The daily bread in Turkey: (clockwise from left) making flat durum bread, a girl carrying a homemade raised loaf, a village bakery.

TURKEY'S WHEAT RESEARCH AND TRAINING PROJECT

Since 1970 Turkey has developed a vigorous national wheat improvement program. CIMMYT and several other organizations have helped by assigning scientists to work in the program during its formative years and by training Turkish scientists.
Traffic jams outside grain storage terminals are a cheering consequence of Turkey's recent investment in modern agricultural research. In the summer of 1976, along roads to the depots, the crush of trucks and wagons heaped with wheat was so great that many waited up to 48 hours to unload. The tie-ups were a trivial price for a harvest that was even larger than the record-breaking crop of 1975. In Turkey, which consumes over 200 kilograms of wheat per person annually —more than any other country— the size of the wheat crop is a measure of national economic health.

Of course the weather was good in both 1975 and 1976. But in the last 10 years not only have yields per hectare been higher than ever before when the weather was good, yields in bad years have not been the disasters that they once were. In the worst year of the decade ending 1975, the national average wheat yield was equal to the yield in the second best year of the previous decade. Overall, yields have risen 3.3 percent a year during the last decade, compared with a population growth of 2.6 percent a year.

Turkey's rapidly rising wheat yields are linked with two notable events: the massive introduction of new varieties, largely from Mexico, in the late 1960's and the founding of the National Wheat Research and Training Project in 1970.

The 50 well-trained and competent scientists and technicians who staff the wheat project are transforming Turkish wheat farming. Their achievements have been so impressive that Turkish policymakers are restructuring research on crops such as barley, potatoes, maize, and sunflowers along the lines of the wheat project.

**Mexican imports**
The seeds, literally and figuratively, of the wheat project were planted by a farmer near Adana on Turkey's Mediterranean coast in early 1965. He planted two short Mexican varieties, Sonora 64 and Lerma Rojo, which a technician of the U.S. Agency for International Development had imported from India—where they were giving startling yields. The field of Mexican wheats looked so good to neighboring farmers that a hundred of them banded together to buy 60 metric tons of Sonora 64 seed from Mexico. The imported seed was planted at the end of 1965. A year later a group of U.S. agricultural scientists, visiting at the request of the Turkish government, suggested, first, making a

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study of the experiences of the 100 farmers with Mexican wheats and, second, considering large-scale imports of Mexican wheats. Turkey both made the study and ordered the imports for the 1967/68 season which was less than a year off. With financial and technical assistance from USAID, Turkey bought 22,000 tons of Mexican wheat and conducted a broad-scale educational campaign to help farmers get the most out of the new wheats.

In the 1967/68 season, 60,000 Turkish farmers planted Mexican wheats on 170,000 hectares. The wheats, primarily Penjamo 62, Lerma Rojo 64, and Super X, yielded 3000 to 4000 kg/ha, double and triple the yields of native wheats in the same region. Other farmers rushed to try the seed. By 1971 Mexican wheats covered 1 million hectares.

The elation over the Mexican wheats was tempered, however, by some ominous signs: the Mexican varieties were not strongly resistant to Turkish strains of two fungus diseases, septoria leaf spot and stripe rust. But neither were most native varieties. (Penjamo remains today the most widely planted wheat in coastal areas. Although it is fairly susceptible to both diseases, it nevertheless yields better than traditional wheats).

The widespread adoption of the Mexican wheats in coastal Turkey underscored how rapidly farmers would respond to profitable new ideas. Turkish officials realized, however, that to hold or raise the yield levels set by the Mexican varieties would take a steady flow of new varieties. Moreover, while the coastal regions had benefited from the Mexican wheats, the vast Anatolian plateau, with three-fourths of Turkey’s wheat land, was unaffected because it requires cold-tolerant “winter wheats.”

Turkey asked the Rockefeller Foundation to help design a program for wheat improvement and for training Turkish scientists.

In 1969 Turkey and the Rockefeller Foundation signed an agreement for a national wheat improvement project. The goals were to make Turkey self-sufficient in wheat and to establish a model agricultural research organization.

In 1970 Bill Wright, a veteran Rockefeller Foundation agronomist who had been working in India, was assigned to be co-director of the Wheat Project with Ahmet Demirlicakmak, one of Turkey’s leading wheat scientists.

From the start, the project called on CIMMYT and Oregon State University (USA) for scientific help in critical areas and to train Turkish scientists. Under a grant from the Rockefeller Foundation, CIMMYT placed two scientists in the project, J. Michael Prescott, a plant pathologist, and Arthur R. Klatt, a plant breeder. Both arrived in Turkey in 1971. Under another Rockefeller grant Oregon State University assigned Floyd Bolton, an agronomist, to the project. In later years the Rockefeller Foundation provided an economist and an experiment station development supervisor. In addition, a four-man team of agronomists from Oregon State University, supported by USAID, worked closely with the wheat project on fallow-farming techniques.

The actions of the Turkish government underscored its deep commitment to the wheat project and to more productive wheat production. When the project started, several dozen government wheat scientists were promptly transferred to it. The government provided offices and experimental land at the Ankara Agricultural Research Institute. It established regulations that permitted foreign scientists and trainees to enter and leave Turkey easily. And not the least, it maintained a price ratio between wheat and agricultural inputs that made farmers eager to find ways to expand their wheat production.

Priorities

The research needs of the spring-wheat areas and the winter-wheat areas were not identical (See box: “The wheat zones of Turkey”). When the wheat project began, the fundamental problems were poor farming practices in the winter-wheat areas and insufficient wheat-disease resistance in the spring-wheat areas.

In the Anatolian plateau, where 80 percent of Turkey’s winter wheat grows, yields were meager because of low rainfall and because conventional tillage practices and the farmers’ indifference to weed control kept the soil from storing much moisture. “The most pressing problem in the winter-wheat area,” Ahmet Demirlicakmak said, “is to develop a set of tillage practices which will permit the early establishment of the wheat seedling (preferably germinating from residual moisture) and the greatest conservation of rain falling on the fallow land.”

In the spring-wheat areas, farmers grew cash crops such as tobacco or cotton in addition to wheat. Farmers were already using improved practices and inputs such as fertilizer on their cash crops. It was not difficult to persuade them to take advantage of the high yield potential of the Mexican wheats. Most of the dozen imported Mexican wheats, however, showed susceptibility to the prevalent virulences of stripe rust in Turkey and to septoria leaf blotch. While Penjamo was not resistant to these diseases it was tolerant enough to yield well, so farmers switched to it in large numbers. Penjamo established that high yielding varieties offered large profits to the spring wheat farmers of coastal Turkey. The clear need was for a flow of new varieties that would combine the productivity of the Mexican wheats with strong resistance to local strains of wheat diseases. In addition, coastal farmers needed varieties with rather special growth habits. Ideally the new varieties would have a long vegetative phase—the period before flowering—so they could be planted in the autumn before the rains made the fields muddy and impassible, yet would not flower until the threat of frost had
passed in the spring. Moreover, the varieties grain should fill and ripen before hot, dry weather of June.

Scientific organization
The wheat project reorganized wheat research in Turkey. One change was to gather scientists with different specialties into a multidisciplinary staff. In Turkey, as in many countries, scientists had been grouped by specialties. One Turkish scientist recently observed, "Before the wheat project it was impossible to have a breeder, pathologist, and cereal technologist work together, even by force. Day by day the philosophy is changing." The wheat project brought scientists together with the common goal of improving wheat production. Under the wheat project, for example, plant pathologists create epidemics of rust in breeding lines and then work side-by-side with the breeders to select resistant plants.

Another change was the creation of a truly national wheat improvement program. Eleven experiment stations in different regions of the country were working on wheat. Some had strong programs and some had weak ones. But there was little exchange of ideas or seed. Bringing the wheat scientists at each station into a nationwide project allowed the stations to reinforce each other's work. Basic to the integration of wheat research is an annual meeting at Ankara at which wheat scientists from all stations review the year's results and plan the next year's work.

Training
The wheat project's policy has been to deliberately suffer temporary understaffing in order to upgrade the knowledge and skill of its scientists. Shortly after the project was formed in 1970 it boldly sent half of the nation's wheat scientists abroad to study. Six scientists went to the USA to study for advanced degrees and three flew to Mexico for CIMMYT's 9-month in-service training course.

Since then, most scientists have been sent to the CIMMYT training program first. After returning to Turkey and working for a time, some are sent abroad again for graduate studies. At CIMMYT the scientist works in the field alongside CIMMYT staff members, gaining first-hand experience in one of the world's largest crop improvement programs. A trainee in the breeding curriculum, for example, becomes familiar with a myriad of genetic materials from throughout the world and he learns how to breed, select, and test thousands of lines a season. Most important of all, the trainee learns by daily example the need for diligence, long hours, teamwork, and a sense of urgency in a successful agricultural research program.

The trainee returns to Turkey and puts his knowledge to use. If he performs well in the CIMMYT training program and at home, he may receive a grant to study for a master's degree.

By 1976, 22 Turks from the wheat project had completed master's degrees, mostly at Oregon State University. Twenty-eight Turks had passed through the CIMMYT wheat training program. All but four of Turkish scientists sent to study abroad by the wheat project are still working in it.

The presence of scientists from OSU and CIMMYT in Turkey has been valuable for choosing candidates who could make the best use of training in other countries. It also has ensured continued contact after the Turkish scientists returned home. Furthermore, the familiarity of OSU faculty members with Turkey has allowed the advanced-degree programs to be tailored to Turkish research needs.

Training has not been limited to overseas studies. When young scientists enter the wheat project they are assigned to work with a more experienced scientist for a time. All young breeders, for example, have gone to the Izmir or Ankara stations to help during crossing and selection and to learn from the scientists at these stations.

The wheat project has also contributed to tillage training programs for Turkish extension workers. The OSU team, in 1973, conducted courses in new tillage techniques for extension workers from 20 provinces where the Ministry of Agriculture was
conducting an intensive wheat production campaign. In 1974, it worked with extension officials from five high priority provinces where the government hoped to make wheat production more profitable. In 1975 teams of researchers and extension agents in Ankara province set up farmer demonstration plots. The extension personnel attended training sessions with the researchers.

The capacity of the wheat project to do training has grown to the point that scientists from nearby countries are coming for training, especially in tillage techniques. Several dozen researchers from Iran, Jordan, and Afghanistan have visited Turkey for training.

Breeding

Plant breeders in the wheat project make over 5000 crosses a year. By this measure, Turkey has one of the world's largest national wheat improvement programs. Most of the crossing is done at three stations: Winter wheat at Ankara in the central plateau and at Eskisehir on the edge of the mountainous transitional zone; spring wheat at Izmir on the Aegean Coast. All winter wheats, however, are sent for testing at Erzurum in eastern Turkey, at Diyarbakir in southeastern Turkey, and at Edime in Thrace (European Turkey) as well as at Ankara and Eskisehir. Spring wheats are tested at Izmir and at Yesilkoy near Istanbul; at Adapazarı, east of the Marmara sea; at Samsun on the Black Sea Coast; and at Antalya and Adana on the Mediterranean Coast.

At each station, scientists select plants that have the greatest disease resistance, most vigorous and productive-looking plant type, the best grain characteristics, and so on, under the local conditions. Seed from the selected plants is grown again at the station and it may be designated for crossing with other lines or varieties to make it better fit local conditions or it may simply undergo further selection.

When a line has passed through several generations of selection it is sent for testing at the other stations. The tests in diverse ecological zones provide data on disease resistance and overall adaptability of the line that would take years to equal if testing were restricted to the station at which the original selection was made.

In addition, the nationwide testing gives scientists at one station access to the best lines from elsewhere. If, for example, a line from Adana performs well at, say, Samsun, the scientists there can make further selections in it to meet the farming conditions of the Samsun area.

The Izmir station plays a pivotal role in the flow of genetic materials. The climate of Izmir allows both winter wheats and spring wheats to be grown. Thus Izmir maintains a crossing block of both spring wheats and winter wheats. A crossing block is a collection of generally superior varieties and lines whose characteristics have been carefully categorized. When one of the smaller stations wants to strengthen a line it has selected, it can send seed of the line to Izmir and specify with what parents it should be crossed. Izmir makes the crosses and returns F1 seed.
Spring wheats
The quest for varieties to supplement Penjamo in the spring wheat regions began with an enormous screening program in 1970. Basri Devecioglu, who had studied in the U.S.A., and who had spent several months at CIMMYT, returned to the Izmir station from Mexico in 1969 with seeds of over a million F2 plants. The seeds were planted in 1970 and 1971. Fortuitously, one of the periodic outbreaks of septoria leaf blotch occurred in 1971 permitting Devecioglu, his colleagues, and CIMMYT scientists to rate the resistance of the lines thoroughly. In subsequent years severe epidemics of stripe rust further helped separate the weak lines from the strong. Aided by the natural epidemics, the Izmir scientists were able to identify good sources of resistance, but they also established that few lines combined high yield potential with resistance to both septoria and stripe rust.

As a result, a crossing program was launched to concentrate desirable characteristics from selected lines. In this program the Izmir station makes most of the crosses and grows the F1 progeny. Izmir sends early generation lines that are segregating genetically to the other spring-wheat stations where scientists can select the lines that are best adapted to the local environment.

After several generations of eliminating undesirable and off-type plants, the lines' characteristics have become fixed (genetic segregation has stopped) and seed has been increased. The Izmir station assembles uniform trials of all advanced lines submitted by the spring-wheat stations. The trials are grown at each of the stations. The results allow the new lines to be compared in performance with each other and with farmer's varieties throughout coastal Turkey. Lines must be grown in uniform trials for three seasons before they can be considered for release as a variety. If a line is released as a variety, the State Farms multiply the seed and distribute it to farmers. The State Farms can produce 300,000 metric tons of wheat seed a year on their own land and through contracts with farmers. That amount of seed is enough to plant a third of the nation's wheat fields.

All these steps take time. It is rarely less than 10 years from the initial cross until farmers have a new variety to pour into their grain drills. Recognizing this, Turkish spring-wheat breeders proceeded to select and test the introduced Mexican crosses even while beginning their own crossing program.

By 1974, Turkish trials confirmed the exceptional yield potential of the Mexican durum variety Cocorit 71. It was released as Dicle 74. By 1975, enough data had been accumulated to release three more spring varieties selected from Mexican crosses. One was a durum named Gediz. This variety, like Dicle, yields 50 to 100 percent more than native durums, but in addition its grain has much better quality than that of Dicle. The new bread wheat varieties were called Cumhuriyet 75 and Sakarya 75. Cumhuriyet, says Art Klatt, "has excellent yield potential, is widely adapted, and has excellent white grain, a factor which will greatly enhance its adoption by the Turkish farmer." Sakarya has early maturity, a valuable feature for farmers who plant wheat after cotton.
Dicle is the most extensively grown of the new varieties. About 4000 metric tons of seed were planted by farmers in the 1975/76 season (1 ton of seed plants about 10 hectares). Only 22 tons of Cumhuriyet seed were in farmers’ hands in 1975/76, but 2000 tons are being planted in 1976/77. Seed of Sakarya and Gediz will be widely available to farmers in 1977/78.

Farmers who have tried the new varieties as replacements for Penjamo are enthusiastic. In a village near Izmir, farmers have placed a voluntary levy on each ton of their wheat production to help support research at the Izmir station. Polat Solen of the Izmir station says, “now farmers are interested in research. They are already asking, ‘Do you have anything better than Cumhuriyet?’”

In 1976, 40 advanced lines were available as candidates for the uniform trials. Many of these lines are capable of yielding over 7000 kg/ha for skilled farmers compared with peak yields of 4500 kg/ha for Penjamo.

Winter wheat breeding
The Anatolian plateau of Turkey not only is colder than the spring-wheat regions, it is drier. In each year farmers have half their land in fallow to store rainfall and the other half in wheat. In the next year, the previously fallowed land is planted and the moisture in the soil plus the precipitation during the crop season may be enough to sustain the wheat crop. Often it is not. Average yields in the Anatolian plateau are half the yields in the spring wheat regions.

Under poor growing conditions, varieties with high yield potential perform little better than other varieties. Thus in the Anatolian plateau the wheat project logically emphasizes agronomic research to find better ways to grow winter wheat.

For farmers who have learned to provide a good environment to the crop, however, two winter-wheat varieties are already available which will provide ample yields. One is Bezostaya. Turkey received 200 tons of Bezostaya in the late 1960’s from the USSR where the variety had been developed. In Thrace (European Turkey), which gets over 500 mm of precipitation a year, Bezostaya was an instant success. By 1972, three fourths of the wheat harvested in Thrace was Bezostaya. In the dry Anatolian plateau, however, farmers adopted Bezostaya more cautiously. At present it covers just 5 percent of the Anatolian wheat area.

The other variety is the result of a cross made in the USA (at the University of Nebraska) and sent to Turkey as part of an international winter-wheat disease nursery. The cross never was named a variety in its home country, but scientists at Eskesehir made selections and released one under the name Bolal in 1974.

Bolal is just beginning to reach farmers, but it promises to become quite popular. In poor seasons it yields better than Bezostaya and in good seasons it yields as well. Both varieties have red seeds

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<th>LARGEST WHEAT PRODUCERS (1971-1975 avg)</th>
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which is a disadvantage—but not an overwhelming one—in Turkey where white seeds are preferred.

The stations of the wheat project have submitted 25 winter-wheat lines to the Regional Variety Testing Institute. This is the final stage of testing before release.

Winter-wheat breeders are selecting for winter-hardiness, disease resistance, and high yield potential. Though winterhardiness is a requisite, Turkey’s winter weather is less severe than the weather in many other winter-wheat areas of the world so breeders can call on a rich stock of genes for this character.

Varieties with better resistance to disease are urgently needed. Mike Prescott estimates that two fungus diseases, common bunt and loose smut, skim 5 percent off Turkey’s wheat production year-in and year-out. Rust outbreaks don’t occur in every year. But because rusts thrive in years of good rainfall they can turn May’s bumper outlook into July’s bitter harvest.

Despite rapid population growth, the per capita food supply is improving in Turkey.

Currently, no widely planted winter-wheat variety has good resistance to stripe rust, the worst threat. The traditional varieties have less resistance than the newer varieties.

The efforts of the breeders and pathologists to create artificial epidemics systematically in breeding lines and then identify ones with strong disease resistance will ensure that future winter wheat varieties have more stable yields.

High yield potential is synonymous with responsiveness to good management. As the wheat project’s agronomists bring better growing methods to farmers, breeders are developing winter wheats that will produce large numbers of plump grains without lodging (falling over). The tendency of tall traditional varieties to lodge in years of good rain-
fall and when soil fertility is high places a low ceiling on their potential response to better techniques of cultivation.

Another goal of the winter-wheat breeders is to produce early maturing varieties. In the Anatolian plateau winter wheats take about 8 months from planting to harvest. Flowering occurs in the middle of May, Breeders would like varieties that flower at the beginning of May, thus shaving 10 or 15 days off the winter-wheat growing season. Such varieties would have two advantages: they would be less vulnerable to late-season drought and they would usually flower and fill grain before the start of hot summer weather.

Genetic sources of early maturity are scarce for Turkish breeders. Nearly all the winter wheats of North America and Europe are even later maturing than existing Turkish wheats. Some winter wheats from USA (Texas and Oklahoma) and Rumania are being used as sources of earliness. But Turkish breeders are placing more of their hopes in crosses of spring wheats with winter wheats.

Spring x winter
Winter bread wheats are the same species as spring bread wheats. But through the history of wheat improvement they have been bred separately. One reason is that the vernalization requirement which is desirable in winter wheats is unacceptable in spring wheats. As a result winter wheats and spring wheats have become rather distinct genetic pools. That is, certain common genes in winter wheat are rare in spring wheats, and vice-versa.

The Turkish wheat project, CIMMYT, and Oregon State University are intercrossing the two pools to produce better spring wheats and winter wheats.

At a village tea house, three farmers discuss the wheat crop with an extension worker and Necati Celik (right) of the wheat project.

The Turkish wheat project annually makes about 1500 crosses between spring and winter wheats. CIMMYT also makes spring x winter crosses and sends part of the seed to Turkey and OSU. OSU adds an extra dose of winter germ plasm and sends part of the resulting spring x winter progeny to Turkey.

Turkey is interested in developing both spring types and winter types from spring x winter crosses. CIMMYT, which acts as the hub of a network of spring-wheat breeders throughout the developing world, is interested in spring types from spring x winter crosses. And OSU is coordinating international nurseries of winter wheats derived from spring x winter crosses. Each of these programs mutually benefits from exchanging new lines and data.

Turkish breeders see the spring x winter crosses to be a bright hope for developing earlier maturing winter wheats. The first Turkish spring x winter crosses were made in 1973. For 2 years before that the wheat project requested and then evaluated winter-wheat-varieties from throughout the world. Spring wheats to use as parents were no problem—a wide spectrum of Mexican-bred spring wheats were available.

Turkish breeders quickly determined that spring growth habit is dominant, so simple spring x winter crosses result in few segregates that have winter growth habit. Now breeders routinely cross F1 spring x winter plants with a winter variety to raise the proportion of winter-type progeny (the cross of an F1 plant with another variety is called a topcross).

In practice the system works like this: At Ankara winter wheats are crossed with spring wheats under the supervision of Ali Bayraktar. The F1 seed is sent to Izmir where the F1 plants are top-crossed to winter varieties and lines. In Izmir’s clement weather the plants produce large amounts of seed which is returned to Ankara. In addition, the Izmir climate permits good ratings of the plants for disease resistance.

Breeders expect that the winter wheats resulting from spring x winter crosses will have better rust resistance and higher yield potential. The spring wheat types will have better drought tolerance, better resistance to septoria leaf blotch, and a wider range of maturities, as well as higher yield potential.

Progeny of the first spring x winter crosses make up about half of all advanced winter-wheat lines in the Turkish program. As advanced lines, they will be yield tested and compared with commercial varieties to determine which are good enough to be released to farmers. Paradoxically, Bolal, which has recently been released, is the result of a spring x winter cross made years ago in the USA.

Durums
Turkey is among the world’s largest growers of
durum wheat (*Triticum durum*). Turks eat durum as flat unleavened bread, as bulgur (steamed, cracked grains), and as noodles.

Most durum varieties grown in Turkey are unimproved native types. They yield feebly, respond poorly to fertilizer, and succumb to rusts. In the spring-wheat areas, durums were largely replaced by the high yielding imported Mexican bread-wheat varieties. Nevertheless, many farmers continue to plant a field of durum to eat while growing the more productive Mexican bread wheats to sell.

In areas where spring-wheat grows, durums are regaining lost ground as new high yielding durums, such as Dicle and Gediz, become more widely available. For areas that require winter wheats, however, durum improvement lags behind bread-wheat improvement.

Durum breeding is frustrating work because so few good potential parents exist. Breeders find themselves crossing one bad type with another, not surprisingly getting bad progeny. By contrast, breeders of bread wheat have a large palette of outstanding parent varieties to cross with locally adapted varieties.

Aside from their low yields and susceptibility to disease, winter durums are not as tolerant to cold as winter bread wheats. Most “winter” durums are facultative types rather than true winter types. The wheat project is screening native durums in hope of finding true winter durums for use as parents.

Breeders of the wheat project are transferring the yield potential of spring durums to winter durums through spring x winter crosses. Unfortunately, simple crosses of a spring and a winter durum result in progeny that have insufficient cold tolerance for the Anatolian Plateau though they grow well in milder areas. Adding an extra dose of winter germ plasm to give spring x winter x winter progeny improves cold tolerance but also concentrates the weak characteristics of winter durums.

Despite these difficulties, several winter-durum lines are already in the final tests leading to release.

**Cereal quality**

The wheat project established Turkey's first laboratory for evaluating cereal quality. The Rockefeller Foundation supplied equipment for the laboratory at the Ankara station and arranged for training one young Turk in cereal technology in the USA.

Each station uses the Pelshenke test to evaluate the flour from its early generation wheat lines. This simple test relates breadmaking quality to how fast a ball of dough falls apart when placed in a beaker of water under standardized conditions. Grain

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**Annual average Wheat production in Turkey 1951-1975**

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From increased yield

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From increased area

A roadside sign marks a demonstration of new varieties and recommended farming techniques.
from more advanced lines is sent to the Ankara quality laboratory for milling and baking tests. The results guide the breeders in crossing and selecting lines for better breadmaking quality.

Pathology
The ability of pathologists to create uniform artificial epidemics in the breeding nurseries frees the breeders from the whims of natural epidemics. Natural epidemics do not strike in every year and without disease breeders can't find and discard susceptible plants. Moreover, even when a natural disease outbreak occurs it may start in one part of a field and slowly spread. So when susceptibility ratings are made, some plants may have been exposed to the disease longer than others making comparisons unfair. By inoculating every plant, pathologists ensure that the breeders will be able to select for disease resistance in each season and that the breeders can be confident that the plants rated resistant are not accidental "escapes."

In addition to creating artificial epidemics of rust, pathologists have also developed ways to screen for resistance to such diseases as bunt, smut, and root rots.

The complementary activities of breeders and pathologists allow the wheat project to produce a gargantuan number of early generation lines and then reject the susceptible ones leaving a manageable number of advanced lines that have been methodically tested for resistance to Turkey's major diseases.

Another activity of the pathologists is the Turkish Trap Nursery. This nursery provides a nationwide record of the occurrence of diseases, it permits scientists to spot the mutations and other changes that are taking place in the disease organisms, and it gives a warning of the prospective vulnerability of Turkey's varieties.

The Turkish Trap Nursery contains 30 varieties currently grown by Turkish farmers, 10 advanced lines, 15 indicator lines for identifying stripe rust races, and 9 indicator lines for identifying leaf rust races. The pathologists plant the entire nursery at 50 locations throughout Turkey and take readings on it several times a season.

Among many uses, the trap nursery can provide an early warning that some minor disease is becoming an important threat or that a new rust virulence is building up. It can help scientists decide which currently planted varieties most urgently need replacement. And, as years of data accumulate, pathologists will be able to calculate the odds on outbreaks of various diseases.

Another project with immense potential rewards is screening for non-specific resistance to stripe rust. Usually, wheats are bred with specific or major-gene resistance to rusts. That is, a single gene confers resistance to a single type of rust virulence. When a new virulence becomes predominant the resistance gene is no longer effective. Then breeders must search for sources of a new resistance gene. Non-specific genes may provide a degree of resistance despite changes in the prevalent virulence.

Pathologists use a mixture of stripe rust spores to inoculate lines in the seedling stage and in the adult stage. They look for lines susceptible as seedlings but resistant as adult plants. Less than one in every 200 lines have this reaction. While several explanations are possible, some of those lines may carry genes that confer non-specific or generalized resistance to stripe rust and they could be used as parental sources of this characteristic.

Lines that are resistant in both the seedling and the adult stage have specific resistance genes though they may also have non-specific genes. It is however impossible to identify those with non-specific genes because of the masking action of the specific genes.

Screening winter wheats for non-specific resistance is done at Ankara by Necati Celik while spring wheats are screened at Izmir by Cevdet Dutlu.

Tillage
Farmers in the Anatolian Plateau leave half their land fallow to accumulate moisture from rain and snow, and plant the other half to wheat. The wheat crop then grows on moisture stored in the soil during the fallow year plus the precipitation that occurs during the season.

Water storage is the chief reason farmers rotate wheat with fallow, but leaving land idle has other benefits. It can improve the structure of the soil permitting better root growth, it can make more nitrogen available to plants through decay of organic matter and breakdown of soil minerals, and it can decrease weeds in the following wheat crop.

The inadequate water retention of fallow fields accounts in large part for low winter-wheat yields in the Anatolian plateau. Some water runs off before it can trickle into the soil, some evaporates, some is sucked up by weeds. Researchers have shown that even the local varieties could yield two or three times as much with better fallow-farming techniques.

Because yields of winter wheat in the Anatolian plateau have been nearly static during the last 25 years, farmers have attempted to meet the growing national demand for wheat by plowing and planting steep slopes and areas of thin soils that were previously relegated to livestock. Consequently, Turkey's total wheat area has doubled since 1950. But at the same time, more cattle and sheep are grazing less land, and erosion which starts easily in overgrazed pasture land can creep into adjoining cropland.

The wheat project's agronomists—Bill Wright, Floyd Bolton, and Nadir Izgin— and the OSU team put top priority on finding a set of farming techniques that would make more moisture available to the wheat crop and that could be readily adopted by Turkish farmers.
The large wheat harvests of recent years have filled wheat terminals to overflowing. In 1976 Turkey had 2 million metric tons of wheat available for export.

Complex experiments which tested tillage implements, timing of tillage operations, herbicides, fertilizers, seeding dates, and so forth, in numerous combinations, were conducted at research stations and state farms where experimental error could be carefully controlled. From these experiments, the researchers chose a few of the best combinations and compared them in farmers’ fields at several locations. These experiments, occupying 1.5 to 2 hectares, were called adaptive research trials. The “package” of practices that gave the best results in the adaptive research trials was set out in 10-hectare blocks in farmers’ fields as a demonstration for farmers and to train extension agents. These demonstration trials were conducted by the provincial extension service.

In adaptive research trials conducted from 1972/73 to 1974/75, the average yield of all sets of improved practices was 2170 kg/ha, double the yields of adjacent farmers’ fields. By 1974, the scientists of the wheat project were able to recommend a set of practices that they felt confident would give farmers yields of at least 2000 kg/ha in all except years of unusually low rainfall.

The extension service put out 10-hectare demonstrations of the recommendations in 10 locations in Ankara Province in 1974/75. These trials yielded 2530 kg/ha while adjacent farmers’ fields averaged 1810 kg/ha. The demonstrations were expanded to five provinces in 1975/76 and seven more provinces are being added in 1976/77.

The recommendations of the wheat project for the Anatolian plateau are as follows: The fields are untouched from the wheat harvest in July, until the next spring. In March or April, as soon as the soil is firm enough to support a tractor, the farmer plows his fields 18-cm to 20-cm deep with a sweep chisel followed by a spike-tooth harrow. A sweep is an implement with heavy curved tines each of which has two wing-like blades attached to the point. The plowing forms a mulch of wheat stubble and other plant material which will retard erosion and keep soil moisture from evaporating. The spike-tooth harrow firms the mulch and top soil layer. Instead of the sweep, a moldboard plow can be used, but it buries surface organic matter leaving the soil vulnerable to erosion.

Two to four weeks after the first plowing, depending on how fast weeds grow, the farmer tills the soil with a sweep to a depth of 12 to 14 cm.

Through the summer the farmer “sweeps” as often as necessary to control weeds (usually two or three more times).

By the time of planting in the fall these tillage operations should have produced a firm weed-free seedbed that is moist 10 to 12 cm below the surface and which is covered with a dry, loose mulch. Seed of a good wheat variety is drilled in the autumn as soon as enough rain has fallen to wet the top 12 cm of soil (although if the rains are late the wheat may be seeded into dry soil).

The farmer spreads 40 to 60 kg/ha of nitrogen fertilizer at the time of the last sweep operation in the summer. At seeding he applies about 40 kg/ha of phosphate. In the spring he can apply another 20 kg/ha of nitrogen if the crop and moisture conditions are good enough to suggest the application will be profitable.

Herbicide, usually 2,4-D, is applied in March or early April when weeds are small (five-leaf stage).

Charles Mann, a Rockefeller Foundation economist assigned to the wheat project, compared the costs and returns of the demonstrations in seven villages with those of farmers in the same localities. He found that all demonstrator farmers (those who
used the recommended set of practices) "realized substantially higher returns than did farmers whose fields served as controls." The recommended practices cost only 25 percent more than usual farmer's practices, but output increased so much that the ratio of increased benefits to increased costs averaged over 5 to 1. Mann tentatively concluded that "the impressive yield increases appear to be due not to large amounts of costly physical inputs but rather to modest amounts of additional inputs combined with better management." Overall, the recommended practices gave farmers a profit of US $285/ha compared with about $150/ha with usual methods.

The tillage and agronomic research behind the new recommendations was aimed at finding ways to raise yields at low cost to the farmer and the nation. Nevertheless, farmers who want greater yields will have to adjust the ways they think about and handle their wheat crop.

For tillage, "our basic suggestion is to get a sweep," says Bill Wright, co-leader of the wheat project. In examining tillage equipment, the scientists ruled out implements that would have to be imported and then compared tools already available in Turkey. According to Mike Lindstrom, an Oregon State University soils scientist who succeeded Floyd Bolton in the project, "No differences were found in the yields between different tillage tools, properly used, so choice of tool is based on speed of operation, power requirements, erosion control, and availability of equipment." After the first plowing, the sweep meets those criteria better than any other implement. Small machine shops in farming communities of the plateau manufacture sweeps and sell them to farmers at low cost. Farmers who do not have a sweep can use a tandem disc after the first plowing, but it requires more tractor power and lower speeds for satisfactory fallow tillage.

Doing fallow tillage well at the proper time to conserve soil moisture by forming and maintaining a mulch and by destroying weeds will have to be learned by farmers. Many farmers delay tilling fallow land in the spring until after livestock have grazed on the weeds. It seems clear, however, that the higher wheat yields that come from good fallow management will more than pay for buying forage for the animals.

The use of grain drills was becoming increasingly popular even before the new recommendations. In 1974 Turkey's farmers had 33,000 grain drills, nearly triple the number a decade earlier. Grain drills give better control of seeding rates than the traditional broadcast seeding. And because they place the seed in the soil more precisely, they should give better germination and seedling survival. In combination with fallow tillage which produces a good seedbed containing stored soil moisture, grain drills permit farmers to save money by lowering their seeding rate. Since the risk of a poor seedling stand is less, farmers can seed about 90 kg/ha instead of the usual 150 kg/ha.

Many farmers are already eager to use herbicides. In 1975, Turkey had enough herbicide to treat only 10 percent of the wheat area. Farmers were willing to pay more than the government price and a vigorous black market in herbicide sprang up. In 1976, twice as much herbicide was
available. Although farmers are interested in using herbicides they need to learn when to apply them. Studies by the wheat project’s agronomists have shown that killing weeds when the wheat begins to tiller (produce extra shoots) will give 25 percent higher yields than the usual herbicide application time a month later.

Research continues to provide farmers with even more profitable recommendations and to anticipate future difficulties. One idea being tested is deep-furrow planting, a technique that has succeeded in other fallow-farming areas. A special planter is used to place the seed in the zone of residual soil moisture. The seed is covered with 5 to 7 cm of soil at the bottom of a furrow about 10 cm deep. The advantage of this technique is that it allows wheat to be planted in September even if rainfall has not been great. The seedlings emerge and by the time snow falls they have developed into stronger and better developed plants than those in fields planted in November or December. The following spring, early seeded plants ripen earlier — during the cool months that encourage high yields.

But deep-furrowing planting fails in some years when the soil moisture content is too low or when the plants emerge into an extended drought. “We haven’t been able to establish the probability of success,” observes Bill Wright. “When you hit you have terrific success, but if you miss you have to replant.” In one trial, planting in early September resulted in yields of nearly 4400 kg/ha while a nearby field in which planting was delayed until late November yielded only 740 kg/ha.

Herbicides are another area of continuing research. Mike Lindstrom points out that perennial weeds are likely to become a greater nuisance in fallow. “Tillage based on weed growth is fine for annual weeds. But for perennial weeds which grow...
The day's rounds for Bill Wright include reviewing promising wheat lines with scientists at the Eskisehir station.

from an established root system such infrequent tillage (three to four times a season) would probably just spread weeds.” Lindstrom says that tillage every 10 to 14 days might work, but it would be impractical for farmers. A better solution, he says, is research on combining tillage with herbicide application to control perennial weeds.

Agronomists are also testing herbicides and combinations of herbicides to find a low cost way to control both grasses and broadleaved weeds as a substitute for the broadleaved weed killers now in use.

**The road ahead**

In 1976 the direct participation of CIMMYT and Oregon State University in Turkey's national Wheat Research and Training Project was winding down. In the past 5 years enough Turks have returned from universities and training programs so that the presence of outside scientists is no longer critical. Art Klatt has moved to CIMMYT's regional wheat program in South America. Mike Prescott has reduced his activities in the project and is now assigned nearly full-time to disease surveillance work in the Mediterranean and Mideast regions.

CIMMYT's contacts continue in other ways, however. Young Turkish scientists are participating in CIMMYT's training programs in Mexico, breeding lines and information are being exchanged, and CIMMYT scientists visit their Turkish colleagues frequently.

With the research component of the project productive and active it seems likely that the training component will become more important. A large share of the farmers in the Anatolian plateau have not seen or tried the new techniques. The national extension wheat advisors have worked closely with the wheat research and training project in placing demonstration plots in several provinces and in conducting training courses for farmers. But the scale needs to be much larger.

The Wheat Research and Training Project has the personnel and facilities to train large numbers of technicians. And a tested set of new practices is available. As Bill Wright says, “the stage is set for a strong production campaign”

Steven A. Breth

*An extension poster used to make farmers aware of improved tillage methods.*
THE WHEAT ZONES OF TURKEY

Turkey has about 25 million hectares of arable land, of which 8 million hectares a year are in fallow. Wheat occupies about 9 million hectares or half of the land under crops.

The wheat-producing areas of Turkey can be crudely classified by whether they grow winter or spring wheat. Eight of every ten hectares of wheat in Turkey is winter wheat.

The practical difference between winter wheat and spring wheats is the strong cold tolerance of winter wheats. Winter wheats are planted in the autumn. They grow for brief periods before cold weather and snow begin. Growth resumed in the spring, flowering occurs, and, in Turkey, the grain matures in July.

Two groups of winter wheats exist: “true” winter wheats and facultative winter wheats. “True” winter wheats will not flower unless they have been vernalized, that is, unless they have passed through a period of cold weather. If true winter wheats are planted in areas that have mild weather, they remain in the vegetative stage and do not flower so they produce no grain. Facultative winter wheats flower with little or no vernalization, yet they have sufficient cold tolerance to survive fairly cold winters and yield well. Generally, however, true winter wheats survive better, especially when insulating snow blows away and directly exposes the seedlings to low temperatures.

The winter wheat areas of Turkey are Thrace, the Anatolian Plateau, the ring of mountains surrounding the Plateau, and southeast Turkey which borders Syria.

Spring wheats are much less cold tolerant than winter wheats. If spring wheats are planted in the autumn in a winter-wheat area, they usually are damaged or killed during the winter.

Planting spring wheats in the spring in a winter-wheat area is impractical because of the short period between the onset of weather warm enough to permit seeds to germinate and the start of hot weather and seasonal drought which end the wheat plant’s life.

In Turkey, as in most nations bordering the Mediterranean, spring wheats, despite their name, are usually planted in the autumn. Coastal Turkey has cool, rainy winters that are well suited for wheat. The wheat is harvested in May and June after the rainy season ends.

An exception to the pattern occurs in parts of the rugged eastern section of Turkey that have winters too severe for winter wheat. In such areas farmers can plant spring wheat in the spring and because excessively hot weather doesn’t occur until late summer, the growing season is long enough for modest yields.

Bread wheats and durum wheats both have spring and winter types. The winter durums, however, are not as strongly cold tolerant as the winter bread wheats.

Durum and bread wheat occupy large areas in the winter-wheat regions. In the spring-wheat regions, however, almost all farmers plant bread wheat except for the Aegean region and the Southeast which have substantial durum production.
ECONOMICS OF NEW AGRICULTURAL TECHNOLOGY.

CIMMYT's economics section has contributed to the understanding agricultural change in Turkey by supporting a study of the introduction of new wheats. The study was based on data from a survey of 800 wheat farmers in Turkey's coastal areas made by Resat Aktan, a leading Turkish economist. The data was analyzed by Nazmi Demir, another Turkish economist, while he was a visiting scientist at CIMMYT. Demir's study, The adoption of new bread wheat technology in selected regions of Turkey, is one of seven studies of adoption of new agricultural technology in various countries which are being done by CIMMYT under a grant from the Rockefeller Foundation.

Among the findings:
- In the year of the survey, 1972, farmers planted high yielding spring-wheat varieties, primarily Penjamo, on 65 percent of the wheat land in the Mediterranean, Aegean, and South Marmara regions. In Thrace, a winter-wheat region, the introduced Russian variety Bezostaya was planted on 79 percent of the wheat land.
- From region to region the adoption rate differed: In the Mediterranean region farmers put 97 percent of the wheat land in high yielding varieties; in the South Marmara region, 40 percent; and in the Aegean region, 35 percent.
- Farmers applied higher rates of fertilizer on high yielding varieties than on local varieties. Nevertheless, the amount of fertilizer farmers used on high yielding varieties was three fourths of recommended rates in the Mediterranean region, two thirds in Thrace, and one third in the South Marmara and Aegean regions.
- High rates of adoption of high yielding varieties and high rates of fertilizer use occur in areas that have higher and more evenly distributed rainfall, lower probabilities of frost, and lower occurrence of disease.
- Farmers who adopt new technology expect more good weather than non-adopters.
- Members of farmers' associations and cooperatives have less difficulty in getting fertilizer, credit for fertilizer, and information on new farming techniques than other farmers.
- Differences in farm size had little influence on adoption of new varieties.

A NEW EXPERIMENT STATION

About 45 kilometers from Ankara, the Turkish Ministry of Agriculture is developing a 400-hectare agricultural experiment station that may soon be one of the best in the Middle East. Although the land will be devoted to research on a number of crops, the wheat project will occupy the largest share—a reflection of the importance of wheat in Turkish agriculture.

The land was previously fragmented in dozens of small fields. Now 20-hectare blocks have been laid out and field roads installed. The ridges marking the irregular borders of the farmers' fields have been removed. Drainage channels have been constructed. Although most of the farm will not be irrigated, a source of irrigation is being developed to serve plots of valuable early generation plants.

A well-planned experiment station makes agricultural researchers more efficient. Experiments can be laid out easily and planted on time. The plots are easy to reach for operations such as note-taking, cultivation, spraying, pollination, and harvest. Finally, steps such as smoothing out humps in the field minimize the experimenter's curse—unexplained variability.

The Rockefeller Foundation assigned Dwight Finfrock to supervise development of the Haymana Farm. John Stewart, manager of CIMMYT's experiment stations in Mexico, has been a consultant during the construction of the Haymana Farm.