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COMMUNICATION INTERACTION PATTERNS AMONG MEMBERS OF TWO INTERNATIONAL AGRICULTURAL RESEARCH INSTITUTES

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ABSTRACT

Twenty-eight senior staff members at the Asian Vegetable Research and Development Center (AVRDC) and 60 senior staff members at the International Rice Research Institute (IRRI) were surveyed regarding the frequency and importance of their work-oriented face-to-face, telephone, and written communication. Analyses of the communication networks show that AVRDC emphasizes face-to-face interaction, while IRRI gives greater relative attention to the telephone and writing. Both centers have organizational structures and use communication mechanisms that enable the staffs to function effectively in research tasks requiring intense cooperation and coordination. Network and statistical analyses suggest that staff size is an important factor in determining which channels serve communication needs best, while also influencing the mechanisms that keep communication frequency within tolerable limits.

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The patterns of human communication relationships in a formal organization may be viewed as a network. If each member is represented by a point, or node, the nodes will be interconnected by lines representing communication linkages. Some lines will link an individual to his immediate contacts, people he knows personally and interacts with on an intensive and continuing basis. These people, in turn, will be linked to others.

Within the network context, communication interactions tend to form into patterns of repetitive transactions that unite people with common interests. Such patterns are diverse and overlap, permitting an individual to belong simultaneously to several groups within a network. The structure of such groups is influenced by social, psychological, and task-oriented relationships between members, and groups tend to merge and split into sub-groups depending on relational changes among members. The formation and maintenance of group relationships depend on message flow along network channels.

When diagrammed, the networks of interactions provide a model of how group members send and receive messages within the context of a larger structure. Although the networks are always temporary and transitional, they reflect organizational structure and, when supported by complementary analyses, can indicate that particular structure's effectiveness in attaining goals.

The purpose of communication network analysis is to identify communication channels in a given structure, identify possible constraints to message flow, and indicate areas needing further study. Within limits, communication network analysis can be a signfficant aid in understanding an organization's communication dynamics.

BACKGROUND

Historically, networks have been described through charts, graphs, and sociograms. Network analysis owes much to the mathematics of topology and graph theory, and has been used to analyze the flows in electrical, fluid, and mechanical circuits. Networks have also been used to describe social structures, and sociometric algorithms using electronic data processing equipment have been developed. Simulated mathematical models have been applied to large social systems such as companies, urban areas, and village communities. However, sociogramatic techniques are still useful for studying small systems.

The sociogram uses points to represent people and connecting lines to express potential or actual relationships between them. Although the lines are often given directionality to show flows, the line length is seldom important. The strength of a flow or its quality can be shown numerically or through thickened or colored lines.

Network analysis using sociograms has some severe limitations: a) it is very sensitive to the accuracy of input data, b) it is valid for a single point

in time, c) it is prone to generalizations and unwarranted extrapolations, d) it is difficult to compare dissimilar networks, and e) the sociograms become very complex as network size increases. Ideally, network analysis best serves as a complement to other analyses.

This paper recognizes a debt to the NEGOPY network analytical system developed by Richards[a] and discussed by Wigand[b], but makes a substantial departure from the methodology of this computerized technique for clique identification. NEGOPY requires a FORTRAN program which was not available for the present analysis. An attempt was made to follow some of the NEGOPY logic but perform the calculations on a hand calculator. Thus, besides the network analysis itself, this paper offers insights into NEGOPY and a procedure for use where a computer is neither available nor practical.

SUBJECTS OF THE ANALYSIS

Twenty-eight senior staff members of the Asian Vegetable Research and Development Center (AVRDC) in Taiwan were surveyed in mid-1979 regarding their face-to-face, telephone, and writing work-related interpersonal communication. The same survey was given to 60 senior staff members of the International Rice Research Institute (IRRI) in the Philippines between October 1979 and January 1980. This paper reports the results, compares the two networks, and tests the validity of the network analysis method.

AVRDC and IRRI are members of a network of 12 international agricultural research centers (IARC) conceived, for the most part, by the Rockefeller Foundation and funded by a consortium of international, national, and private donors. The overall goal of the IARC's is to improve the quality and quantity of major food crops, and to develop appropriate crop production technology that will help the world's small-scale farmers improve their yields and, thereby, their incomes and standards of living.

AVRDC employs an international staff which is divided into a "junior" group who are all Chinese and a "senior" group of Filipinos, Chinese, Koreans, Japanese, North Americans, and Indians. For this paper, research assistants at AVRDC have been classified as senior staff. Except for some of the Chinese, the senior staff lives on the institute grounds a short walk from the office and laboratory buildings. Except for the Chinese, social contact with the Taiwan community is minimal; work-related contacts are handled almost exclusively by AVRDC's Chinese senior staff. English is the official institute language and every senior staff members speaks, reads, and writes it fluently.

IRRI employs an international staff composed of a junior group who are all Filipinos and a senior group of Filipinos, Australians, Indians, Chinese, North Americans, Japanese, Koreans, British, French, and Thai. About 72% live in an

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[a]Richards, William D. Jr. 1975. A manual for network analysis (using the NEGOPY network analysis program). Stanford University, California Institute of Communication.

[b]Wigand, Rolf T. 1976. "Communication network analysis: a computerized tool for organizational development and the analysis of large social systems." Paper presented to the American Society for the Advancement of Science, Social Science Section.

enclosed staff housing compound and the remainder live among the local community; IRRI's office and laboratory buildings are at least a 5-10 minute drive from any residence. Contact with the larger Filipino community is extensive for almost all the internationals. English is the official language and every senior staff member speaks, reads, and writes it fluently.

IRRI, established in 1960 as the first IARC, was the model for AVRDC, which was set up in 1971. The founding director of IRRI was also the founding director of AVRDC. AVRDC's physical plant is patterned on that of IRRI. Many of the programs and policies are similar, and staff members are frequently exchanged between the two centers and among all the IARC's. The two centers are dissimilar in budget: US$14 million per year for IRRI and US$3 million for AVRDC in 1979. The adverse political situation in Taiwan places pressures on AVRDC that do not exist at IRRI.

AVRDC's scientists engage in basic and applied research focusing on six vegetable crops of importance in the tropics as nutritional complements to the rice diet. Research is performed in the laboratories, greenhouses, on a 102-ha experimental farm, and on farmers' fields. The scientists belong to invisible colleges of vegetable researchers in other countries, and they travel internationally to confer with colleagues, advise national programs, and attend professional meetings.

IRRI scientists focus on rice both as a mono-crop and as the major part of a multiple cropping agriculture. The facilities available for research are far more extensive than those at AVRDC and include laboratories, greenhouses, a 250-ha experimental farm, a controlled environment facility (phytotron), and a plant experimentation center. A world-wide network of outreach programs and cooperators test IRRI rice varieties and technology under local conditions. The scientists travel widely and frequently; several spend a major part of the work-year abroad.

Organized horizontally into broad-based research programs, scientists at AVRDC and IRRI are also members of multidisciplinary teams which tackle specific problems at their respective center (see Appendix 3). At any one time a scientist may be involved in a variety of tasks. At AVRDC for example, a plant pathologist may be part of the horticultural crops program; a member of teams studying the effects of a potato virus on yields, nematodes that attack tomatoes, bacteria on Chinese cabbage, and micro-organisms in tropical soils; and he may be called upon to supervise a trainee, give a seminar, organize a meeting to discuss a research proposal, and consult with a visitor. Scientists at IRRI have similar responsibilities.

The program/team organization provides great versatility in handling complex research problems. However, it puts exceptional demands on a scientist's time and energy. For scientists whose training traditionally focuses on laboratory work, the program/team approach often requires a reorientation in work habits to include extensive field activities, multidisciplinary teamwork, and the cross-cultural collaboration that accompanies international programs. The program/team approach demands intense cooperation between scientists and this depends on extensive and intensive interpersonal communication. Furthermore, the teams require a leadership strong enough to keep researchers focused on the problem at hand, but liberal enough to permit individual initiative. The Administration must be supportive without undue interference, yet must maintain

enough control to orchestrate all the program/team projects toward the attainment of goals that satisfy the Board, the donors, and the public. All communication channels must be open and functional but actual message transfer must not take too much time away from research activities.

The fact that the two centers are similar in many ways invites comparison. Although IRRI is older, larger, and the programs are more complex than those at AVRDC, both centers appear to be developing along similar lines. Whereas AVRDC is a small center still in the initial stages of program formation and the establishment of its reputation internationally, IRRI has passed through this stage, gained its reputation as the originator of "miracle rice" and "the Green Revolution," and is now deep into an expansion phase. IRRI's programs are so complex now that there is talk of moving into a consolidation phase during the institute's third decade.

But size appears to have an important effect on task accomplishment through its effects on communication. When the pool of scientists is large and the research programs are not expanding, an individual scientist's program/team involvement will be reduced, permitting him to specialize on selected tasks for more in-depth research. Under these conditions his communication network will tend to become fixed around those contacts necessary to his work. On the other hand, when the scientist pool is large and the programs are expanding, as they are at IRRI, interpersonal communication will expand also as a scientist responds to increasing work responsibilities and the growing network of contacts that accompany wider task involvement. The interpersonal communication required under these conditions and during the day-to-day maintenance of social and work relationships may require personal or organizational controls that enable sufficient time for research tasks.

Unlike scientists at AVRDC, IRRI staff members complain that too much time is spent in meetings, with visitors, supervising workers, on paperwork, and in the daily maintenance of relationships. Certain control mechanisms which permit effective task accomplishment seem to have evolved at IRRI that do not exist - or are just now coming into existence - at AVRDC. These appear to be a function of staff size and organizational complexity. Generally, as size and complexity increase, staff members become compartmentalized and hierarchically structured, group cohesion decreases, more time is spent on administrative and supervisory matters, research coordination becomes more complex, and it takes longer to get things done.

Although the program/team approach at AVRDC and IRRI offers versatility in responding to an important mission, it makes more serious demands on communication at IRRI than at AVRDC and requires controls that reduce interaction to manageable levels. It is our hypothesis that AVRDC emphasizes face-to-face communication in order to achieve the levels of interaction necessary for effective program/team task accomplishment, and that this is possible because AVRDC is still a small center in its initial growth stage IRRI, on the other hand, focuses on telephone and written communication relatively more than on face-to-face communication in order to gain more control over interaction. IRRI appears to have institutionalized certain communication "adjuncts" that help boost the power of interaction, thereby reducing the time interaction takes. This paper will present the results of communication network analyses at AVRDC and IRRI that support this hypothesis.

METHODS

In order to identify communication linkages at AVRDC, 28 senior staff members were surveyed twice at 6-week intervals in mid-1979 (see Appendix 1). A similar survey was given to 60 senior staff members at IRRI on 4 October and 4 November 1979, and on 4 January 1980.

Each respondent in the surveys was identified by a node identification number (see Appendix 2). The procedures followed at the two centers were identical and the following methodology was performed in the same way on all the surveys. We asked each respondent named to indicate the *frequency* (F) he initiated work-related communication with others on the list. A frequency scale was provided which ranged from 0 (no communication) to 6 (communication 3 or more times per day). Each respondent was also asked for a subjective judgment of the *importance* (I) of that communication by indicating a number on a 0 to 9 scale, 9 being the highest. This procedure was followed for each of three modes (channels): *face-to-face, telephone,* and *written communication*. The survey form and procedure correspond to that used by NEGOPY. F and I were then multiplied to give an index called COMVALUE for each mode on each survey.

COMVALUES for each mode were put on matrices to show scores for communication from ego to all other nodes (LINE) and from all other nodes to ego (COLUMN). The COMVALUES from all the respective surveys were then averaged and the rounded scores placed on a single matrix for each mode for each center. The individual matrix means were computed and COMVALUES below the mean were discarded. This procedure attempts to approximate the "alpha criterion" in NEGOPY.

Communication interaction was separated into three linkage types: *symmetrical* two-way communication in which both linked nodes employ the same one, two, or three modes; *asymmetrical* two-way communication where both linked nodes use different modes or combinations of modes; and *unidirectional* one-way communication in any one, two, or three modes with the direction of flow shown by arrows. The various combinations of linkage type were assigned colors and the interactions plotted on a single matrix for each center. From these, the sociograms were drawn and selected sociograms were chosen for analysis.

The COMVALUES relative to each interaction were placed on the respective sociogram. Based on means and standard deviation (SD) criteria, heavy, medium, or light lines were drawn to connect nodes; the heavier the line, the more intensive the communication.

The respondents from each center were divided by program involvement and, for IRRI, according to an organizational chart[a]. Sociogram designs and content were then manipulated in various ways for analysis: for AVRDC the program involvement of respondents was depicted as discrete sub-networks; for IRRI the actual above-average communication was overlaid on the organizational charts for both the minimum program linkages (those involving the minimum acceptable communication for cohesion between program leaders and their respective members) and for linkages between the administration and the department heads.

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[a]The organizational charts are informally drawn when the IRRI administrators wish to explain internal operations to visitors. These charts are not rigid in the sense that they set down "chains of command." However, they do show a hierarchy of responsibility and, therefore, establish prescribed communication channels between senior staff members.

The AVRDC networks were assessed for density, flexibility, and centrality communication indices (see Tables 1-3 for definitions). The approximate distances between offices were measured to determine if these had any meaningful effects on communication. Native languages and nationalities were also considered.

The IRRI networks were likewise assessed for the three communication indices. The distances between offices were also surveyed. Data were collected regarding native languages, sex, age, nationality, highest academic degree, residence and office locations, job title, department and program affiliations, and degree discipline. These variables were analyzed by Statistical Analysis System (SAS) programs to determine their effects on communication at IRRI.

RESULTS AND DISCUSSION

Table 1 provides a summary of several measures of the modal relationships before and after the COMVALUE averaging procedure at each center. The individual network COMVALUE means were chosen as selection criteria in order to identify the "important" communication in the centers. If the criteria were reduced by one SD, the magnitudes of the Table 1 values would change as more interactions with low COMVALUES were added to the calculations; however, the relationships between the respective modes and between the centers would not change significantly. Furthermore, as more interactions were added, the sociograms would become more complex and less instructive.

When all the responses from the surveys are considered, face-to-face communication is favored at both IRRI and AVRDC. However, the ratio between densities at the respective centers suggests that IRRI depends much more on telephone and written communication than does the smaller center. This is supported by values for the mean links/node. Although the mean links/node is higher for face-to-face communication than for the other modes at both centers, the coefficients of variation (CV; see Table 1) at IRRI suggest that there is very little range between individual responses and that the three modes have equal importance as communication channels. The CV's at AVRDC suggest the opposite: that the use of telephone and written modes may be biased by several heavy users. The suggestion that IRRI gives equal attention to all three modes is further supported by the mean COMVALUE/node values. These are nearly equal at IRRI, while at AVRDC the senior staff members rate face-to-face communication at nearly twice the value they give the other two modes. The very high CV's for telephone and written modes at AVRDC again suggest a few heavy users. In fact, an analysis of the effects of distance on communication at AVRDC (Fig. 8) shows three staff members considerably removed from the majority and direct inquiry revealed that these three use the telephone and the memo pad for almost all communication. Therefore, we conclude that AVRDC emphasizes face-to-face interaction, while IRRI gives greater relative attention to the telephone and writing.

Figures 1 and 2 provide comparative examples of sociograms at AVRDC and IRRI, respectively, for the networks of symmetrical linkages that are above the COMVALUE means. The node shape indicates the job title and the accompanying letter refers to the programs in Appendix 3. The line thickness is a rough measure of the intensity of interaction: the thicker the line, the more redundant channels are employed symmetrically.

The AVRDC network (Fig. 1) shows the entire senior staff and their symmetrical linkages. Nine key staff members are interlocked in a sub-network of three-mode linkages with two of the directors (#14 and 15) well integrated into the larger network. If the one- and two mode linkages are added to this sub-network, nearly half the senior staff are brought into a strong reciprocating system. The remaining members are included when the asymmetrical linkages are added.

The IRRI network (Fig. 2) shows an intensively interlocked sub-network of three-mode interactions almost exclusively among directors and administrators. At this level of communication, the scientific staff, with the exception of a breeder (#25) and two editors (#18 and 45), is excluded from direct communication with the center administration. The Office of Information Services (OIS; code M), which works closely with the Director-General (#4), is connected to this sub-network at two points. Several of the breeders are also connected. However, all the other departments seem to exist at this level of communication as isolated dyads and triads or as very tenuously connected sub-networks of their own. For example, the Economics (E), Multiple Cropping (D), and Agricultural Engineering (G) departments are all tied to the administration by a visiting geographer (21) who works in the Economics department. Although located in three different buildings, these departments cooperate on many projects and several programs; the geographer has visited IRRI on two separate occasions and is well-known by the permanent staff members. The small group of soil microbiologists (R) and pathologists (P) is noteworthy: nodes #35, 57, and 59 are IRRI's three Japanese scientists.

The AVRDC and IRRI networks contrast sharply in the way their administrations are connected to the scientists: whereas AVRDC's is well integrated and the Director (#15) is peripheral to the main body, IRRI's administration is peripheral and the Director-General (#4) is central.

The AVRDC program sub-networks (Fig. 3) are depicted as discrete to exemplify the internal interaction. Tables 2 and 3 give the interaction indicators for each program sub-network and for each node. All the linkages are represented in the tables but only the above mean COMVALUE linkages are shown on the sociograms.

The Administration sociogram at AVRDC shows that all communication channels are open but the total nodal COMVALUES (the sum of the in-place linkage COMVALUES and placed near the respective node on the sociogram) show that all channels are not used to the same degree. The integration with the rest of the staff is clearly shown by the external density of 78%. The Services program appears to have the greatest communication reach with a mean COMVALUE of 112 and an external density of 83%. HORT program is the weakest with a mere 84 total COMVALUE ($\bar{x}$=21) and 68% external density. HORT is also the most centralized (flexibility=38%) of the sub-networks, while the administration is completely decentralized. The situation in HORT might change slightly if the tomato breeder, who was on sabbatic leave, was included. However, it is unlikely that his presence would bring HORT's total COMVALUE in line with that of the other programs.

Figures 4-7 are drawn so that the IRRI program and administration sociograms can be overlaid on the respective organizational charts. Figure 4 shows

the linkages which should exist if the members of each program interacted only with their respective leaders. This can be considered the minimum acceptable communication for maintaining program cohesion and task effectiveness. Figure 5 shows the corresponding sociogram of the actual above-average linkages between program members. GEU (100-113), MGMT (300), and CROPSYS (900) are the only programs with several linkages that correspond when the figures are overlaid. Several designated leaders (e.g. #32 and 55) do not seem to be in touch with their members at this level of interaction; several others (#10 and 20) appear to be in contact with several programs besides their own.

One assumes that, if the actual communication does not follow the organizational plan but tasks dependent on that plan's structuring effects are accomplished anyway, either the plan is wrong or some unaccounted for communication is taking place that compensates for what is missing. Figure 4 is derived from the Director-General's appointment of scientists with major responsibility for sections of IRRI's Annual Report. Because the reporting cannot be done without participation in the research program, the chart must be correct. On the other hand, the 73% density for face-to-face interaction (Table 1) suggests that the unaccounted for communication may exist at levels eliminated during the COMVALUE averaging process.

Low level interactions between the scientists at AVRDC and IRRI were most often the result of low frequencies (e.g. a frequency of one interaction/month with an importance of 9 would be eliminated at both centers). Such interactions may be typical of scientists working on specific tasks within the scope of a program who only meet other program members (who work on other tasks) at infrequent coordinating meetings. However, because of the multidisciplinary nature of IRRI's and AVRDC's missions, the scientists may more frequently consult members of other programs. Thus, Figure 5 may represent interaction between programs more than it does interaction within programs. Further analysis would be needed to verify the implications of Figures 4 and 5.

Figures 6 and 7 provide the organizational chart of minimum linkages and the sociogram of actual communication from the administration to IRRI's department heads. Although there are many linkages on the sociogram at various levels of interaction, only a few match the chart. In this case, the addition of lower levels of interaction do not change the situation. Six department heads are not included in the network, seven heads are included as unidirectional three-mode contacts (only one of these flows from the administration), three are asymmetrical contacts, and only one is symmetrical. At these levels of communication, only four interactions join the services group with the department heads, but 14 interactions join services with the administration. And the directors are linked symmetrically to five non-department heads.

The discrepancies between Figures 6 and 7 suggest that the IRRI network is unbalanced in favor of communication between administrators and services. Figure 2 supports this suggestion. According to the sociograms, IRRI does not appear to be hierarchically organized. Administrative control issues directly from the Director-General to individual senior staff members in most cases: the system is designed this way (Fig. 6 is derived from an unpublished paper written by the Director-General).

Tables 4 and 5 provide interaction indicators for the IRRI program sub-

networks. Although there are 10 programs and numerous sub-programs, it was necessary to combine the management (300-400), the economics (700-800), and the machinery development and training (1000-1100) programs because participant numbers were individually too small for the correlation analyses. Thus, the following discussion involves three programs and three combined programs and, to this extent, there are some minor distortions in the latter.

In comparing the AVRDC research programs (LEGUME, HORT, and NEM) from Table 2 with the six IRRI programs from Table 4, although all the densities are similar, IRRI programs have lower flexibility indices, i.e. the network structures are more centralized. Rigidly centralized structures may be detrimental to effective program/team interaction. IRRI's mean COMVALUES are very low compared to those of AVRDC, suggesting weak internal communication which agrees well with the sociogram (Fig. 5). However, the external densities are also very low, implying that the channels available for communication between programs and with non-members are not actually used as much as are similar channels at AVRDC. This does not seem to match the interpretation of Figure 5, that the sociogram reflects interaction between programs more than it does interaction within programs. The values in Table 4 were not subjected to the COMVALUE averaging procedure as were those in the sociogram and, thus, include low level interactions. Therefore, at first glance it seems that the interpretation was wrong and that the sociograms accurately portray the communication situation within programs at IRRI. However, it may also mean that some communication mechanisms are operating to reduce the time-consuming interactions within and between programs to only those that matter for task accomplishment.

Interviews with many of the IRRI scientists reveal that communication control mechanisms are indeed operating to screen out unnecessary interaction, focus interaction more specifically on task problems, and boost the communication power of an interaction. Such mechanisms do not yet exist at AVRDC. To a great extent the informal interaction patterns currently used at AVRDC have given way to more formalized exchanges at IRRI. Appointments are essential at IRRI, whereas the "open door" policy exists at AVRDC. The regular coffee break and the institutionalized cocktail party at IRRI permit the brief encounters during free periods which keep people posted on current events but also allow focused consultation that does not detract from a busy research schedule. A widely disseminated Calendar of Events and numerous executive memos formalize activities by regulating the way staff members use time. These and other communication mechanisms are the tangible results of a center-wide concern for how time is spent. Every scientist interviewed said that he did not have sufficient time to perform as he would like; too much time was spent entertaining visitors, supervising junior staff, doing paperwork, and maintaining all the social and work relations important to task accomplishment. Furthermore, every scientist said that the problems of time did not exist when IRRI was smaller but growth has brought greater responsibilities, greater opportunities, and more social distance between staff members.

Table 6 shows a summary of statistical indicators relating selected variables to linkages/node (LINE) and average COMVALUE/node for IRRI. These were not done at AVRDC. Of the 12 variables tested for their effects on communication at IRRI, 7 were found to have no statistically significant effects.

Although there are nine languages spoken at IRRI, 55% of the senior staff

are native English speakers and another 25% (Indians and Filipinos) historically speak English as a second language. About 93% of the senior staff are male; only one female is a field researcher, the others are in services. Ages range from 32 to 62, with a mean of 44.3 years. Over 76% of the staff hold PhD degrees and 13% hold Master's. According to the way the data were coded, no department nor any combination of two departments had any significant effects on overall communication at IRRI. The disciplines represented were too diverse and would not compute; the largest representation was agronomists (6).

Nationality, residence and office locations, job title, years spent at IRRI, and distance between offices were all significant (Table 6). Duncan's Multiple Range Tests (DMRT) were performed on these six variables to identify the sources of variation. Nothing conclusive resulted from DMRT's on nationality and residence location, however.

Table 7 shows the results of DMRTs on office location and job title. Although LINKS was not significantly different between Chandler Hall, the GEU Building and the Forest Hill Lab, Chandler Hall stood out clearly as an important influence on COMVALUES. This is not surprising because the administration, library, and Office of Information Services are located in this building.

The job title of a senior staff member has the most distinct influence on communication at IRRI. The title of "Director" clearly has the most influence. The remaining titles split up in distinctive ways. The title of "Scientist" influences LINKS but does not differ significantly from other titles when it comes to COMVALUE. Associate scientists and administrators have about the same impact. The title "Visiting Scientist" has the least effect on LINKS or COMVALUE, probably due to the short term nature of their contracts (most are for one year). However, because visiting scientists come to IRRI either to gain hands-on experience in rice research or because they have expertise to offer, the low scores may mean that the visits lose some of their value due to the low levels of interaction with permanent staff members. The positions of visiting scientists in the sociogram (Fig. 2) support this possibility.

The influence of distance between offices on communication was determined by statistical association at both AVRDC and IRRI. The shortest walking distance from each office to every other office was paced off, converted to meters, and charted (Fig. 8). When compared to LINKS, distance was found to have no significant effect on communication at either institute. F scores in the statistical tests at IRRI confirmed this and added that the effects of distance on COMVALUE were only significant at the 10% level. The reason for this uniformity between AVRDC and IRRI, despite very different spacial arrangements, seems to stem from the purposive nature of task-oriented communication. The results would have been different if the survey had measured social interaction.

The correlation coefficients for YEARS (Table 6) suggested that it might be worthwhile to perform a linear regression with the idea of predicting communication activity based on longevity at IRRI. The analysis of variance for LINKS x YEARS ($Y = 16.88^{**} + .48^{+}$ years) indicates that a newcomer at IRRI starts off with about 17 contacts; the mean is 20.3 for the group as a whole. However, the CV is a high 62.9% and the R^2 is a low .055 showing that the curve is not a very good fit and probably not very useful. The average staff member

has been at IRRI for 6.9 years (the calculation included 12 visiting scientists with one year tours), and the range is from 1 to 19 years.

The regression equation for COMVALUE x YEARS (Y = 22.91** + .51*years) shows that newcomers tend to start out at IRRI with an average COMVALUE of about 23 per contact; the mean of the group is 26.3 per contact. The CV for this analysis of variance is 21.7% and the R^2 is .68, both within acceptable ranges. Although the equation is significant at the 1% level, its predictive value is probably affected by the subjective bias built into the COMVALUE index.

Figure 9 shows regression curves for COMVALUE x LINE. The linear regression was the first attempt to fit an equation to the survey data and, although the fit is good (R^2 = .68), the straight line seems illogical. Logic suggests that the line should be a curve that climbs steeply at lower LINE values when a staff member is building his network of contacts after his arrival at IRRI. As his network expands, the COMVALUES per contact increase but at a slower rate, indicating that he is adjusting his communication according to work priorities as he settles into his task assignments. Finally, as his network approaches its maximum size, the COMVALUES drop slightly and then level off as he achieves equilibrium between the amount of time available for and the amount of time required to maintain his network of contacts. The logarithmic curve fits the data a little better (R^2 = .712) and reflects the logical sequence just described. Graphically, the initial network construction ends between 12-15 contacts when the curve goes into a nearly linear phase during network adjustment. Equilibrium begins around 85-90 contacts when the curve flattens entirely. The final COMVALUE is about 45 per contact.

Figure 10 compares regression equations for COLUMN x LINE for both AVRDC (Y = 10.22 + .38 line) and IRRI (Y = 10.54 + .78 line). If the LINE values of an individual exactly equalled his COLUMN values, the line of regression would fall on the 45 degree mean ($\bar{x}$). This would imply that what he reports about his contacts coincides with what others report about him. The amount and direction of deviation from this mean would then give a measure of the subjectivity introduced into the surveys. The results from both centers are consistent. When ego knows one other person at either AVRDC or IRRI, about ten people know him. These numbers increase at nearly the same rates at the two centers with IRRI, the larger center, slightly steeper. Nodes to the left of the mean line are known by more people than they know; those to the right know more people than know them. At IRRI, all the visiting scientists except #21 are to the left of the mean line. The similarities between the two regression equations and the high R^2s suggest that whatever subjectivity exists in the survey methodology is consistent and may be discounted. Furthermore, some of the statistically based conclusions at IRRI may also apply to AVRDC.

CONCLUSIONS

The channels of communication between the 28 senior staff members at AVRDC and between the 60 at IRRI are extensive. Virtually every person is linked to some degree to every other person at their respective center. For AVRDC, a third the size of IRRI, the complete network of communication interactions is

bewildering; it is even more so at IRRI. Clearly there can be no overall constraint in message flow at either center because of the tremendous number of network pathways open for message transfer.

AVRDC is a small center; offices are only a few steps apart and the senior staff members can easily meet for conversation regarding their various research tasks. In the AVRDC context, a focus on face-to-face communication allows busy staff members the chance to iron out disputes in person, seek clarifications and make arrangements through on-the-spot dialogue, and exchange ideas in open discussion. Memo writing and telephoning are back-ups to face-to-face communication: writing formalizes and records what was said; the telephone is used for setting up, confirming, or changing meetings. Face-to-face communication fits the program/team approach to research well. Programs can be easily and efficiently coordinated through direct personal contact between the program leader and his membership. Teams can be assembled rapidly to work up or evaluate proposals, trouble-shoot a specific problem, or consult with visitors. They can be dissolved and reformed in new contexts without confusion and loss of time. The program/team approach works best with face-to-face communication.

However, as AVRDC matures as an organization and the staff and research program grow, the interactions between staff members will increase in complexity and require increasing time for the maintenance of contacts. When these interactions begin to interfere with the research program, changes will occur in the way people communicate, in their networks, and in the structure of the organization. Informal communication will be replaced by more formal patterns: standard forms will replace a verbal request for services and new forms will be designed for what were once routine operations. Mimeographed memos will replace personal notes. Meetings will need to be scheduled weeks in advance and informal meetings will occur rarely or only in prescribed ways. The telephone circuits will need expanding, a center-wide calendar or newsletter will inform staff members about things they once learned first hand, and staff meeting will be held more often. In short, AVRDC will tend to become like IRRI is today.

Staff members say that IRRI is too big. To some extent this is a reaction to the increasing amount of time required to maintain necessary contacts. Changes have occurred that tend to compensate for the time that is taken from research. In some cases secretarial barriers have been erected to protect busy staff members from unwanted communication. Other staff members have purposively disassociated themselves from all minor contacts. Interaction has been formalized through the relative emphasis on telephone and written communication. And institutional mechanisms to control and "adjuncts" to boost the power of communication have evolved.

Coffee breaks and formal cocktail-buffet parties are examples of communication adjuncts. These do not exist at AVRDC with the frequency and importance they have at IRRI. Some IRRI staff members ritually go to coffee at 10am and again at 3pm to learn the latest center news and to make both social and work arrangements. There are now two cafeterias at IRRI; staff members note that coffee break communication was much better when there was only one cafeteria. The formal cocktail-buffet parties are also mechanisms for controlling and, at the same time, boosting communication. The parties seem to be an essential

substitute for the informal face-to-face encounters that staff members report having when IRRI was smaller. Today one cannot simply "drop in" on the Director-General and, in most cases, the other Directors, to discuss personal or work-related problems. An appointment must be made in advance and the caller should expect cancellations and new appointments as the administrators respond to priority communication. One often waits until a cocktail-buffet party and then corners the Director-General for a quick consultation. This is accepted practice at IRRI and much work is accomplished this way.

The network analysis of IRRI shows that the administration is separated from the researchers at high levels of communication. It also shows that the research programs are fragmented at these levels but that the departments are not. Of the 13 problem area team leaders in the GEU program, only 4 are represented in the top 7 centrality positions (Table 5). Of the other programs at IRRI, only one leader is the most central for his group. Although communication is not significantly affected by department affiliation (Table 6), the network shows that department members are generally linked at high communication levels (Fig. 2), however, apparently important communication takes place at low levels of communication within programs. This suggests that the centralized structure of IRRI (Fig. 5) is a more meaningful determinant of task-related communication than is the decentralized structure of the program/teams. On the other hand, tasks may be accomplished at IRRI precisely because the centralized administration is separated from the decentralized researchers and the two do not interfere with each other.

This network analysis provides the baseline for comparison with future studies. Network analysis freezes a point in time and constructs a map of relationships which no doubt change even before the sociograms are drawn. In this sense, recommendations may be of limited value. However, one recommendation for IRRI might be to establish additional mechanisms for boosting the communication power of interaction.

In terms of the network analysis methodology: it is important to test this over time as well as spacially; little has been done in this regard. We suggest that the survey series be run again at AVRDC and IRRI, as well as at the other international centers to determine to what extent the conclusions regarding size apply to organizational structures similar to those of the international agricultural research centers.

Table 3. Interaction indicators within program sub-networks at AVRDC, 1979.

Program node ID	Internal links	Cent[a]	External links	Program node ID	Internal links	Cent	External links
SERVICES				LEGUME			
3	5	6.4	18	26	6	9.7	14
6	5	6.4	21	17	5	8.3	21
9	5	6.4	19	19	4	7.3	19
10	5	6.4	15	22	4	7.3	12
1	4	5.3	15	24	3	6.4	13
7	4	5.3	21	4	2	5.8	10
				11	3	5.8	20
ADMIN				NEM			
2	5	5.0	12	8	5	7.2	18
13	5	5.0	24	25	5	7.2	18
14	5	5.0	18	5	4	6.0	16
15	5	5.0	19	20	4	6.0	18
18	5	5.0	19	21	4	6.0	14
HORT				28	2	4.5	15
12	3	5.3	13				
16	2	4.0	20				
27	2	4.0	17				
23	1	3.2	16				

[a]Cent = $\frac{\Sigma \text{ of the shortest no. of links from every node to every other node}}{\Sigma \text{ of the shortest no. of links from ego to every other node}}$

Table 4. Interaction indicators for the program sub-networks at IRRI, 1980.

	GEU	RICEPEST	MGMT	CONSCONS	CROPSYS	MACHTRNG
INTERNAL						
No. of nodes	21	9	9	8	9	11
Possible links	420	72	72	56	72	110
Density (%)[a]	42	38	53	32	68	63
Flexibility (%)	38	29	29	36	27	27
Mean COMVALUE	27	23	23	24	28	28
EXTERNAL						
No. of nodes	39	51	51	52	51	49
Possible links	819	459	459	416	459	539
Density (%)	29	20	27	27	34	36

[a]See Tables 1 and 2.

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Table 5. Interaction indicators within the program sub-networks at IRRI, 1980.

Program node ID	Internal links	Cent[a]	External links
GEU			
7	18	33.9	19
18	15	29.6	32
6	14	27.3	15
25	14	24.5	16
50	13	24.5	9
24	12	23.7	10
9	10	22.9	6
23	12	22.9	23
29	8	22.9	7
55	9	22.9	11
34	10	22.2	7
20	10	20.9	14
49	6	19.8	6
36	4	19.2	13
47	5	19.2	2
59	5	19.2	7
42	4	18.7	15
15	3	18.2	1
10	1	17.8	24
35	4	15.8	16
53	1	13.4	1
RICEPEST			
20	8	12.5	16
9	7	10.6	9
40	6	9.9	0
49	5	9.9	7
30	6	9.2	22
10	6	8.6	19
47	4	8.6	2
29	4	7.3	11
12	2	6.9	8
MGMT			
57	8	12.2	33
3	5	11.1	23
10	5	11.1	20
42	5	9.4	14
1	4	8.7	7
51	4	8.7	3
37	3	8.1	11
13	2	7.2	8
46	3	7.2	4
CONSCONS			
20	4	9.9	20
27	4	9.2	17
14	5	8.7	31
10	3	8.2	22
9	1	7.7	15
15	4	7.7	0
16	3	7.3	0
13	2	6.3	8
CROPSYS			
60	7	11.2	16
5	7	10.1	11
14	6	10.1	30
43	7	10.1	18
27	7	9.2	14
30	5	9.2	23
19	3	8.4	18
31	4	8.4	1
10	2	6.3	23
MACHTRNG			
3	8	13.2	20
11	7	13.2	31
26	8	13.2	4
39	8	13.2	41
54	8	13.2	29
32	6	11.3	2
7	6	10.5	31
28	5	10.5	9
19	4	9.3	17
58	5	9.3	11
10	2	7.9	23

[a] See Table 3.

Table 6. Summary of statistical tests relating selected variables to COMVALUES and the number of linkages of 60 staff members at IRRI, 1980.

	NATION-ALITY	RESI-DENCE	OFFICE	TITLE	YEARS	DIS-TANCE
Linkages	2.43*	7.88**	4.01**	18.77**	.234+	ns
COMVALUE	2.96*	4.76**	3.44**	5.61**	.317*	1.93+

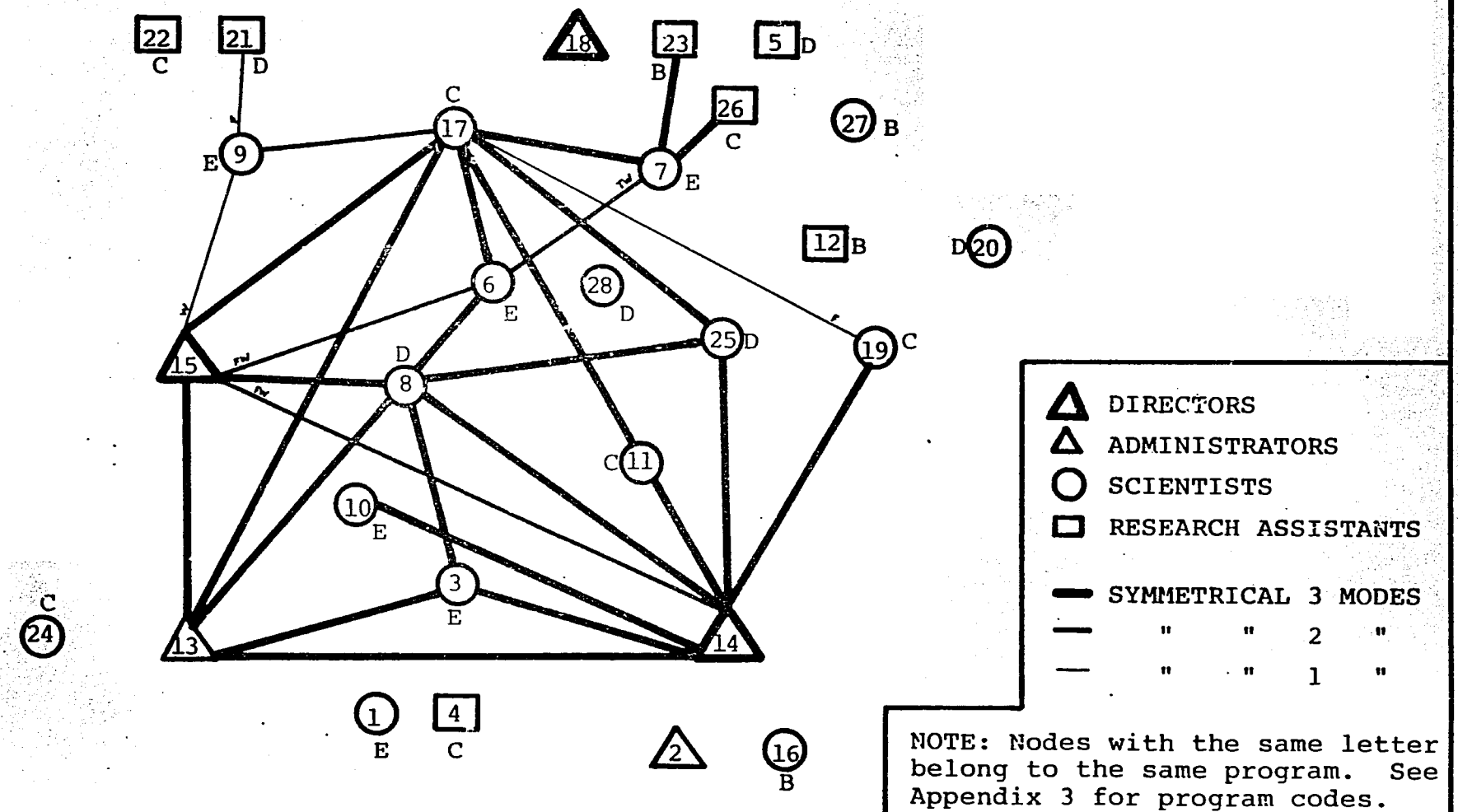
Note: All values are F scores except "YEARS," which are correlation coefficients. ** = significant at 1%, * = 5%, + = 10%. The values for LANGUAGE, SEX, AGE, DEGREE, DEPARTMENT, and DISCIPLINE were all not significant (ns).

Table 7. Duncan's Multiple Range Test for the effects of office location and title on number of linkages and COMVALUE, IRRI, 1980.

OFFICE LOCATION	N	LINKS	COMVALUE
Chandler Hall	11	34.3a	32.3a
Genetic Resources Bldg.	11	21.8a	27.5 b
Forrest Hill Lab	11	18.5ab	23.4 b
LTCC Bldg.	16	13.7 b	23.2 b
Services Bldg.	7	13.3 b	22.7 b
Main Cafeteria & Dorm.	4	13.3 b	21.7 b
TITLE			
Director	5	40.2a	37.2a
Scientist	30	23.5 b	28.9 b
Associate Scientist	8	17.3 c	28.2 b
Administrator	5	15.8 c	23.8 b
Visiting Scientist	12	7.8 d	16.8 c

Note: Means having a common letter are not statistically significant at the 5% level for the respective variable.

FIGURE 1. A NETWORK OF COMMUNICATION LINKAGES WITH ABOVE-AVERAGE COMVALUES AMONG THE SENIOR STAFF OF THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER



NOTE: Nodes with the same letter belong to the same program. See Appendix 3 for program codes.

FIGURE 2. A NETWORK OF COMMUNICATION LINKAGES WITH ABOVE-AVERAGE COMVALUES AMONG THE SENIOR STAFF OF THE INTERNATIONAL RICE RESEARCH INSTITUTE

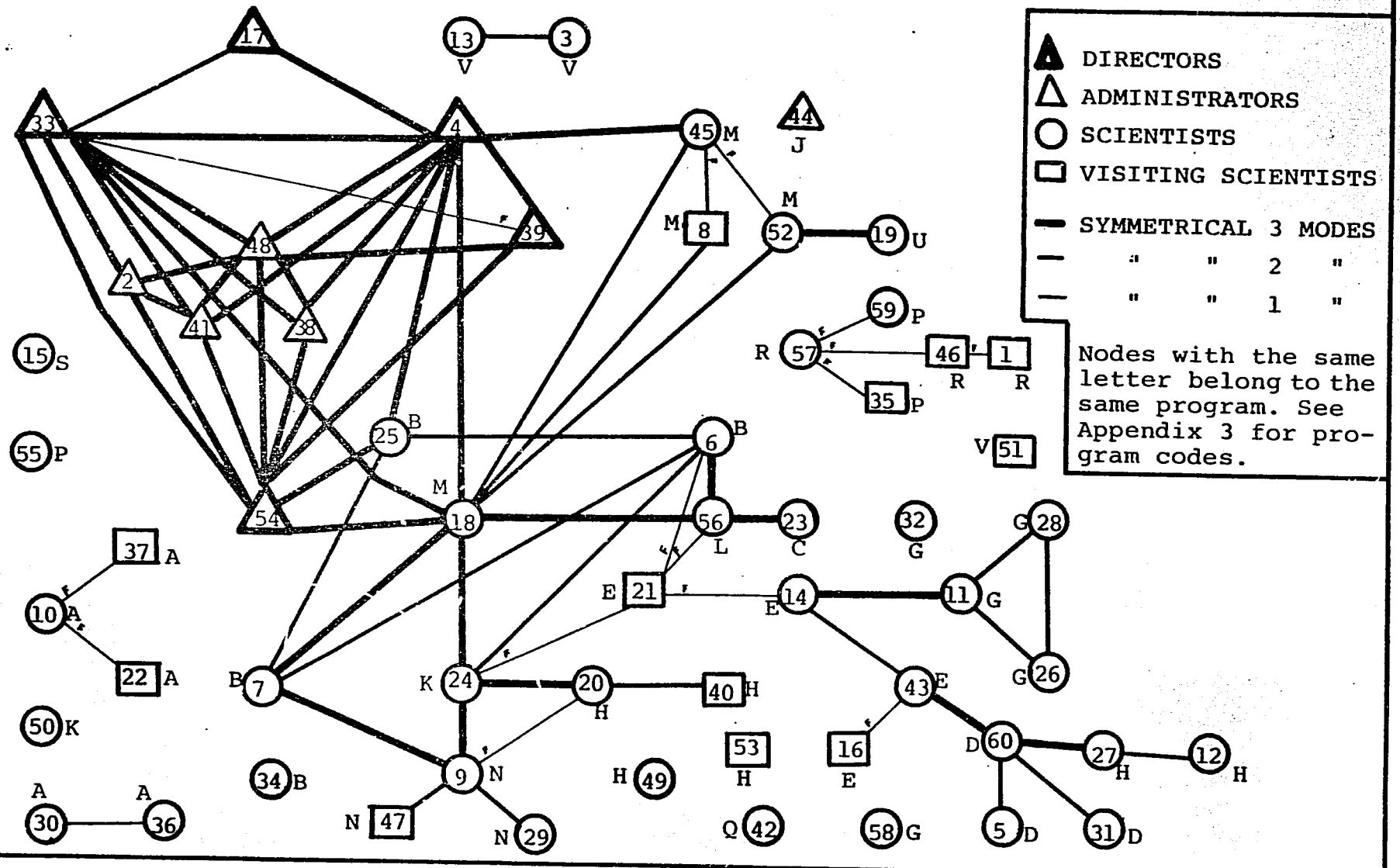


Table 1. Some comparisons between various networks at IRRI and AVRDC, 1980.

	IRRI (N=60)			AVRDC (N=28)		
	FACE	TELE	WRIT	FACE	TELE	WRIT
BEFORE DISCARDING						
Possible links/node	3540	3540	3540	756	756	756
Density (%)[a]	73	48	55	89	50	46
Mean links/node	43	31	34	24	13	12
C.V. (%)[b]	7	6	7	16	49	58
Mean COMVALUE/node	10	9	11	15	7	6
C.V. (%)	31	42	37	33	74	78
AFTER DISCARDING[c]						
Links > mean COMVALUE (%)	40	40	33	40	20	18
Mean links/node	17	11	11	10	3	2
C.V. (%)	9	9	11	39	59	72

[a]Density = $\frac{\text{Actual links}}{N^2 - N}$ [b]C.V. = $\frac{\text{Standard deviation}}{\text{Mean}}$

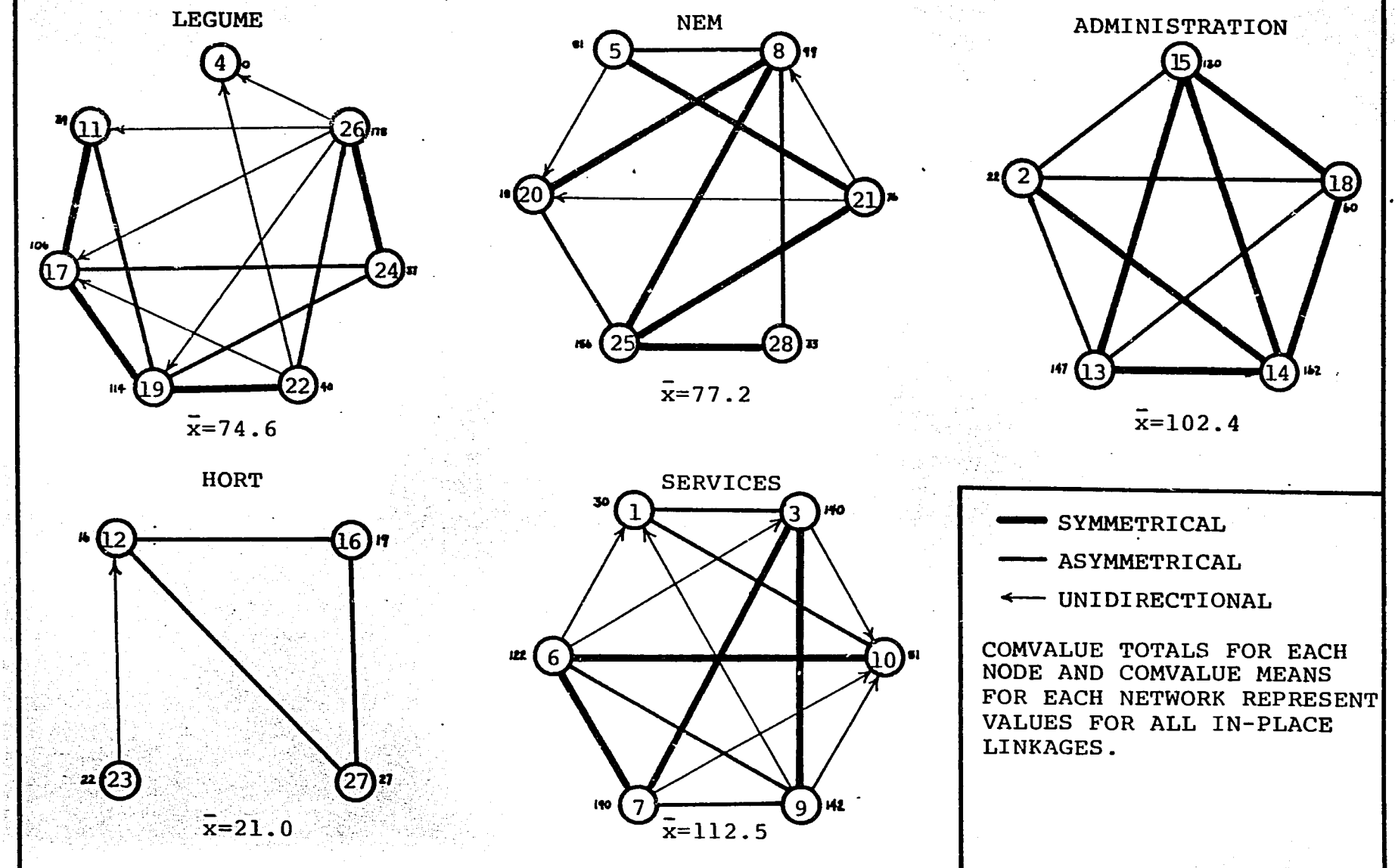
[c]Entries with COMVALUES below the respective network mean were discarded.

Table 2. Interaction indicators for program sub-networks at AVRDC, 1979.

	LEGUME	HORT	NEM	ADMIN	SERVICES
INTERNAL					
No. of nodes	7	4	6	5	6
Possible links	42	12	30	20	30
Density (%)[a]	50	58	67	100	73
Flexibility (%)[b]	63	38	58	100	68
Mean COMVALUE	75	21	77	102	112
EXTERNAL					
No. of nodes	21	24	22	23	22
Possible links	147	96	132	115	132
Density (%)	74	68	75	78	83

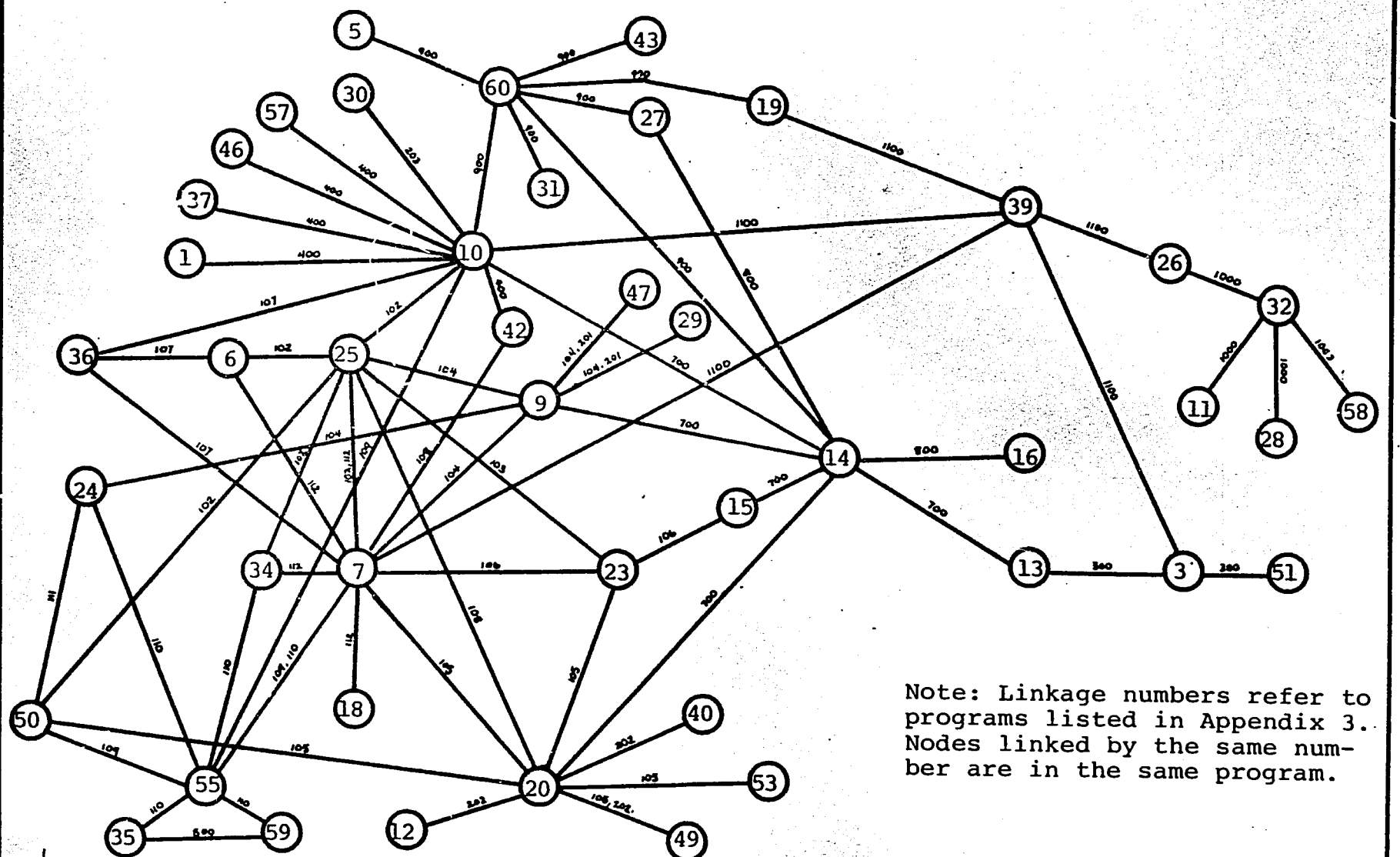
[a]See Table 1. [b]Flexibility = $\frac{\text{Actual links} - N}{N(N-2)}$

FIGURE 3. PROGRAM NETWORKS AT THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER



20

FIGURE 4. MINIMUM POTENTIAL COMMUNICATION LINKAGES CONNECTING MEMBERS OF THE RESEARCH PROGRAM NETWORKS AT THE INTERNATIONAL RICE RESEARCH INSTITUTE, 1980



Note: Linkage numbers refer to programs listed in Appendix 3. Nodes linked by the same number are in the same program.

FIGURE 5. COMMUNICATION LINKAGES WITH ABOVE AVERAGE-COMVALUES FOR THE RESEARCH PROGRAM NETWORKS AT THE INTERNATIONAL RICE RESEARCH INSTITUTE, 1980

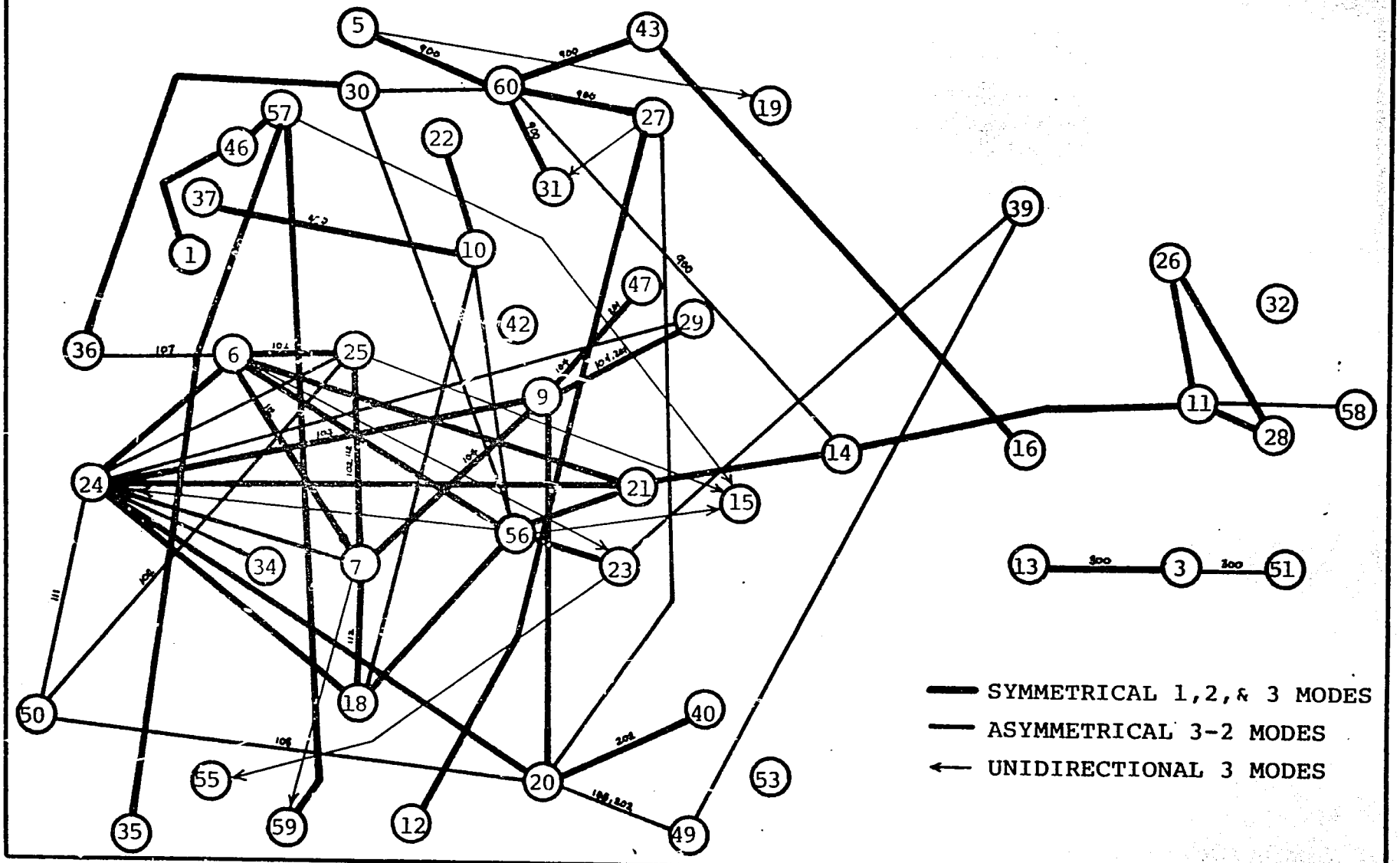


FIGURE 6. ADMINISTRATIVE ORGANIZATION AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

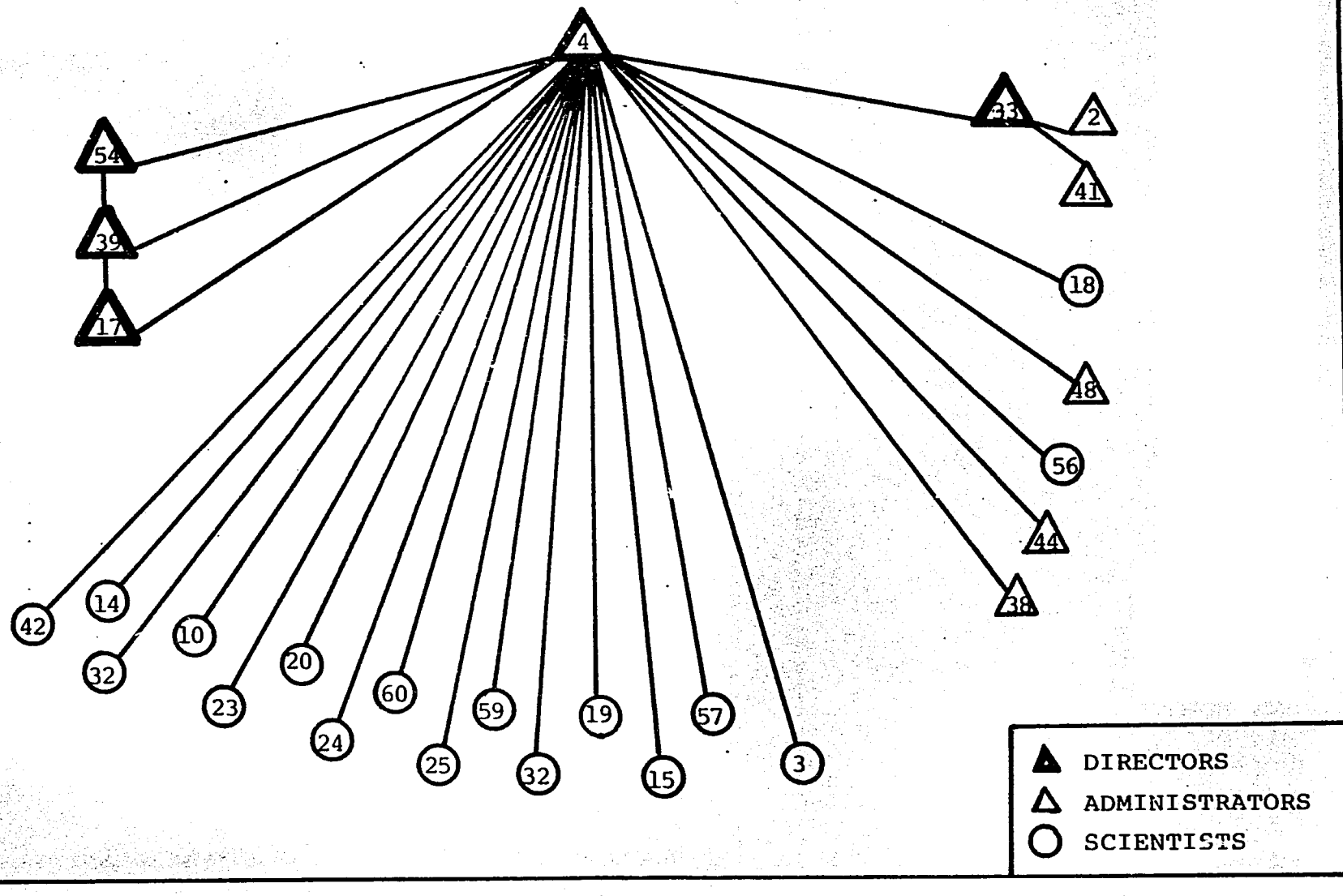


FIGURE 7. NETWORK OF ABOVE-AVERAGE COMMUNICATION LINKAGES AMONG THE ADMINISTRATION, SERVICES, AND HEADS OF RESEARCH DEPARTMENTS AT IRRI

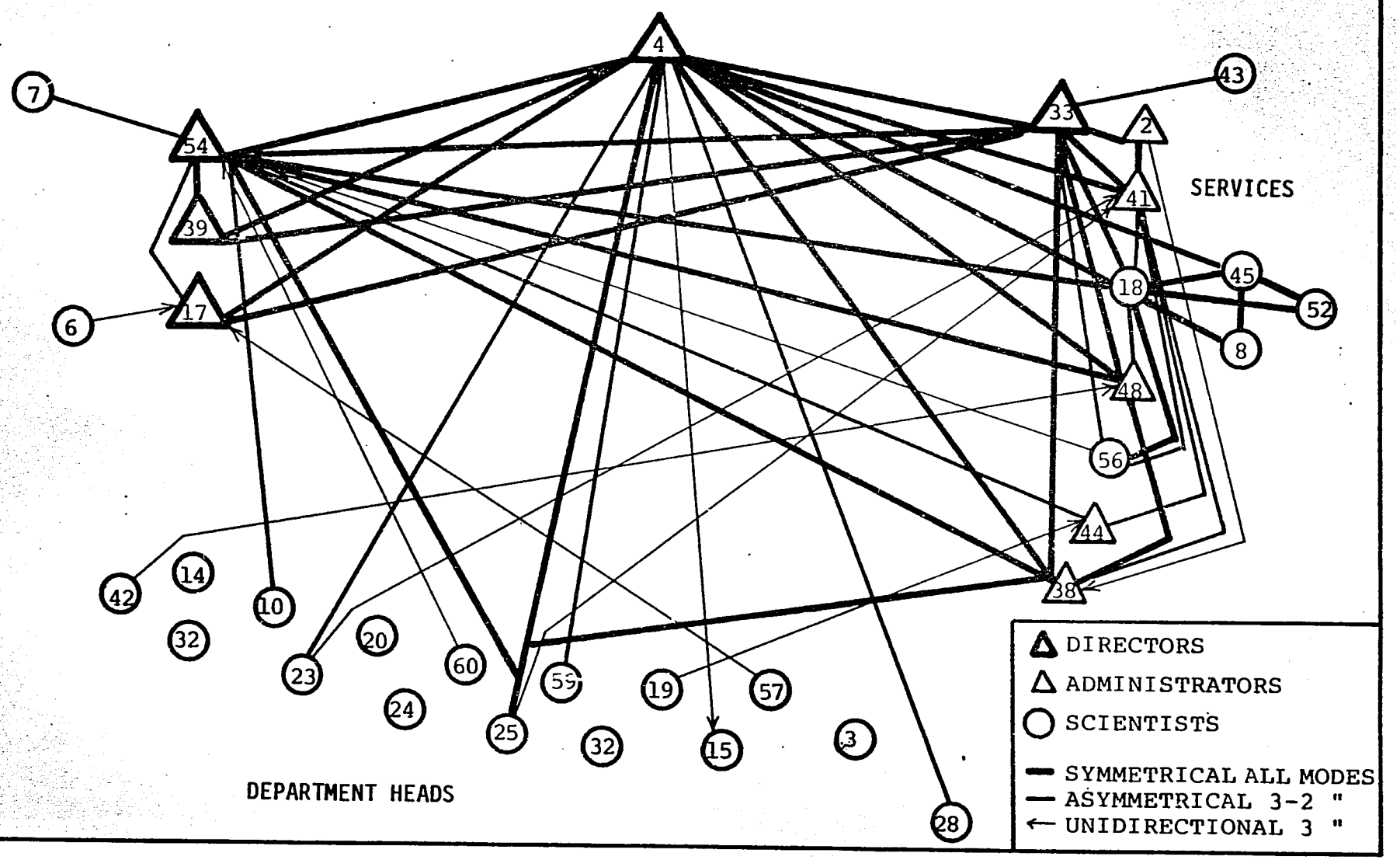
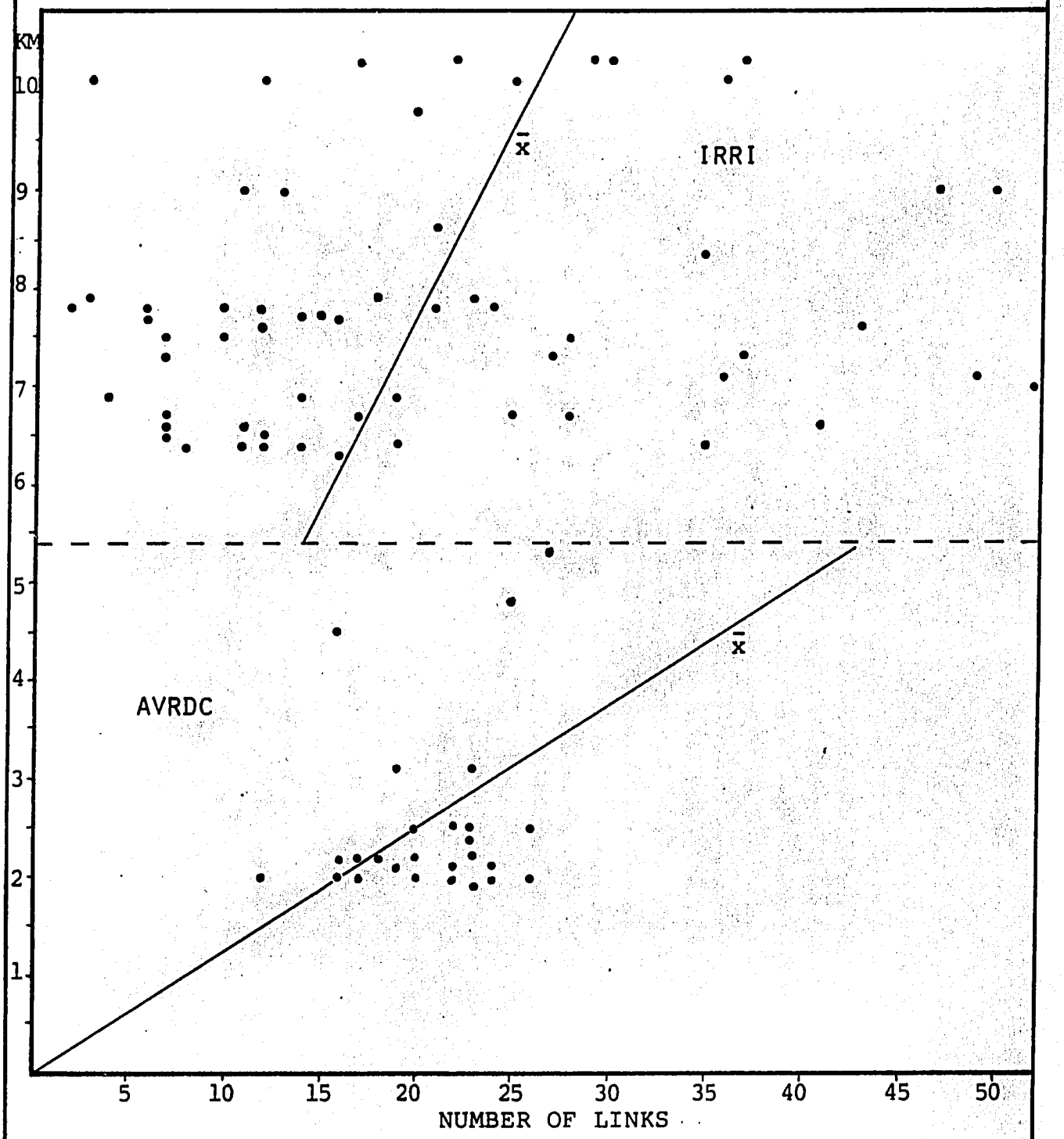


FIGURE 8. RELATIONSHIP BETWEEN TOTAL LINKAGES AND TOTAL DISTANCE BETWEEN OFFICES FOR NETWORKS AT IRRI AND AVRDC



Note: The total distance (km) is the sum of the distances between ego's office and all other offices at the respective institute.

FIGURE 9. RELATIONSHIP BETWEEN NUMBER OF NODES COMMUNICATED WITH BY EGO (LINE VALUES) AND COMVALUE IN THE SENIOR STAFF NETWORK AT IRRI, 1980

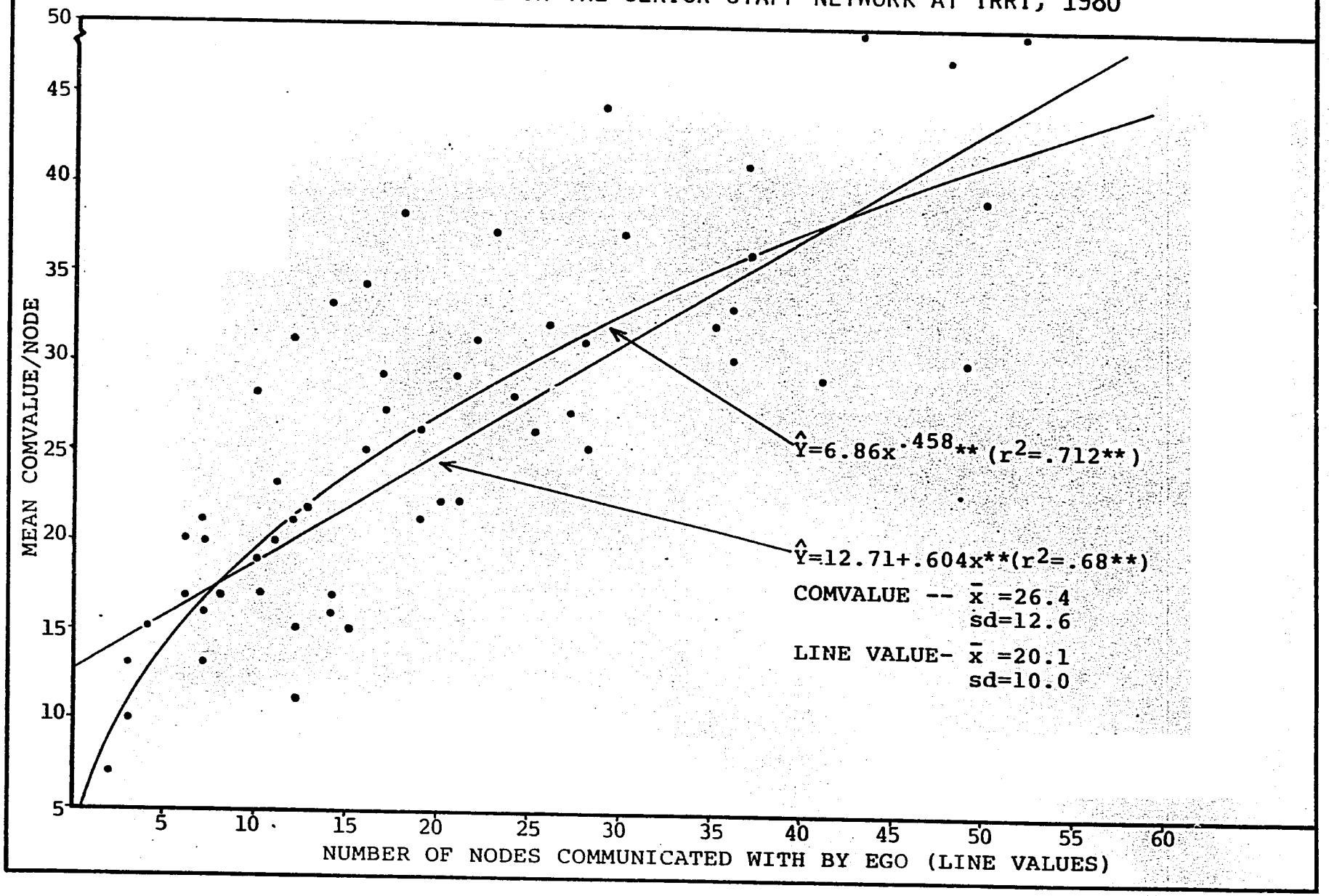
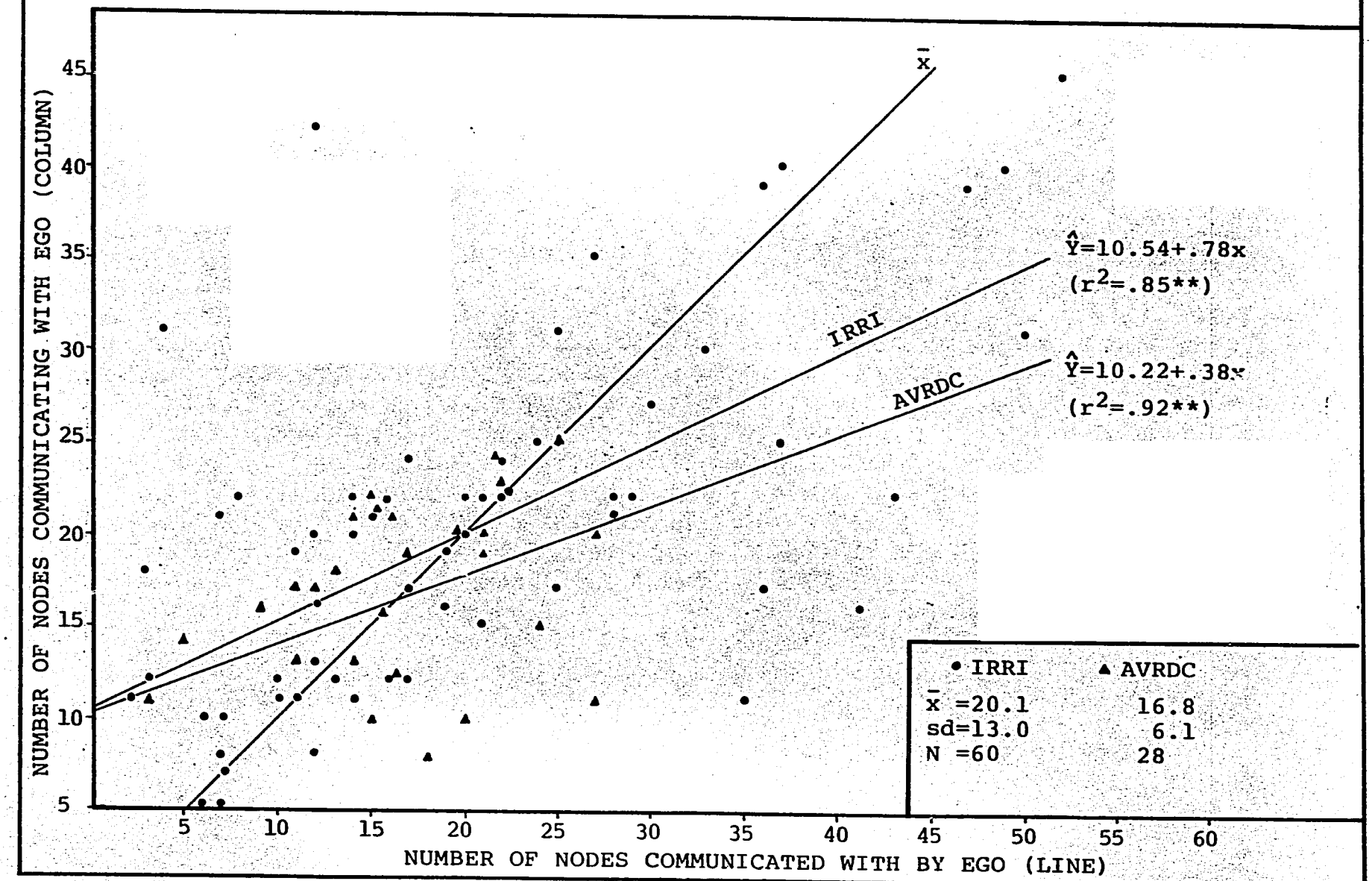


FIGURE 10. RELATIONSHIP BETWEEN NUMBER OF NODES COMMUNICATED WITH BY EGO (LINE) AND NUMBER OF NODES COMMUNICATING TO EGO (COLUMN) IN NETWORKS AT IRRI AND AVRDC



APPENDIX 1: COMMUNICATION NETWORK ANALYSIS SURVEY FORM

_____
print your name in English above

Below are the names of senior staff members. We wish to determine the frequency and importance of three kinds of communication acts between you and others on the list. The scores should represent only work-oriented communication during working hours at the center. Using the *Communication Frequency Scale* below indicate how often you communicate with each person on the list face-to-face. Then subjectively evaluate the importance of this communication using the *Communication Importance Scale*. Then repeat this procedure for communication by telephone and in writing. Please return this survey by: _____.
Thank you for your cooperation.

Communication Frequency Scale

6 - Three or more times /day
5 - Once or twice each day
4 - Several times each week
3 - Once each week
2 - Several times each month
1 - Once each month
0 - No communication

Communication Importance Scale

0——————5——————9
low high

	FACE-TO-FACE		TELEPHONE		WRITING	
	FREQ.	IMP.	FREQ.	IMP.	FREQ.	IMP.
01 Juan de la Cruz						
02 John Smith						
03 John Q. Citizen						
04 etc.						
⋮ n						

APPENDIX 2: INDEX OF RESPONDENTS' TITLES

IRRI SENIOR STAFF

01 Soil microbiologist
02 Attorney, purchasing & security
03 Agri-engineer, water mgmt.
04 Director-General
05 Agronomist, multiple cropping
06 Plant breeder
07 Plant breeder
08 Editor
09 Pathologist
10 Agonomist
11 Agri-economist, engineering
12 Entomologist
13 Agri-engineer
14 Agri-economist
15 Statistician
16 Anthropologist
17 Director, research
18 Editor
19 Head, rice production training
20 Entomologist
21 Geographer
22 Soil scientist
23 Nutritional chemist
24 Pathologist
25 Plant breeder
26 Agri-engineer
27 Entomologist, multiple cropping
28 Agri-engineer
29 Pathologist
30 Agronomist (weeds)
31 Agronomist, multiple cropping
32 Agri-engineer
33 Director-administration
34 Plant breeder
35 Physiologist
36 Agronomist
37 Agronomist
38 Head, food & dormitory services
39 Director, training & international
40 Entomologist
41 Attorney, personnel
42 Soil chemist
43 Agri-engineer
44 Farm manager
45 Editor
46 Soil microbiologist
47 Pathologist
48 Controller
49 Entomologist
50 Plant breeder
51 Agri-economist, water mgmt.
52 Editor
53 Entomologist
54 Deputy Director-General
55 Physiologist
56 Librarian
57 Soil microbiologist
58 Agri-engineer
59 Physiologist
60 Agonomist, multiple cropping

AVRDC SENIOR STAFF

01 Training officer
02 Superintendent, buildings & grounds
03 Development officer
04 Research assistant, breeding
05 Research assistant, crop mgmt.
06 Editor
07 Seed technician
08 Agronomist, crop mgmt & statistics
09 Librarian
10 Editor
11 Physiologist
12 Research assistant, breeding
13 Farm manager
14 Assoc. Director, administration
15 Director
16 Plant breeder
17 Plant breeder
18 Assoc. Director, research
19 Plant breeder
20 Entomologist
21 Research assistant, crop mgmt.
22 Research assistant, breeding
23 Research assistant, breeding
24 Pathologist
25 Nutritional chemist
26 Research assistant, breeding
27 Pathologist
28 Soil scientist

APPENDIX 3: INDEX OF PROGRAM AND DEPARTMENT NAMES

IRRI

DEPT CODE	PROBLEM AREA NO.	COMPUTER NAME	DEPARTMENT and/or PROGRAM[a]
A			Agronomy
B			Plant Breeding
C			Chemistry
D	0900	CROPSYS	Multiple Cropping Systems
E			Agricultural Economics
F	0100	GEU	Genetic Evaluation and Utilization of Rice Program
G	1000	MACHTRNG	Agricultural Engineering
H	0200	RICEPEST	Entomology
J			Experimental Farm
K			International Rice Testing Program (IRTP)
L			Library and Documentation Center
M			Office of Information Services (OIS)
N	0200	RICEPEST	Plant Pathology
P			Plant Physiology
Q	0400	MGMT	Soil Chemistry
R			Soil Microbiology
S			Statistical Services
U	1100	MACHTRNG	Rice Production Training and Research Program (RPTR)
V	0300	MGMT	Irrigation and Water Management
	0500	--	Environment and its Influence on Rice
	0600	--	Post-Harvest Managment of Rice
	0700	CONSCONS	Constraints to Rice Yields
	0800	CONSCONS	Consequences of Rice Technology

AVRDC

CODE		DIVISION and/or PROGRAM
A	ADMIN	Administration
B	HORT	Horticultural Crops Program
C	LEGUME	Leguminous Crops Program
D	NEM	Nutrition, Environment, and Management Program (NEM)
E	SERVICES	Services and Support Group

[a]Departments with corresponding problem area numbers have major responsibility for research into those problems. Problem areas without corresponding departments have shared responsibility.