Development of an Interdisciplinary Agroecology Major with Input from Surveys of Students, Graduates, and Employers

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Abstract

In 1996 a questionnaire was distributed to Agronomy alumni and employers to evaluate the undergraduate Agronomy major. In response to survey results and environmental impacts of agriculture, an interdisciplinary major was developed by faculty from the departments of Agronomy, Entomology, Horticulture, and Plant Pathology. The new Agroecology major emphasizes cropping systems and pest management with a systems perspective. Core courses are team taught by faculty from more than one department, and are designed to enhance students' communication skills and teamwork. Two internships are required. Five years after the Agroecology major began, a questionnaire was distributed to Agroecology students and graduates to evaluate the major. Students were attracted to the agricultural, ecological, and science-based systems emphasis. They valued hands-on applied agricultural science courses, advanced technical coursework in multiple disciplines, and most described the internships as very educational. Course requirements that were not overly prescriptive allowed for diverse student interests. An administrative and academic paradigm shift was necessary for faculty and administrators from independent departments. Collaboration and administrative leadership was needed to: (1) improve coordination of course curriculum and schedules, (2) inform students about courses, requirements, and new courses, and (3) inform potential employers and students about the Agroecology major.

Introduction

Since the 1970s, scientists and the public have become more aware of the need to understand and address the ecology and environmental consequences of agricultural practices (Carson, 1962; Georghiou, 1986; NRC, 1989; Tilman et al., 2002). The value of considering the scientific, social, and economic aspects of science, agriculture, and engineering, has also been recognized by educators from many disciplines (Barbarick, 1992; Grabau and Graveel, 1995; Barrett and Skelton, 2002; Karsten and O'Connor, 2002). In 1995, Grabau and Graveel summarized how many Land Grant Colleges of Agriculture were broadening their research and education activities to appeal to concerns of a larger group of students and society, rather than lose public and financial support. Examples included addressing the needs of new clientele, including environmental issues in research agendas, and developing new curriculum. To communicate to a larger audience, many Agronomy departments changed their department name to Plant, or Crop and Soil Sciences (Raun et al., 1998), and the name of their undergraduate Soil Science major to Environmental Soil Science (Pierzynski and Thien; 1997).

Barrett and Skelton (2002, p. 335) argued that academic institutions "have failed to promote and establish mechanisms or structures to administer… interdisciplinary fields of study." They suggested an undergraduate degree that would include two years of liberal arts, two years of science and a one year internship. The internship would provide an opportunity for students to learn about the challenges in agroecology that require an interdisciplinary perspective, and both basic and applied science. Cessna (1977) surveyed students in College of Agricultural Sciences at Colorado State University who had completed internships; and the majority of the students described their internships as beneficial because they gained practical knowledge, exposure to professionals, and an opportunity to mature and develop self-confidence.

In 1996, the faculty in the Agronomy Department at Penn State University recognized that enrollment was declining. To identify the strengths and weaknesses of the Agronomy major, a questionnaire was distributed to Agronomy employers and alumni. Survey results were used to help design a new interdisciplinary undergraduate major in Agroecology to better address the agricultural sector needs and student interests, and environmental issues. Five years after the initiation of the Agroecology (AGECO) major, a second questionnaire was distributed to all graduates and enrolled students of the AGECO major to monitor students' experiences, and the successes and weaknesses of the new interdisciplinary major.

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Materials and Methods

1996 questionnaire prior to the new Interdisciplinary major

In 1996, a questionnaire was sent to 198 Turfgrass, Agronomy, and Soil Science graduates of the Pennsylvania State University (PSU) Agronomy Department, and 108 employers of the graduates. Only the Agronomy graduates and employer responses will be reported here. Alumni were asked to rate the required knowledge/skill level for their job responsibilities and the adequacy of their undergraduate training knowledge/skill level on a scale of one to four (where 4= very high, 3= high, 2=average, and 1=low). Employers were also asked to evaluate the knowledge/skill level required of employees. Then, employers were also asked to rate the knowledge/skill level of their entry level alumni employees using the same rating scale. Alumni and employers were also asked about the need and value of an internship during the undergraduate degree.

For alumni, the mean difference for each area of emphasis was calculated by subtracting the ratings for what was required by the profession value from the PSU education value. A positive difference indicated that the Agronomy program provided more than what was required, and a negative difference indicated that the education provided was less than required for the job. The difference between the employers' ratings of the value required to meet the employer's job responsibilities from the observed employees' level of skill was also calculated. Due to low response numbers encountered in both questionnaires, the very high and high ratings were combined and the average and low ratings were combined. A 2x2 contingency chi-square test was conducted on the data for each area of emphasis. A significant chi-square value of 10% or lower indicated that the relationship for the two rating levels was not consistent over the categories.

2002 Questionnaire sent to Agroecology graduates and enrolled students'

In fall of 2002, all alumni of the Agroecology major and students registered in the major were sent a questionnaire that asked them to rank their most important reason (1= most important; 6= least important) for choosing the AGECO major from the following choices:

a) The AGECO major was the most similar to the earlier agronomy major that focused on production agriculture.

b) I'm interested in learning about agriculture and ecology, and how to manage cropping systems with management practices that are environmentally friendly, productive, and profitable.

c) I couldn't find a major in organic agriculture; the AGECO major provides the scientific basis for practicing organic agriculture and was the best substitute.

d) The AGECO degree is a reputable, science-based, systems program that prepares me for a wide variety of job opportunities.

e) I'm considering going to graduate school and the science coursework and wide range of courses is good preparation for graduate school.

f) I am interested in international agriculture work and the AGECO program is good preparation for international agriculture work.

Alumni and students were also asked to rank the educational value of their internship experiences on a scale of one to five (1 = very educational experience that I would recommend to others, 2 = educational that in most cases I would recommend to others, 3=no opinion, 4= not a very good experience, 5= not an educational experience at all that I would tell others to avoid.) Rankings were compared using a multiple comparisons analysis for a nonparametric ranked randomized block with a test is similar to Tukey's procedure for ranked-data in a one-way ANOVA design (Zar; 1996). Comparisons were considered different when $p < 0.05$.

The questionnaire also included open-ended questions that asked: (1) which courses required for the program were of the most educational value to the students and alumni, and (2) how best to inform prospective students about the AGECO major. Graduates of the major were asked to describe their jobs or further studies, and how well the AGECO program prepared them for their activities after graduation. Finally, alumni and enrolled students were asked to provide any other comments. In addition, exit interviews were conducted with students upon graduation from the major.

Results and Discussion

1996 Questionnaire, prior to development of the Interdisciplinary major

The 1996 questionnaire was returned by 35% of all alumni and 29% of them (n=20) were graduates of the Agronomy major. Alumni reported that their education prepared them adequately for their jobs and 94% reported that they were very competitive with professionals who graduated from other institutions. Graduates rated their training in crop management production practices, and basic plant-related sciences including plant selection and identification of plants and weeds as very-high to high.

Alumni recognized a need for more preparation in diagnosing and controlling insects, nematodes, and scouting techniques, as well as pesticide safety, pesticide environmental effects, and operation maintenance and safety of agricultural equipment (Table 1). They also identified the need for more education in oral and written communication,

laboratory and problem solving skills, practical field experience, knowledge of environmental regulations and ethics, business management, and personnel management (Table 1). Most alumni who had not taken an internship for credit indicated that it would have helped them in performing their job.

Employer Responses

Twenty-five percent of the employers returned the questionnaire (n = 27). When compared to employees from other institutions, 44% of employers said that their PSU graduates were better prepared, 56% said they were the same, and none said they weren't as prepared as others. Employers rated PSU graduates as having adequate knowledge in the plant-related sciences (physiology, anatomy, genetics), identifying crops, selecting plant materials and production practices; and operating agricultural equipment. However, employers reported that graduates needed additional preparation in organic soil amendments, pest scouting techniques, and environmental effects of pesticides, plant nutrition, and tillage practices (Table 1).

Employers also reported that graduates were deficient in writing, speaking, problem solving, data collection, and the ability to learn on their own (Table 1). Graduates' skills were not adequate in business management, including financial, time, and personnel management, marketing, and sales. Further, employers responded that graduates lacked awareness of some environmental issues, different cultures and attitudes (Table 1). Nearly all employers reported that the practical experience of an internship would improve the chances that graduates would be hired by their company, and half replied that it was necessary.

Table 1: Summary of alumni and employer responses to questionnaire evaluating knowledge skills required by profession and knowledge skills provided by education (4= very high, 3= high, 2=average, and 1=low)

	Average rating					
1. Communication skills	Education provided by PSU	Knowledge required by profession	Difference (provided minus required)+	Chi-square test of alumni significance level	Difference of employers ratings of observed level - required level	Chi-square test of employers significance level
ability to write clearly and effectively	2.82	3.55	-0.73	0.01	-1.17	0.005
ability to speak clearly and effectively	2.78	3.75	-0.97	0.005	-1.14	0.005
familiarity with computer skills	2.27	3.10	-0.83	0.005	-0.27	ns
2. Business management						
determining costs	1.72	2.90	-1.18	0.005	-0.26	ns
marketing/sales/advertising knowledge	1.49	2.56	-1.07	0.005	-0.75	0.10
personnel management	1.49	3.03	-1.54	0.005	-0.69	0.005
accounting	1.49	2.10	-0.61	0.005	-0.16	ns
financial management	1.54	2.64	-1.10	0.005	-0.82	0.01
3. Personal development						
awareness of different cultural perspectives	2.18	2.51	-0.33	ns	-0.62	0.005
ethical standards	2.38	3.36	-0.98	0.005	-0.46	ns
ability to learn on your own	2.65	3.70	-1.05	0.005	-0.76	0.005
environmental awareness	2.61	3.52	-0.91	0.005	-0.47	0.10
time management	2.40	3.77	-1.37	0.005	-1.15	0.005
data collection and recording	2.85	3.42	-0.57	0.05	-0.57	0.10
4. Miscellaneous						
laboratory skills	2.92	1.85	1.07	0.005	0.12	ns
problem solving skills	2.87	3.49	-0.62	0.005	-1.04	0.005
practical/field experience	2.13	3.85	-1.72	0.005	0.00	ns
5. Basic Plant Sciences						
plant nutrition	2.90	3.17	-0.27	ns	-0.56	0.025
plant anatomical & morphological structure	2.90	2.70	0.20	ns	-0.08	ns
plant genetics	2.25	2.13	0.12	ns	0.06	ns
agronomic crop identification & taxonomy	2.92	2.31	0.61	0.10	-0.09	ns
weed plant identification & taxonomy	3.20	3.36	-0.16	ns	-0.55	0.10
6. Cropping Systems & Agricultural Equipment Table 1 continued						
grain crop selection & production practices	2.65	2.00	0.65	0.05	-0.13	ns
forages & pastures selection & production	2.67	1.95	0.73	0.05	-0.25	ns
organic soil amendments	2.32	2.75	-0.43	ns	-0.43	0.025
tillage practices	2.59	2.31	0.28	ns	-0.35	0.05
equipment operation	1.51	2.66	-1.15	0.005	-0.27	ns
equipment maintenance	1.44	2.53	-1.09	0.005	-0.31	ns
agricultural safety	1.56	2.58	-1.02	0.005	-0.38	ns
7. Pest Diagnosis and Control						
insects	2.42	3.05	-0.63	0.10	-0.59	0.10
weeds	3.13	3.13	0.00	ns	-0.57	0.10
nematodes	1.85	2.44	-0.59	0.025	-0.08	ns
scouting techniques	2.31	3.00	-0.69	0.01	-0.52	0.05
8. Pesticide Use						
pesticide types	2.67	3.10	-0.43	0.10	-0.39	ns
pesticide selection	2.50	3.10	-0.60	0.10	-0.50	ns
pesticide application techniques	2.70	3.03	-0.33	ns	-0.47	ns
Pesticide safety	2.65	3.13	-0.48	0.025	-0.47	ns
Pesticide environmental effects	2.60	3.08	-0.48	0.025	-0.67	0.025
9. Environmental issues						
basic knowledge of ecosystems	2.36	2.68	-0.32	0.10	-0.53	0.10
knowledge of plant and animal habitats	2.26	2.63	-0.37	ns	-0.36	ns
environmental management skills	2.21	2.82	-0.61	0.025	-0.58	0.10
environmental ethics	2.00	3.03	-1.03	0.005	-0.49	ns
knowledge of environmental regulations	1.82	3.29	-1.47	0.005	-0.89	0.005

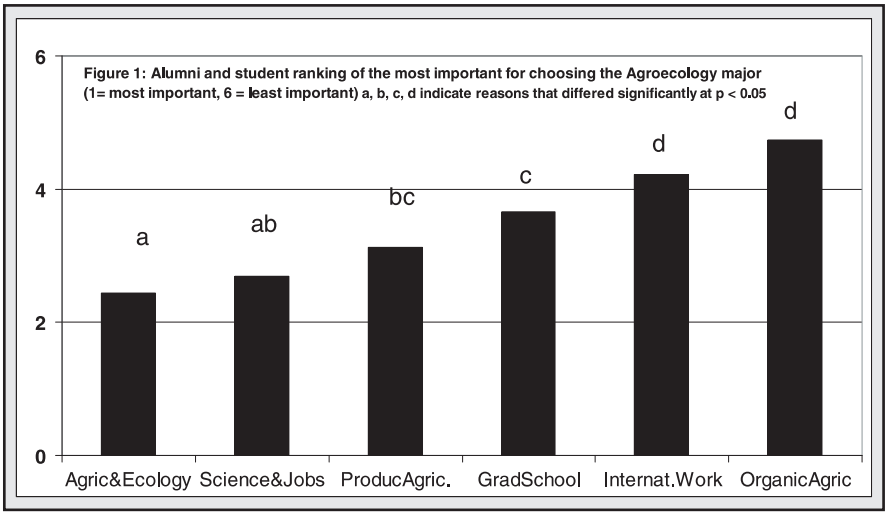
Creation of the Interdisciplinary Agroecosystem Science major

In response to the survey results, declining student numbers, and environmental impacts of intensive agriculture, faculty from the Agronomy, Entomology, Horticulture, and Plant Pathology departments, designed a new interdisciplinary Agroecosystem Science undergraduate major. The program objectives are to provide students with a broad scientific and production-based understanding of agronomic and horticultural cropping systems, and to address the new and evolving needs of the agricultural sector. In addition to the applied agricultural science courses, the major includes rigorous math and science course prerequisites, ethics, business management, and courses that emphasized development of communication skills. Core agroecosystem courses are team taught by faculty from more than one discipline to integrate material into a systems perspective. The core courses emphasize experiential learning, problem solving, learning to work in groups, and developing technical oral and written communication via fieldtrips, guest speakers, case studies, and oral and written reports. A number of educators have documented the educational benefits of these approaches (Fletcher and Branen,1993; Herreid, 1994; Koontz et al, 1995; Marshall et al, 1998; Karsten and O'Connor, 2002). Two internships are also required, one involving farm or field experience and one working for agricultural cooperative extension or a consulting firm, an agribusiness, or a regulatory agency. To prepare students who plan to begin working immediately upon graduation from the major, or students who plan to attend graduate school, two course programs called "options" were created within the major. The Integrated Crop Management option requires more applied science and business courses, while the Plant Science option requires more basic science courses that are usually required for graduate studies (i.e. Inorganic Chemistry, Physics; Table 2).

Oral exit interviews with the first graduates and enrolled students revealed that the long name for the major (Agroecosystem Science) was cumbersome and confusing to many people, including potential students and employers. Therefore, in the summer 2002, the faculty voted to shorten the name of the major to Agroecology; the new name became official in July 2003.

Agroecology graduates and enrolled students' questionnaire

All of the AGECO graduates (n=8) returned the questionnaire, and 18 of the 19 undergraduates who had declared the major and were sent the questionnaire, completed and returned it. Seventy eight percent (14 of 18) of the undergraduate respondents were seniors or juniors. The most important reasons that graduates and students chose the AGECO program were: i) an interest in learning about agriculture and ecology, and how to manage cropping systems with practices that are environmentally friendly, productive and profitable, and ii) it is a reputable, science-based systems program that prepares me for a wide range of job opportunities. The least important reasons were that: v) an interest in international agriculture work and vi) the major provided the best scientific basis for practicing organic agriculture (1= most important; 6= least important; Figure 1).



Agroecology Courses Rated Very Educational

The courses that graduates and enrolled students identified frequently as most educational were listed with similar frequency, and could be categorized in two groups: a) courses that emphasized crop production and pest management, and b) advanced technical science courses. Courses that emphasized crop production, pest management, and courses that emphasized experiential learning were frequently listed. These included three applied crop management and production courses (grain crops, forage crops, and vegetable crops), integrated pest management, and entomology. Graduates and students explained that classes with "hands-on work" and farm visits, a colloquium that featured a series of farmers as guest speakers, and the required internship courses were also most educational. Others have also reported that students preferred and learned well when they had experiential learning opportuni-

ties (Cessna, 1977; Fletcher and Branen, 1993; Koontz et al, 1995; Marshall et al., 1998). Student comments from the survey that illustrate this theme include:

- "Agriculture is not like the liberal arts where you can learn everything from books. You must have a large hands-on component."
- "Hands-on learning (was most educational) - all my plant physiology, ecology, and pest management education became a lot more interesting once I saw the real life significance of it on a farm internship. A class or a cluster that took place on a farm would be awesome."

Advanced technical courses were also listed as very educational with similar frequency. Graduates identified these courses as very important for their current jobs, and for learning specific expertise in agricultural technologies, and management tools. These included Geographic Information Systems (GIS), Nutrient Management, Plant Breeding and Transgenic Crops, Plant Pathology, Soil Chemistry and Fertilizers, Soil Microbial Ecology, and Business courses, including Economics and Marketing.

Internships

All of the graduates had completed two internships, and most of the enrolled students who responded to the questionnaire had completed at least one internship. Student and graduate internships, included working: (1) on a farm (26%), with researchers at Penn State, USDA-ARS, or other research institutions (29%), or (2) working with a private company or crop consultant (37%), or with NRCS (8%). Just under 70% rated the internship experience as very educational and 30% rated the internship as educational. Only one student who worked on his family farm ranked no opinion of the educational experience. None of the respondents rated the internship as not educational.

Agroecology Graduates Job Preparation

When the survey was conducted in autumn 2002, graduates were working in a variety of job positions: one farm manager, two NRCS specialists, one entomology laboratory research assistant, and two farmers (one first time and one returned to the family farm and took an off-farm job working with people with disabilities). One graduate was studying weed ecology in graduate school, and one was studying environmental law in law school. Only one of the eight graduates (13%) stated that without having had farm background, the major had not emphasized enough "practical knowledge" to begin farming alone. One of the student's internships had been field research, and emphasized research rather than learning how to farm.

The other seven graduates stated that the major had prepared them well for their jobs, although two identified specific coursework that was important for their work, but was not required to graduate. One, a graduate student, explained that he lacked an in depth understanding of statistics for graduate research. The other explained:

"…had I not taken certain electives (GIS and the Nutrient Management Certification Course) I might not have been quite so prepared. But overall the AGECO major gave me a solid information base that has allowed me to get this job and succeed."

Graduates who were pleased with the major, explained that the breadth of disciplines and the critical thinking and problem solving that was emphasized in many courses was helpful preparation for their current jobs and graduate work. Graduates' comments from the survey that illustrate this:

- " I have a solid background in the practical aspects of modern farming systems and a basic understanding of the ecological interactions occurring in these systems."
- " The diversity of the course work and the focus on problem solving not just identification, is crucial in my current job."
- "AGESS (Agroecology) emphasized critical thinking, which is the essence of law school. "

Opportunities to Improve the Interdisciplinary Agroecology major

The second questionnaire and exit interviews with students who were graduating revealed both strengths and weaknesses of the program. With the program in its infancy, faculty are identifying and addressing opportunities to strengthen the major. First, in order to provide students with a systems perspective and an in depth understanding of the components of agroecosystems, the major requirements include a wide range of courses from the basic sciences, applied agricultural sciences, and the social sciences. However, students who declare the AGECO major or transfer from a commonwealth campus during or after their sophomore year, have had difficulty completing the required coursework in four years. Early in the program, a few students transferred out of the AGECO into majors with fewer course requirements. Therefore, three years after initiating the program, the faculty reduced the number of required courses, and identified a wider selection of supporting courses. Students in the Plant Science option preparing for graduate school were not required to take as many production agricultural courses as students who selected the Integrated Crop Management option. This enabled more students to complete the requirements for the major and to select courses that matched their specific interests.

Judging from responses to the second questionnaire, reducing the required credits and allowing students to choose from a wider range of courses within disciplines was successful. When asked to

provide additional comments in the survey, graduates and students stated that the freedom to select courses that matched their individual interests within a breadth of disciplines (the agricultural sciences, business, and policy) was a strength of the major.

Administrative structure and cross-departmental communication

Second, developing the interdisciplinary major required an academic and administrative paradigm shift for faculty and administrators who are from independent academic departments. During the exit interviews and in the open-ended comment questions on the survey, students complained that the material in upper level courses was redundant, and that team-taught courses were not well coordinated. Faculty needed to develop team-taught interdisciplinary courses, agree on new cross-disciplinary coursework requirements, and insure that the curriculum of established courses was complementary and offered at different times to enable students to attend all upper level courses within the final two years. Barrett and Skelton (2002, p.334) also discussed the need to address "academic and disciplinary fragmentation", one of the barriers to interdisciplinary science and education.

Exit interviews, students' class feedback comments, and the survey helped faculty recognize the need to identify course curriculum redundancy, eliminate redundant material, and replace it with more advanced material. Faculty are meeting more often to discuss and coordinate courses, and co-instructors in team-taught courses are present for more team-taught classes. To further coordinate course curriculums among courses and within team taught courses, the Dean of Undergraduate Education offered to fund an off-campus faculty retreat, to promote more discussion of course materials and team work.

Third, in the open-ended questions and exit interviews, students stated that they had difficulty learning about new courses and changes in program requirements, and that some faculty advisors had given them different recommendations to resolve their scheduling and requirements. Since the interdisciplinary major is not contained within one department, an administrator or faculty/staff committees are needed to coordinate core course curriculum and schedules, monitor and update the course options list, advise students, and review the program occasionally to insure that it is addressing multiple students' needs and interests. Since required courses are offered by more than 15 different departments, informing students and academic advisors about new and changing courses is an administrative challenge, however, necessary to guide students scheduling courses each semester. Some students recommended that a website with the updated course requirements and optional courses would facilitate communication among faculty and students. Such a website with course requirements and options is being developed.

Educate potential employers and students about the new interdisciplinary major

Finally, in the open-ended survey questions, graduates and students expressed the need to educate more potential employers and students about the major. Faculty also recognize that Agroecology is a relatively young field that is new to many science teachers, advisors and potential employers. Consequently, steps are being taken by a faculty committee and staff to develop: (1) a new educational brochure, (2) a website to describe the undergraduate major, and (3) a graphical computer presentation for high school audiences. In addition to other recruitment activities, educational programs well received by high school students and teachers include: (1) a summer elective course on Agroecology and an Agroecology field day for high school students who attend the Governor's School for the Agricultural Sciences at PSU, and (2) an Agroecology field day for high school students and teachers, at the PSU Crop and Soil Sciences Department, Russell Larson Research Farm.

Summary

Regular review of the interdisciplinary program by students, faculty, and employers was beneficial and will be continued. In 1996, surveyed alumni and employers replied that an understanding of cropping systems, pest management, environmental issues, and business management were important for job preparation. They also expressed a need for graduates to have more problem solving and communication skills. In response, an interdisciplinary Agroecology major emphasizing cropping systems, pest management, and developing problem-solving and communication skills was developed by faculty from Crop and Soil Science, Entomology, Horticulture, and Plant Pathology departments. In 2002, graduates and students had chosen the Agroecology major because they were interested in learning about agriculture, ecology, environmentally-friendly and profitable cropping systems, and a science-based systems program that prepared them for a wide range of job opportunities

Alumni and students valued hands-on, crop production and pest management courses, as well as advanced technical science courses. Internship experience was valued by virtually everyone. Most of the recent graduates stated that the major had provided them with the fundamental knowledge base and training in critical thinking and problem solving.

Retaining students with diverse interests in the Agroecology major required allowing students to choose from a wide range of courses. Managing and promoting this interdepartmental program with faculty from four departments required an academic paradigm shift. Success of the program depends on identifying a coordinator and committees with responsibilities to: (1) provide guidance and mechanisms to promote faculty communication and collaboration around course curriculum; (2) update the required and elective course lists offered by multiple departments on the internet; and (3) inform potential employers, students, and high school teachers about the new interdisciplinary program.

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