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SUSCEPTIBILITY OF SOME VEGETABLE SPECIES TO FEEDING OF *CEPAEA HORTENSIS* (MÜLLER) AND *ARION RUFUS* (LINNAEUS)

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Abstract: Vegetables in addition to arable crops and ornamentals are also at high risk from slug and snail attack at all growth stages. The no-choice tests were conducted under laboratory conditions to assess the harmfulness of the slug *Arion rufus* (Linnaeus) and the snail *Cepaea hortensis* (Müller) to young vegetable plants. Ten species representing leaf and root vegetables, allium, brassica, cucurbit and edible pulse plants were chosen to compare their susceptibilities to feeding of these pests (agrotechnical classification – Polish National List of Varieties of Agricultural and Vegetable Plants 2005). The evaluation of the growth of the tested vegetables included a percentage of the damaged plant area and changes in aboveground plant mass. The trend toward increase of mass was defined by the means of regression analysis. Losses of aboveground plant mass resulting from pest feeding and plant growth restraint caused by the slug or the snail damage were assessed. Variance analysis of the general linear model and orthogonal contrasts were calculated to compare the vegetable groups included in the research. The highest losses of aboveground plant mass, by both pest species *A. rufus* and *C. hortensis*, were on common bean plants and the smallest on plants of leaf vegetables (lettuce, dill), brassica plants (cauliflower, white cabbage) and allium plants (garden onion).

Key words: slug, *A. rufus*, snail, *C. hortensis*, vegetables, no-choice tests, incomplete block design, orthogonal contrasts

INTRODUCTION

In the recent years increased damages on vegetable crops by both slugs and snails are common in Europe (Kozłowski 1999, 2003, 2005; Port and Ester 2002). *Deroceras reticulatum* (O.F. Müller, 1774) is the most widely distributed slug among the number of slug species occurring in vegetable crops. On other crops different slug species may dominate such as *Arion rufus* (Linnaeus, 1758) from family *Arionidae* and *Cepaea hortensis* (O.F. Müller, 1774) from family *Helicidae*. These species appear occasionally in large numbers and may cause significant damage on horticultural crops. The injuries resulting from the slug and the snail feeding on germinating young shoots, seedlings and all parts of mature plants and moreover remaining of mucus trails and feces affect the yield size and devalue the harvest quality below required standards. Thus the plant products might be either rejected from sale or reduced in value. *A. rufus* is slug that can grow up to 15 cm in length. It occurs commonly in the eastern regions of Poland and infrequently in other areas where its distribution is often "patchy" (Wiktor 2004). It can be found mostly in woodlands and thickets however, field ridges and home gardens are also the places of its often appearance. *C. hortensis* is a snail with a shell size of 10–17 mm x 14–20 mm and occurs in similar habitats. Both species show high potential of sitotropism, they occur abundantly and graze intensively on vegetable crops in Poland (Wiktor 2004).

The laboratory tests were conducted to compare susceptibility of selected vegetables to feeding of *C. hortensis* and *A. rufus*. The presented results show the size of mass loss of tested plant species resulting from the slug and the snail damages.

MATERIALS AND METHODS

Assessment of damage caused by *A. rufus* and *C. hortensis* to the chosen vegetable species was based on the no-choice tests. The slugs and the snails were collected from the fields few weeks prior to the beginning of the experiments and reared in the separate containers. Fresh food (wheat bran, oats, cabbage leaves, carrot roots, powder milk and calcium carbonate) was replaced three times per week. The slugs and the snails starved for 48 hours prior to the start of the tests. The initial weight of *A. rufus* was on average 2.16 g and the mean size of *C. hortensis* shell 18.85 mm.

The no-choice tests were performed on 10 vegetable species chosen from the leaf vegetables (lettuce; cv. Michalina Tor and dill; cv. Szmaragd), the brassica plants (cauliflower; cv. Rober and white cabbage; cv. Amager Pol), the root vegetables (red beet; cv. Czerwona Kula Noe, carrot; cv. Amsterdamska and radish; cv. Rowa), the allium plant (onion; cv. Wolska), the edible pulse plants (common bean; cv. Zlota Saxa) and the cucurbit plants (cucumber; cv. Parys F1). All plants were at the growth stage of 2–5 leaves. Ten seeds of each plant species were sawn into the plastic containers of size 26 cm x 26 cm x 14 cm equipped with a ventilation system. Each container was filled in 1/3 of its size with soil. To assess aboveground plant mass the experiments consisted of an excluded control. In three containers (size 80 cm x 40 cm x 20 cm) 50 seeds of each plant species were sawn, 10 seeds in one row. When plants reached the growth stage of 2–5 leaves and the height of 6–10 cm either 1 starving slug or 1 starving snail was placed in the container.

The no-choice tests were carried out in the growth chamber at the daily temperature of 17°C, night 14°C, RH 90% ±3% and day length 12 h. The evaluations of damage caused by the examined pests and weight of aboveground plant mass were performed 2, 5, 8 and 12 days after the beginning of experiments. Due to a wide range in the growth rate of the tested vegetables, the tests were conducted for both, the slug and the snail at two different times (blocks) and each time the tests included the cabbage plants. The scheme of the arrangement of ten studied treatments in the blocks for both experiments was the same. The incomplete block design was applied (Elandt 1964). The white cabbage plants were repeated in 20 replications (containers) and the remaining plant species in 10 replications.

Evaluation of plant mass consumed by the pests was performed using a 5-degree scale (where 0% equaled no losses and next 25%, 50%, 75% and 100% of consumed mass) on all 10 plants of individual species, each plant was assessed separately. Five randomly selected plants of each vegetable species growing in the control containers were checked for the aboveground mass weight at the chosen days.

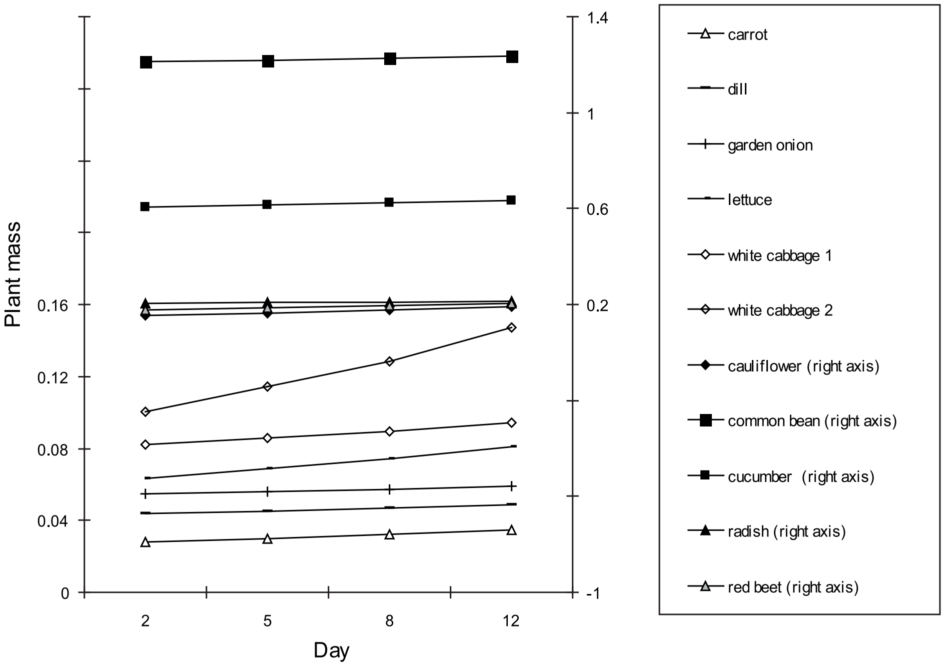
Mean percentage of plant damage for each experimental unit and mean weight of aboveground plant mass for each excluded control unit were calculated. Based on the mean weight of aboveground plant mass the trend toward mass increase was described using the regression analysis. Losses of aboveground plant mass caused by feeding either of the slug or the snail were estimated (consumption plus growth suppression resulting from the pest feeding). For each experimental unit the value of mass loss was estimated by calculating the product of mean percentage of damage and evaluated value of aboveground plant mass. The obtained data were submitted to the statistical analysis for each species and time of observations separately. The variance analysis of the general linear model was applied (Searle 1971; Trętowski and Wójcik 1988). The orthogonal contrasts were estimated for the groups of tested vegetables that were classified according to the agrotechnical classification. The F procedure was used and the p-value was calculated.

RESULTS AND DISCUSSION

To compare the size of mass loss of chosen vegetable groups the trend toward the aboveground mass increase and the adjusted means of mass loss were evaluated (Fig. 1 and Table 1, respectively).

Table 1. Adjusted means (due to non-orthogonal experimental design) of mass loss of tested vegetable plants caused by the *C. hortensis* and *A. rufus* feeding

Classification of plants	Species	*C. hortensis*				*A. rufus*			
		2 days	5 days	8 days	12 days	2 days	5 days	8 days	12 days
Allium	garden onion	0.0113	0.0306	0.0708	0.0865	0.0266	0.0272	0.0383	0.0567
Cucurbits	cucumber	0.0514	0.1790	0.3754	0.7036	0.0475	0.1002	0.1824	0.3155
Brassicas	cauliflower	0.0212	0.1332	0.4404	0.8608	0.1364	0.1822	0.2096	0.2283
	white cabbage	0.0083	0.0239	0.0746	0.2209	0.0495	0.0859	0.1369	0.1986
Root vegetables	red beet	0.0546	0.1257	0.2872	0.7630	0.0752	0.1279	0.1872	0.2662
	radish	0.1232	0.3370	0.4895	0.6784	0.0134	0.0407	0.0929	0.1715
	carrot	0.0209	0.0726	0.1255	0.1169	0.0222	0.0241	0.0341	0.0440
Leaf vegetables	lettuce	0.0000	0.0000	0.0025	0.1358	0.0181	0.0347	0.0580	0.0549
	dill	0.0000	0.0000	0.0058	0.1303	0.0000	0.0005	0.0120	0.0094
Edible pulses	common bean	1.0066	1.2598	1.5948	3.8620	0.3279	0.5171	0.6306	0.7997



white cabbage 1 – trend based on the observations from the block 1
white cabbage 2 – trend based on the observations from the block 2

Fig. 1. Trend toward changes of aboveground plant mass of examined vegetable species

Within 2 and 5 days of *C. hortensis* feeding there was no damage recorded on the dill and the lettuce plants. Also *A. rufus* did not injure the dill plants until the 5th day. The highest mass losses were registered on the common bean plants from the beginning to the end of the tests.

Nine orthogonal contrasts were defined for the plants representing the leaf and root vegetables, allium, brassica, cucurbit and edible pulse plants (Table 2). The contrast c_1 compared the leaf vegetables and brassica plants with the species from root vegetables and alliums, cucurbit, edible pulse plants; c_2 compared the plants from the leaf vegetables with the brassicas, c_3 compared the been plants with the root vegetables and the allium plant and the cucurbits, c_4 compared the cucurbit plants with the root vegetables and the allium plants, c_5 compared the allium plants with the root vegetables, c_6 was defined for the comparison of the root vegetables within the group i.e. carrot with red beet and radish, c_7 compared red beet with radish, c_8 the leaf vegetables within the group; lettuce with dill, and c_9 compared cauliflower with white cabbage.

For *C. hortensis* the high significant differences ($p < 0.001$) were found for the comparison of the common bean plants with the root vegetables and the allium plant and the cucurbit plants and also for the contrast comparing the species representing the leaf vegetables and the brassica plants with the species from root vegetables and allium, cucurbit, edible pulse plants (Table 3). These differences were registered after 2 days of the snail feeding and after 5, 8 and 12 days as well. After eight days of the snail grazing the significant differences were found for the contrast comparing cauliflower with white cabbage ($p = 0.008$) and the species from the leaf vegetable group compared with the brassica plants (p = 0.016). Twelve days after the snail eating the high significant differences were found within the group of root vegetables i.e. the comparison of the carrot species with the red beet and radish plants (p = 0.002) and for the onion compared with the root vegetables (p = 0.019). No differences were identified for the cucumber plants compared with the root vegetables and the onion and also for the red beet plants compared with the radish and for the comparison the lettuce with the dill.

Table 2. Indices of orthogonal contrasts for the comparison of tested vegetable species classified according to Agrotechnical Classification

Contrast	Allium	Cucurbits	Brassicas		Root vegetables			Leaf vegetables		Edible pulses
	garden onion	cucumber	cauli- flower	white cabbage	red beet	radish	carrot	lettuce	dill	common bean
c_1	–4	–4	6	3	–4	–4	–4	6	6	–4
c_2	0	0	–2	–1	0	0	0	2	2	0
c_3	–1	–1	0	0	–1	–1	–1	0	0	5
c_4	–1	4	0	0	–1	–1	–1	0	0	0
c_5	3	0	0	0	–1	–1	–1	0	0	0
c_6	0	0	0	0	–1	–1	2	0	0	0
c_7	0	0	0	0	–1	1	0	0	0	0
c_8	0	0	0	0	0	0	0	1	–1	0
c_9	0	0	2	–1	0	0	0	0	0	0

As far the *A. rufus* is considered and the damaged caused by this species, 2, 5, 8 and 12 days after the slug feeding the high significant differences ($p < 0.001$) were found for the been plants compared with the root vegetables, allium and cucurbit plants, for the leaf vegetables compared with brassica plants and for the group comparison of the leaf vegetables and brassica plants with the root vegetables, allium and cucurbit plants (Table 4). Also the high significant differences were observed within the brassica group between cauliflower and white cabbage. Eight days after the slug feeding the compared groups differed significantly excluding the c_8 contrast. Throughout the entire course of the experiment there were no differences between the lettuce and the dill plants.

Based on the results it was concluded that *A. rufus* and *C. hortensis* showed strong preference to the common bean plants (cv. Zlota Saxa) among all species included in the tests. The observations revealed the greatest loss of aboveground plant mass of common bean compared to other vegetables. In general, plants of most vegetable species are more damaged by the snails and the slugs at the mature growth stages (Port and Ester 2002; Kozłowski 1999, 2005). Fully developed foliage provides sufficient food source, humidity and light conditions that create the environment favoring the feeding activities and in result the pest development. The plants of common beans are damaged the most at the seedling growth stage and when first young leaves are fully unfold (Port and Ester 2002; Kozłowski 2005). The results presented in this paper prove high palatability of the common bean plants to the snails and the slugs at the early growth stage.

Table 3. Values of the orthogonal contrasts for *C. hortensis* and the results of statistical analysis (F_{cal} – calculated values of F, p – value)

Contrast	2 days			5 days			8 days			12 days		
	value	F_{cal}	p	value	F_{cal}	p	value	F_{cal}	p	value	F_{cal}	p
c_1	1.0793	21.1	< 0.001	2.2560	32.3	< 0.001	3.3572	27.7	< 0.001	12.6463	51.4	< 0.001
c_2	0.0025	0.1	0.826	0.0705	1.0	0.31	0.7334	6.1	0.016	1.9005	7.7	0.007
c_3	7.5896	148.1	< 0.001	10.2823	147.2	< 0.001	14.6330	120.8	< 0.001	95.8971	389.8	< 0.001
c_4	0.0000	0.0	0.989	0.0113	0.2	0.689	0.1397	1.2	0.286	0.6839	2.8	0.099
c_5	0.0227	0.4	0.508	0.1640	2.4	0.129	0.3965	3.3	0.073	1.4057	5.7	0.019
c_6	0.0308	0.6	0.440	0.1679	2.4	0.124	0.4607	3.8	0.054	2.4304	9.9	0.002
c_7	0.0236	0.5	0.499	0.2232	3.2	0.077	0.2045	1.7	0.197	0.0358	0.2	0.704
c_8	0.0000	0.0	1.000	0.0000	0.0	1.000	0.0001	0.0	0.983	0.0002	0.0	0.980
c_9	0.0011	0.0	0.884	0.0796	1.2	0.288	0.8918	7.4	0.008	2.7296	11.1	0.001

Table 4. Values of the orthogonal contrasts for *A. rufus* and the results of analysis (F_{cal} – calculated values of F, p – value)

Contrast	2 days			5 days			8 days			12 days		
	value	F_{cal}	p	value	F_{cal}	p	value	F_{cal}	p	value	F_{cal}	p
c_1	0.0308	9.1	0.003	0.1052	24.6	< 0.001	0.2108	54.3	< 0.001	0.6055	89.2	< 0.001
c_2	0.0804	23.6	< 0.001	0.1550	36.3	< 0.001	0.2184	56.3	< 0.001	0.3756	55.3	< 0.001
c_3	0.7051	206.8	< 0.001	1.7110	400.7	< 0.001	2.2851	588.7	< 0.001	3.2966	485.8	< 0.001
c_4	0.0014	0.4	0.526	0.0163	3.8	0.053	0.0711	18.3	< 0.001	0.2618	38.6	< 0.001
c_5	0.0008	0.2	0.629	0.0102	2.4	0.125	0.0331	8.5	0.004	0.0809	11.9	0.001
c_6	0.0033	1.0	0.330	0.0241	5.7	0.019	0.0748	19.3	< 0.001	0.2038	30.0	< 0.001
c_7	0.0191	5.6	0.020	0.0380	8.9	0.004	0.0445	11.5	0.001	0.0448	6.6	0.012
c_8	0.0016	0.5	0.490	0.0059	1.4	0.244	0.0105	2.7	0.102	0.0104	1.5	0.220
c_9	0.0504	14.8	< 0.001	0.0618	14.5	< 0.001	0.0352	9.1	0.003	0.0059	0.9	0.354

The plant species slightly damaged by *A. rufus* and *C. hortensis* were lettuce, dill (leaf vegetables), cauliflower and white cabbage (brassica plants) and onion (allium plant). In the conducted tests the lowest losses in plant mass were recorded for these vegetable species. All these vegetable species, excluding the onion, are greatly damaged by the slugs under field conditions (Port and Ester 2002; Kozłowski 1999, 2003, 2005). The injuries are mainly observed at mature stages. It is most likely that the registered in the presented tests damages on the leaf vegetables and brassica plants were low due to the early growth stage of the examined plants (2–5 leaves).

CONCLUSIONS

1. Both examined pests: *A. rufus* and *C. hortensis* caused the greatest loss of aboveground plant mass on the common bean plants.
2. The species representing the leaf vegetables, brassica and allium plants showed the lowest preference to the slug and snail feeding.
3. There observed high significant differences in mass loss caused by the feeding of *A. rufus* and *C. hortensis* comparing the common bean plants and species of the root vegetables, allium and cucurbit plants with the leaf vegetables and brassica plants (contrast c_1) and comparing the root vegetables, allium plant, cucurbit plants with edible pulse plant (contrast c_3).
4. There were no differences between lettuce and dill in the losses of plant mass resulting from *A. rufus* and *C. hortensis* feeding.

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POLISH SUMMARY

PODATNOŚĆ NIEKTÓRYCH GATUNKÓW WARZYW NA ŻEROWANIE *CEPAEA HORTENSIS* (MÜLLER) I *ARION RUFUS* (LINNAEUS)

Obok roślin rolniczych i ozdobnych, warzywa są najczęściej uszkadzane zarówno przez ślimaki nagie jak i skorupkowe. Ślimaki niszczą siewki i sadzonki oraz wszystkie organy dojrzałych roślin oraz zanieczyszczają rośliny śluzem, co prowadzi do obniżenia plonu i zmniejszenia wartości handlowej produktów roślinnych. W celu określenia szkodliwości dwóch gatunków ślimaków: nagiego – ślinika wielkiego (*Arion rufus*) i skorupkowego – ślimaka ogrodowego (*Cepaea hortensis*), w warunkach laboratoryjnych wykonano testy bez wyboru nad uszkodzeniami młodych roślin kilku gatunków warzyw wybranych spośród roślin liściowych (sałata głowiasta i koper), kapustnych (kalafior i kapusta głowiasta), korzeniowych (burak ćwikłowy, marchew jadalna i rzodkiewka), cebulowych (cebula zwyczajna), strączkowych (fasola zwykła) i dyniowatych (ogórek). W przeprowadzonych testach co 3–4 dni określano procent uszkodzonych powierzchni roślin poszczególnych gatunków warzyw, posługując się pięciostopniową skalą uszkodzeń. W doświadczeniu zastosowano kontrolę zerową wyłączoną w celu zaobserwowania zmiany masy nadziemnych części roślin badanych gatunków warzyw.

Wyznaczono dla każdej jednostki eksperymentalnej średni procent uszkodzenia roślin, a dla każdej jednostki eksperymentalnej kontroli zerowej wyznaczono średnią masę części nadziemnych roślin. Na ich podstawie określono trend przyrostu masy za pomocą analizy regresji. Podjęto próbę oszacowania ubytku masy części nadziemnej roślin badanych gatunków spowodowanego żerowaniem ślimaka (konsumpcja plus zahamowanie wzrostu w wyniku uszkodzeń). Obliczono zatem dla każdej jednostki eksperymentalnej wartość ubytku masy jako iloczyn średniego procentu uszkodzeń i oszacowanej z kontroli wartości masy części nadziemnej rośliny. Wartości te dla każdego gatunku ślimaka i w każdym terminie obserwacji osobno poddano analizie statystycznej. Zastosowano analizę wariancji o ogólnym modelu liniowym, ponieważ testy przeprowadzono w układzie o blokach niekompletnych. Wyznaczono kontrasty ortogonalne dla porównywanych grup gatunków roślin sklasyfikowanych według klasyfikacji agrotechnicznej. Zastosowano test F, wyznaczono krytyczny poziom istotności p. Na podstawie przeprowadzonych badań stwierdzono największy ubytek masy części nadziemnej dla roślin fasoli, zarówno dla *A. rufus* jak i *C. hortensis*. Natomiast do roślin, dla których stwierdzono najmniejszy ubytek masy należały rośliny liściowe, kapustne oraz cebulowe.

Review of book of Regnault-Roger C. 2005 – continued from page 214

In chap. 10 "Allelochemicals: tomorrows's herbicides?" (p. 139–155) G. Chiapusio et al. discuss phenomenon of allelopathy, allelochemicals, hydroxamic acids and stress that allelopathy meets current societal demands of environmentally sound approaches to agriculture.

In chap. 11 "The role of phenols in plant defense mechanisms" (p. 157–171) C. El Modofar and E-.-S. El Boustani indicate that phenolic compounds (polyphenols) represent a large group of secondary metabolites e.g. flavones, chalcones and stilbens that play important role in resistance of plants to infections caused by *Fusarium*, *Verticillium* and *Phytophthora* species.

In chap. 12 "Nematicidal and nematode-resistant plants" (p. 173–224) C. Dijan-Caporalino et al. very broadly discuss economic importance and control methods of plant parasitic nematodes. Of special interest is part referring to: (1) mechanism of plant resistance to nematodes, and (2) use of nematode non-host plants in crop rotations with extensive tables indicating: (A) plant species that are nematicidal after decomposition, (B) principal nematode-resistant plant species undergoing genetic studies.

In chap. 13 "Impact of plant proteins, expressed in transgenic plants, on beneficial insects (parasitoids and pollinators)" (p. 225–244) A. Couty et al. report that no detrimental effect of transgene products was noticed on honeybee (*Apis mellifera*) and on two hymenopterous parasitoids *Aphidius ervi* and *Aphelinus abdominalis* reducing populations of potato aphids: *Myzus persicae* and *Macrosiphum euphorbiae.*

In chap. 14 "Synthesis of odorant reception-suppressing agents, odorant-binding proteins (OBPs) and chemosensory proteins (CSPs): molecular targets for pest management" (p. 245–266) J.-F. Picimbon points out that the control of insect pests could be achieved either be gene knock out or by locking the active sites of the proteins using *Lymantria dispar*, *Manduca sexta* and *Heliothis sexta* as examples.

In chap. 15 "Vegetable oils and monoterpenes in agrochemical formulations" (p. 267–281) C. Gauvrit and F. Cabanne discuss effect of vegetable oils and monoterpens on spray retention increase and on efficacy of clodinafop-propartyl in oat crops.

In chap. 16. "Problems and opportunities for the commercialization of botanical insecticides" (p. 283–291) properties of the major botanical insecticides currently available in the United States are presented in tabulated and descriptive way: pyrethrum, rotenone and neem.

In chap. 17 "Appendix: post-harvest systems and biopesticides in Africa" (p. 293–299) A. I. Glitho provides information on research network concerning plant-derived biopesticides in Africa.

Without any question this book contains a large volume of information on biopesticides of plant origin supported by extensive bibliography on this subject. Absolutely, the book is an outstanding achievement and contains information valuable for crop protection specialists, plant and animal physiologists, entomologists, and environmentalists. Therefore, I strongly recommend this book to all agricultural and natural sciences libraries.

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