistical information available. These statistics are summarized in illustrative ways with figures—bar graphs, pie charts—and/or tables. Students engage in an in-lab plagiarism exercise to ensure that text, tables or figures are not downloaded directly. As a double-check in the process, papers from each Phase are submitted to the University of Minnesota's online plagiarism check. Phase I papers are submitted in electronic form by uploading the document onto the class website. A Phase I grading rubric serves as a guideline during the writing process, to ensure that students are not missing any goals and objectives within this phase. Following submission, all papers are peer reviewed by two fellow student colleagues, as well as edited and graded by the course Instructor and Teaching Assistant [34].

3.4. Phase II, WI Assignment

This portion of the writing assignment continues to build on the peer-reviewed and edited written framework of Phase I. Phase II is incorporated into the Phase I portion, to make a seamless writing endeavor. The first assignment in Phase II is to edit and rewrite (revise) the Phase I portion of the *Writing Intensive Assignment,* based on the peer reviews and graded (instructor, TA) comments. Students expand, as necessary, upon the ideas gained from the Peer Review Process [34], fixing any incorrect information (including omitted information), improving the written portions appropriately, and expanding on the writing sections, as indicated in their reviews. Students address any suggestions that they did not agree with in a Revision Memorandum [34]. In class Memoranda formats are presented to use in this portion of the assignment. Students are to submit their 1–2 page Revision Memoranda along with Phase II for the next Peer Review Panel as noted in the course syllabus.

Goal 5. Current Production Practices. For this goal, students delineate the current production practices and statistics for their country. Current horticultural production practices are covered by writing about the current state-of-the-art production for all of the horticultural crops being produced. Current horticultural practices, while easier to find, may be numerous such that a student may need to wisely choose terms for use in search engines. We review basic search terms that can be used to refine the specific subject in their searches. Students consider questions such as: “What is the state-of-the-art for greenhouse production of all crops?” “What are the current trends in production?” and “Have new procedures been recently incorporated?” Is new equipment being trialed?” For production in controlled environments (greenhouses, low tunnels, high tunnels, shade houses), students organize their discussion around the important factors pertinent to the environment. For instance, with greenhouse production they might categorize discussion into paragraphs covering glazing materials, structural framework, foundations, benches or support systems, lighting, heating, cooling, computerization, irrigation, fertilization, harvest, or automation. As each practice is covered, students identify whether or not each method—or portion thereof—was ‘sustainable’. If practices are completely sustainable, students note these. Examples of questions students answer include: “What is the source material used for greenhouse glazing?” (Example answer: The ancient Romans used mica, which, while sustainable, was only partially translucent.); “Is the use of fossil fuel based glazing compounds (fiberglass reinforced polycarbonate, polycarbonate, Exolite, or polyethylene) sustainable when building greenhouses, low tunnels or high tunnels? Why or why not?”

Goal 6. Integration of Historical and Current Production Practices; Ranked Strategies. After students integrate the historical (Goal 3) and current (Goal 5) production practices for their study country, they compare and contrast these practices over time. In this goal, students are not to reiterate what they have already written, but rather synthesize the practices into commonalities and delineate progress or regression regarding sustainable production. To accomplish this, students are encouraged to create tables or flowcharts that illustrate the trends over time as they discuss these. Illustrations are to be organized in a meaningful way (synthesized) for ease of illustration and understanding. One possibility is to formulate their discussions around the type of controlled production environments, subsequently subdivided by commodities and then by crops, highlighting the sustainable elements when they appeared. Next, students create a strategic ranking of historical and current sustainable practices for production environments that could be used for future production of each important commodity and crop types. The ranking strategy process is discussed in class noting that, while students illustrate many potential sustainable practices, it may not be feasible or economically possible to implement some of these options. Based on their knowledge of the country’s resources and potential, each student is to determine what is appropriate within the contextual framework of their study country. Students need to explain their reasoning for the ranking. One suggestion is to select the most economically important crops (using the statistical information in Goal 4) that could be grown with the highest ranked sustainable practices to test their future strategies in Phase III. These would have the greatest economic impact and serve as test models for other crops in the future once some of the challenges were overcome. Where possible, students choose the top 1–2 crops in more than one commodity group for widespread benefit and research potential. For other potential ideas, students consult the United Nations sustainable development strategic initiative for the 2009 conference on the UN National Sustainable Development Strategies [47]. Phase II papers are again submitted on a specific date in electronic format (in accordance with the Phase II Grading

Rubric, data not shown) by uploading each onto the class website. Subsequently, online peer reviews are conducted and the Instructor and Teaching Assistant also edit and grade each paper [34].

3.5. Phase III, WI Assignment

This final phase is designed to be the capstone effort in this assignment where students use their critical thinking and processing skills to build future sustainable production practices in their country. The process built on their vision by identifying the research gaps, potential rewards and frustrations with implementing their country's Sustainable Development Strategy.

First, students edit, revise and rewrite any sections of Phase II that their reviewers indicate for improvement. The Sustainable Development Strategy may require further iteration based on their proposed rankings in Goal 6. There may be sections that are unclear to their reviewers or a student's ranking process perhaps did not seem rational to the peer reviewers. As with Phase II, students again write a Revision Memorandum to their peer reviewers and Instructor/TA, specifying what they have changed to clarify their writing or those things that they felt do not need to be implemented and why. The Revision Memorandum is submitted along with their final, complete paper at the end of Phase III.

Goal 7. Finalized Sustainable Development Strategy. After the students write, edit, and rewrite a thorough discourse on the history and current production practices in light of their country's definition of sustainability, followed by a ranking of these for specific commodities and crops they are then ready for the critical task of determining future directions. Based on their revised set of commodity- and crop-specific rankings for production environments (Goal 6), these now need to be developed into a Sustainable Development Strategy. Here is the student's opportunity to dissect the challenges (opportunities), rewards (profitability), cost-effectiveness, and frustrations (lack of standards, legislative challenges, enforcement, *etc*.) connected with modern-day implementation of the various sustainability practices identified. Students re-examine their strategic rankings of historical and sustainable practices and proceed with a step-wise approach from the perspective of what would need to happen in order for each protocol or procedure to be implemented by asking questions such as: "What critical gaps in our understanding may be missing?", "What research needs to be accomplished to fill these critical gaps?", "How might these gaps in our understanding be tested?", "What are the energy resources available to accomplish development of alternative heating systems (wind, solar, geothermal)?", and "Which resource(s) is in abundant supply with developed technologies for use in implementing these alternative(s)?" These questions provide the commodity- and crop-specific directions required for future implementation in order to formulate research questions that need to be answered before a specific sustainable production practice can be commenced. In writing their Sustainable Development Strategy, students need to address the advantages and disadvantages of the proposals to inform their international readership about their strategic thinking process.

Goal 8. Design A Future Sustainable, Controlled-Environment Production Facility. While each student's Sustainable Development Strategy includes many possibilities for future research and development prior to actual implementation, time and money may not allow for each of these to be tested in the near future. Based on their rankings, students choose the best and potentially the most successful commodity- or crop-specific production idea for designing a future sustainable, controlled-environment test production facility (greenhouse, low tunnel, high tunnel) in their country, justifying their choice such that future critics will have a high likelihood of agreement.

Students need to choose a specific location in their country to build this test facility that integrates the resources available, location (latitude, elevation, coastal or inland effects, *etc.*), and proximity to markets or shipping facilities. Designing this test facility encompasses the feasibility of researching each sustainable component for the specified crops. Students are directed to explain how their research structure would be built, including all necessary structural components and equipment. They also include the sizes of each growing range, section or compartment and the treatments that will be tested. Each proposes a series of experiments to test the effectiveness of each treatment with each crop over time (seasons and years) and create production schedules for each crop and procedure being tested. Students need to explain how they create these as well as how they will accommodate unforeseen problems that may arise during the future test phases while additionally informing their readers how many production cycles and years worth of testing were envisioned to adequately test the sustainable components.

Phase III is submitted electronically by uploading each final paper onto the class website. These are graded and edited for final quality by the Instructor and Teaching Assistant, according to the Phase III rubric (data not shown). Papers with a passing grade (≥70%) are subsequently published online. The last two goals (Phase III) provide plant breeders with potential breeding objectives for country-specific cultivar development within a sustainable production framework. Completed papers are web-published for global availability to enable each country's researchers and policy makers to access sustainable ideas for future development.

3.6. Online Publishing

Papers that are determined by the instructor to be professionally acceptable are passed on to the staff at the University of Minnesota Libraries and uploaded into the University Digital Conservancy [48], the University's online repository and archive. Thus, the full text of each paper, in PDF format, is available to anyone with Internet access.

There are several advantages of including the papers in a site such as the Conservancy, instead of housing them on a personal or departmental Web site. Google and other search engines give very high rankings to items in trusted archives such as the Conservancy, especially those housed at educational institutions. The papers will not disappear from the Web if there are the inevitable changes in maintenance or oversight of personal or departmental Web installations. Statistics on downloads are readily available and, should preferences for formats change in the future, the papers will automatically be migrated. Each paper is assigned a permanent URL (PURL) and students will be able to point potential employers or graduate school admissions committees to a sanctioned University of Minnesota site that contains their work.

4. Conclusions

Given the high number of user downloads for published papers (>3900), undergraduate writing can stimulate interest in sustainable crop production. A future need is to identify the source country of each download to determine whether this is impacting the studied country. The long-term impacts of this writing initiative are unknown for their impact on sustainable horticulture policy development, shifts in country-based production trends, and research-driven sustainability. However, the potential to evoke change is tremendous. Integrating undergraduate student education with the potential for country-specific R&D on sustainable horticulture production, as well as establishing students as published authors and experts in their country of study is a new component in horticultural production education. Within this course, this WI assignment provides students with the opportunity to integrate and apply sustainable production information in ways meant to refine their understanding. The assignment focuses student's awareness and deepens their understanding of sustainability production complexities around the globe. The potential plant breeding contributions to future sustainability research for each of the strategic crops cover a wide range of breeding objectives, covering the range of cultivar improvement or adaptation to sustainable low/high tunnel and/or greenhouse conditions (the highest proportion) to heat/drought/cold stress tolerance, adaptation to hydroponics, desalinization, and alternative nutrient sources, or soilless media (Table 1). Improved consumer acceptance of developed cultivars, based on sensory evaluations, is also an important follow-up to cultivar improvement. As Anderson *et al*. have reported [18], sensory evaluations are complicated breeding objectives and require cultivar-specific testing to evoke consumer satisfaction (appearance, taste, texture, purchasing) while balancing productivity and cost for growers. Linking these breeding objectives with all identified crops, but particularly the high ranking ones, infers that both public and private sector tomato, cucumber, rose, orchid, pepper, and coffee breeders should join forces to prioritize breeding objectives and maximize potential breeding gains for sustainable world-wide production.

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