Quote: Three main factors contribute to low yield . . . young trees do not bear as early as they should. . . alternate bearing is a serious problem . . . non-uniform trees exist in orchards.

Present Status and Problems of Apple Production in China

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Apple is the most important fruit crop in China with the largest acreage and production of all fruit species. Apple production has played an important role in Chinese agriculture and the national economy. In recent years, it has developed rapidly in both acreage and annual production and, in many fruit-growing areas, it has become an economically important local industry. As the domestic market transforms from bulk selling to consumer purchases, apple quality is improving considerably and apple export is increasing.

ACREAGE AND DISTRIBUTION

Based on national statistics, the total orchard acreage was 7,260,000 ha (17,939,000 acres) in 1994. Of this, 2,690,000 ha (6,647,000 acres) were apple, ranking Chinese apple production first in the world. In 1996, the total acreage of apple in China grew to 2,987,000 ha (7,380,877 acres) (Table 1). Recently, 1996 to 1998 average, acreage was 3,677,697 ha (Table 2).

Apple production is important in many provinces, particularly in four geographical districts (Table 1). The Bohai Gulf apple-growing region, including Hebei, Shandong and Liaoning provinces, is the largest with 53% of the acreage (Figure 1). The other districts of importance are the Northwest Loess region (29%) (provinces of Shanxi, Shaanxi, Gansu), Yellow River Basin region (12%) (provinces of Henan, Jiansu, Anhui), and Southwest Plateau region (3%) (provinces of Guizhou, Sichuan). The nine most important provinces in production (1996 to 1998 average) in descending order are Shandong (1/3 of the total production), Shaanxi, Hebei, Liaoning, Henan, Gansu, Shanxi, Anhui and Jiansu (Figure 1).

MAIN APPLE-GROWING REGIONS

Bohai Gulf

The Bohai Gulf region falls between 35˚ and 45˚ N latitude. It has relatively wet summers with annual precipitation of 650 to 800 mm (26 to 32 inches). The annual average temperature is 9 to 13°C (48 to 55˚F) with mean temperatures ≥ 22°C (72˚F) during June to August and high night temperatures. The frost-free period is 200 days. Autumn is cool and dry (September to October). Soils are brown and most suitable for growing apples. Late-ripening cultivars in this region have high soluble solids and firmness with long storage life.

Northwest Loess

The northwest loess region is at a higher elevation, has lower night temperatures than in the Bohai Gulf region in summer and is relatively dry. The daily temperature extremes are larger with annual average temperature 9 to 11˚C (48 to 52˚F) and mean temperatures during June to August of 21 to 22.5˚C (70 to 72.5˚F). The frost-free period is 195 to 200 days. Annual precipitation is 572 to 664 mm (22.5 to 26 inches). The region has strong ultraviolet sunlight and brown yellow fine loess soils. Most cultivars produce top-quality fruit and high yields.

Yellow River Basin

Yellow River Basin south of Shandong Province has high day and night temperatures. Annual average temperature is 13 to 15°C (55 to 59˚F) with a mean >25°C (77˚F) during June to August. The frost-free period is 200 to 210 days. It is wet in summer and annual precipitation can be excessive and unfavorable for tree growth and fruit ripening. Soils are mainly yellow, moist and sandy or grit brown.

Southwest Plateau

Southwest plateau is a mountainous zone in central China. Annual average temperature is 11.6 to 19.6°C (53 to 67˚F) with average temperatures in July of 18.6 to 28.7°C (65 to 84˚F). Annual precipitation is 467 to 1422 mm (18 to 56 inches) and the frost-free period is approximately 200 days. Soils are red, yellow and yellowish-brown. The plateau zone has higher air temperatures than the other regions, cool and wet summers, high annual precipitation, a long growing season for apple trees and no freeze injury in winter.

PRODUCTION

China has ranked first in world apple production for many years (Table 2). Total production was 11,200,000 metric tons (MT) in 1994, 14,010,000 MT in 1995, and 17,052,000 MT in 1996. Production increased rapidly with 1994 production 3.9 times that of 1978, nearly a 10% growth rate per year. In recent years, the output has increased by 2 to 3 million MT every year due to improvements in growing techniques and the large number of young trees coming into bearing. Because there are so many young trees (30% to 40%), it can be predicted that the total production will increase further. Moreover, the increase will appear mainly in newly planted regions in the near future.

CULTIVARS

The cultivars grown at present in China originated in the USA or were introduced from other countries, although there are a few cultivars native to China. In the 1950s and 1960s, the main cultivars were Ralls Janet, Jonathan and Baldwin. In the 1970s and 1980s, Ralls Janet, Golden Delicious and Delicious became the main cultivars. In 1980s, several new cultivars were introduced from United States, Japan and New Zealand, and these have been planted in the main apple-growing regions.

At present the range of cultivars in new plantings is similar to the rest of the world, with the most important being Fuji, Starkrimson Delicious, and Jonagold. These cultivars have played an important role and will have a far-reaching effect on the Chinese apple industry. For example, the growing area for Fuji reached 1,305,000 ha (3,225,000 acres) in 1996 with total output of 6 million MT (approximately 310 million 42-lb boxes). Fuji accounts for 43% of the area and 35% of the production. Furthermore, these new cultivars possess potential marketing advantages in both quality and quantity. In combination these three varieties occupy 70% of the total acreage.

A few new cultivars bred in China have been planted. One of these is Qinguan which has been planted on a large scale in Shaanxi, Shanxi and Hebei provinces. Qinguan bears early, with large fruit, strong red color and is very easy to manage. Its shortcoming is inferior flavor. Selling will surely be difficult in the future as many new, high quality cultivars are introduced. Qinguan acreage will decrease with time. The number of other new cultivars being tried is numerous, but the acreage of each is very limited. There still exist some fruit quality and production problems in the cultivars being developed or popularized currently no matter whether they were bred domestically or introduced from abroad. It is, therefore, necessary to breed new cultivars to meet future market needs.

TRADITIONAL GROWING TECHNIQUES

Apple growing has been an industry for many centuries in China, although the native cultivars are seldom seen today. Through long-term accumulation of growing experiences, many cultural systems have developed. In recent years, these traditional practices have been, more or less, changed.

Ground Cover Management

Clean-cultivation is most commonly used in China. Grass sod between rows is very limited due to the lack of available water. Several grass species have been selected which proved suitable to the climates and soils in some districts of China. In some arid hilly orchards, mulching is practiced by many growers. Digging deeply (using a spade to 60 to 80 cm [24 to 32 inches]) is still a common practice in autumn but, in some cases, also in spring or summer.

Hilly orchards are common in China and they are usually terraced or have contour plantings to prevent soil erosion.

Most small orchards still manually remove weeds, but some larger orchards are beginning to use herbicides.

Fertilization

Nutrients are typically applied according to growing stage and age of apple trees. For mature trees, there are generally four times for soil-applied fertilization: 1) early spring before bud break (in late March), usually nitrogen; 2) young fruit setting stage (in mid-May), usually a mixture of nitrogen and phosphorous; 3) fruit swell stage (from mid-July to late-August), usually a fertilizer with N, P, and K; 4) fall-applied basic organic manure (from mid-September to late-October) of various types incorporated into the soils.

Amount of fertilizer needed is mainly based on experiences in different districts. The basic principle is to resupply the nutrients taken from the soil by trees, i.e., yield and growth determine the amount needed. Although diagnosis of nutrients is feasible through leaf analysis, its application is very limited because of the expense and limited availability of formulated fertilizers. In addition, foliar application of elements is often used, sometimes alone and sometimes mixed with pesticides.

Irrigation

In most orchards, there is insufficient water for irrigation. This negatively affects both yield and quality. Many orchards are non-irrigated. In irrigated orchards, the frequency of irrigation is usually limited to four to six times per year, which should match the times for fertilization. In apple-growing regions in China, spring drought is a serious problem requiring more irrigation at that time.

Flood and ditch irrigation are commonly used in China and drip and sprinkler irrigation are limited because of higher costs and purity of water. In recent years, a new kind of irrigation, permeating irrigation, has developed in China and has broad application because of its easy operation and lower cost. Permeating irrigation involves placing a plastic tube between the rows 40 cm (16 inches) below the soil surface. Tiny holes are made in the tubes. A water containment area is established beside a plot of fruit trees to which the tubes are connected. No machines or electricity are needed.

Thinning of Flowers and Fruits

Thinning of flowers and fruits is conducted more carefully in China than in other countries. In general, flower thinning by hand begins at the pink bud stage. Fruit thinning is usually conducted twice, in mid-May and early June. There is quite a good understanding of fruit thinning in China, with consideration given to ecological conditions, tree vigor, tree age, trunk thickness, nutrient area, structure of trees and distribution of fruits. To determine a proper load, thinning practices have proven successful in some orchards after several years' experience.

Usually the thinning procedure is as follows: 1) determine the cropload per unit land according to the cultivar, density, age and management level; 2) determine the average yield per tree and adjust by trunk thickness (medium to vigorous tree 0.4 kg/cm^2); 3) determine the number of fruits which should remain according to the weight per fruit; 4) add 10% more fruit in case of accidental drops; 5) determine the distance between fruits according to flower amount and distribution; 6) make proper adjustment among individual trees.

Measures to Improve Flower Bud Formation

In China, apple trees usually grow too strongly because of vigorous rootstocks and the unfavorable climate (severe drought in spring and extensive rain in late summer and early autumn). Therefore, it is necessary for growers to apply great effort to induce sufficient flower bud formation every year to keep the trees bearing normally. The main measures used include: 1) little pruning when trees are young; 2) training branches horizontally as early as possible; 3) girdling the trunk or limbs; 4) spraying or root-feeding growth inhibitors (e.g., PP333) or flower-inducing agents; 5) judicious management of soil, fertilization and irrigation; 6) controlling diseases and pests perfectly; 7) summer pruning to adjust accumulation and distribution of nutrients.

Growth Regulator

Many growth regulators are used extensively in apple production. Four of special importance are: 1) Promalin and auxin plus gibberellin-like substances which are used to increase longitudinal growth of a fruit; 2) root-inducing products (ABT Rooting Powder series No. 1-5) which are used in planting or transplanting young trees; 3) PP333 which is used for controlling tree growth in high-density orchards; 4) auxin and auxin-like substances which are used for inducing dormant bud break.

Bagging

Fruit bagging with paper bags has had a long history in pear growing and in recent years the techniques have been applied to apples. The use of bagging has increased to supply international market needs and to increase grower income. Several paper-bag factories have been established in the main apple-growing regions and many kinds of bags for different cultivars and districts have been developed. With bagging, fruit appearance has been improved greatly and sprays have been reduced.

A set of comprehensive techniques for bagging is successfully used in the main apple-growing regions. The trees used for bagging should be healthy, of medium vigor and have a good supply of flower buds. It is important to thin surplus flowers and young fruits as early as possible and to allow only one fruit per cluster. Insecticides and fungicides are applied 1 or 2 days before bagging. Fruit are bagged 35 to 50 days after flower abscission. Leaves on spurs and bourse shoots around the fruit are removed 5 to 7 days before removing the bags to improve light penetration to the fruits. Total defoliation is between 30 and 60%. Outer bags are removed 1 month before harvest and the inner bag 3 to 5 days later. After defoliation and bag removal, reflective film mulching is placed under the trees and fruits are turned to expose the green side of the fruit to light.

Winter Injury to Young Trees

In northern China, freezing and drying injuries are great threats to 1 to 3-year-old trees. Drying causes excessive losses every year. Drying injury is physiological drought which happens when a water balance between absorption and transpiration cannot be maintained. Some preventive measures have been used with young trees to reduce drying: 1) control late-stage growth by reducing irrigation and nitrogen application; 2) spray growth inhibitors or use pinching to stop tree growth in late autumn; 3) apply enough water before the soil freezes; 4) make an earth mound around the southwest side of a tree; 5) whitewash the trunk, crotch and sometimes part of the central leader before freezing; 6) mulch around a tree with plastic film in winter; 7) paint with protective substances such as methyl cellulose and polymeric ethyl alcohol.

Establishing an Orchard

In China, establishment of an orchard to a high standard has been advocated for many years. The main recommendations include: 1) select the desired cultivar and proper rootstock (usually seedlings of *Malus baccata* or *M. macromalus* or interstems of M.26 on the seedlings); 2) choose Extra or First-class grafted trees which have been in the nursery for over 2 years and, if possible, use virus-free dwarf trees; 3) improve the soil thoroughly by digging a deep ditch and filling with manure and weathered soil; 4) soak root systems in water for at least 24 hours before planting, use proper root pruning, and dip in a solution of root-inducing powder; 5) plant trees to avoid being either too shallow or too deep; 6) irrigate the trees immediately after planting and mulch with plastic film around each tree; 7) head back and cover the whip with a long, narrow plastic bag to reduce evaporation; the bag is removed when new growth is about 5 cm (2 inches) in length.

The usual between-row spacing used by Chinese apple growers is 3 to 5 m (9.8 to 16.4 feet) with vigorous rootstocks, 4 to 6 m (13.1 to 19.7 feet) with vigorous rootstocks if tractors are used and 2 to 4 m (6.5 to 13.1 feet) with dwarfing rootstocks or interstocks. Spacing within rows is usually 2 to 3 m (6.6 to 9.8 ft).

Training and Pruning

A great change has taken place in training and pruning of apple trees in recent years, as growers move to higher density plantings. The main training systems used are slender spindle for dwarf trees and free spindle for standard trees although, in some cases, small canopy central leader systems are also used.

In China summer pruning and training are used extensively. Many measures for summer pruning and training have been used: scoring above buds, ringing, spreading in the growing season to move scaffold branches to a horizontal position with spreaders or string, inverting bark, bending, pinching, twisting, pruning to thin out and remove water sprouts, girdling, widening angles of scaffold branches by supporting, pulling down and hanging weights, and shoot softening. Softening is damaging a shoot from base to apex by bending and twisting several times but not breaking.

IMPROVEMENT OF GROWING PRACTICES

The techniques used in apple production which play an important role in increasing yield and quality have been improved in recent years.

Planting system change from low density and large canopy systems to high density small canopy (compact trees) systems is a major feature in the overall reform in cultural practices. With high-density planting, training and pruning are greatly simplified with comprehensive management of soil, fertilization and irrigation. New training systems with small canopies and simple structures have shortened the training time compared with the past. Together with effective measures to hasten flower bud formation and to control the canopy growth, the time from planting to bearing has been shortened. Early production occurs in the third year after planting, with full production in the fifth year, and the unit output, under good care, can attain production of 15 to 26 MT/ha.

In China, apples are produced in many areas, some of which are not very suitable from the standpoint of producing top-quality fruit. After the introduction of Fuji apples into China, inferior coloration and poor fruit finish were obvious in some districts at low elevation and latitude. The inferior fruit could not compete in the marketplace. In recent years, the apple project team at the Agricultural University of Hebei has made systematic studies of many factors which influence fruit quality. Based on the climatic characteristics in lower-latitude regions in central Hebei, they proposed a set of cultural techniques by which the extra-fancy fruits can be produced with overall red color and attractive appearance comparable to those produced in Japan. The techniques were listed above under bagging. It can be predicted that fruit quality will be raised soon with the popularization of these techniques.

PROBLEMS

Lower Yield per Unit Land Area

Although the total output of apples in China has ranked first in the world and the yield will increase undoubtedly with time, a marked difference exists between China and more developed countries in productive efficiency per unit of land (Table 2). The yield of apples from some advanced countries ranges from 20 to 35 MT/ha, e.g., France 32 MT/ha, New Zealand 34 MT/ha, Italy 29 MT/ha and US 25 MT/ha. The average yield in China, however, is much lower. In China there are small differences among provinces, e.g., Liaoning 4.48 MT/ha, Shandong 4.39 MT/ha, Henan 3.55 MT/ha, and Shaanxi 3.24 MT/ha.

There is great potential for increasing yield in China. In China, the level of management varies with different farmers and orchards. It is possible that yield could reach 37.5 to 45 MT/ha in some Fuji plantings, and 40 MT/ha or so in some Starkrimson Delicious plantings. These orchards will play an important role in teaching other growers. It is reasonable to assume that one of the shortcuts to narrow the difference between high- and low-yield orchards is to popularize the existing experience.

Three main factors contribute to low yield. First, young trees do not bear as early as they should. In China under excellent care young apple trees can reach yields of 10 MT/ha in 4 to 5 years after planting. However, many young trees delay fruiting until 5 to 6 years, some even longer. The initial output is less and the rate of yield increase is slower. Second, alternate bearing is a serious problem in some orchards with an over 20% differential between on- and off-years. Third, non-uniform trees exist in orchards, with a low proportion of trees which bear annually and many low-yielding trees.

There are six reasons for low yields. First, inferior cultivars are within an orchard which are either out-of-date or local low-yielding cultivars. Second, poor establishment practices are common. Lack of soil improvement, noncertified nursery trees, poor orchard layout and negligent care after planting cause a lower survival rate, a longer time for young trees to start growing, inconsistent growth and weak tree vigor. Third, young trees are not managed properly during the winters in the first several years after planting, causing freezing injury or “branch drying” of some trees and resulting in inconsistent growth. Fourth, in some high-density orchards, it is common to still use the training and pruning techniques for large canopies. By using heavy pruning, too much heading-back pruning and maintaining upright branches, flower bud formation is delayed. Heavy pruning results in a high proportion of long branches and vigorous growth, delaying the beginning of bearing and reducing yield potential. There are many orchards which become heavily shaded by intercrossing branches. With inferior air circulation and sunlight distribution as soon as they start to bear, fruiting moves to the outer parts of a canopy. The branches inside the canopy become weak, further affecting yield and fruit quality. Fifth, the crop load is not controlled appropriately and thinning techniques are not carried out carefully. Overcropping occurs commonly although fruit thinning has been done to some extent. In this way, alternate bearing occurs because of the effect of overcropping on flower bud differentiation. Sixth, poor fertilization and neglect of the balance of different elements has affected the normal growth and flower bud formation of young apple trees. Nitrogen use has been overemphasized, and phosphorous, potassium and other minor elements have been overlooked. Low content of organic matter in soil, salinization and physiological disorders due to deficiencies of Fe, Zn, B and Ca are also problems.

Inferior Quality

As the output of apples increases and living standards are raised, there is a higher demand for top quality fruit. At present, the consumption is mainly fresh fruits, and the proportion of processed apples is limited. Both external and internal qualities of fresh fruit are important as they influence sales and grower profits. In addition to natural conditions and cultural measures which control fruit quality, handling after harvest is also critical. Harvesting, sorting, packing, storing, shipping, and selling are all important factors which affect fruit quality.

There are many causes of inferior quality in China. Many undesirable varieties are produced with poor appearance and flavor. Some newer promising cultivars do not show their best characteristics. For example, Red Fuji often produces an asymmetrical fruit with poor color, rough appearance, small size, poor flavor, strong acidity, and coarse flesh. In the marketplace there are fruits of different sizes, coloration, shape, even a mixture of different cultivars, mechanically damaged, diseased, pest injured, or rotted fruits, so as to reduce market acceptability and income.

The reasons for inferior quality include the following: 1) excessive application of nitrogen, with lower organic content in soil (at present the average organic content is only 0.6 to 0.8%); 2) poor training and pruning, resulting in excessive growth with inferior air circulation and sunlight within the canopy; 3) thinning of flowers and fruits is not done properly, resulting in serious overcropping and uneven distribution of fruits in a tree; 4) diseases and insects are not controlled in a timely way so that fruits, leaves, branches and limbs are injured seriously; 5) poor handling after harvest, including poor sorting, packaging, shipment and storage; 6) lack of enough advanced techniques (e.g., CA) and facilities for storage and transportation.

Popularization and Extension of Growing Techniques

Apple is a species that needs much more care than other crops in order to obtain high yield and top fruit quality at the same time. As the most important fruit crop in China, the apple industry has a huge potential to develop further, considering its extensive acreage, production, and mature growing technology. What is required now is to narrow the management difference between low and high yielding orchards by improving the technical factors contributing to production. A new extension education system must be established quickly because the original education system for growers has broken down as a market economy has developed. Much work needs to be done in the near future to establish social services and raise growers' specialized skills by training and guiding them in order to keep up with and surpass the advanced production levels in the world.

Table 1. China apple acreage and production by province in 1996.

Provinces	Land area (ha)	Land area (million acres)	Production (metric ton)	Yield (MT/ha)
Shandong	663,300	1.639	6,056,428	9.10
Shaaxi	470,200	1.161	2,958,884	6.29
Henan	341,300	.843	1,820,507	5.30
Hebei	384,800	.950	1,566,759	4.07
Liaoning	261,400	.646	1,505,993	5.76
Shanxi	191,700	.474	919,660	4.79
Gansu	211,500	.523	515,083	2.44
Jiangsu	78,900	.195	440,737	5.59
Xinjiang	45,400	.112	247,444	5.45
Anhui	42,400	.105	218,354	5.15
Beijing	23,100	.057	172,088	7.45
Sichuan	34,500	.085	138,831	4.02
Ningxia	31,500	.078	109,159	3.47
Heilongjiang	31,230	.077	78,073	2.50
Tianjin	13,200	.033	71,164	5.39
Yunnan	47,200	.117	65,763	1.39
Jilin	20,500	.050	57,618	2.81
Hubei	13,500	.033	42,984	3.18
Inner Mongolia	35,800	.088	39,200	1.09
Qinghai	4,500	.011	18,935	4.21
Guizhou	7,200	.018	4,785	0.66
Xizang	1,400	.003	3,049	2.18
Zhejiang	400	.001	611	1.53
Fujian	200	.0005	137	0.69
Total	2,986,930	7.380	17,052,246	5.70

Table 2. China apple statistics in comparison with other nations for acreage (ha), total production (MT) and yield/ha. Data are averages of years 1996, 1997 and 1998 (FAO database http://apps.fao.org/).

	Area (ha)	Production (MT)	Yield (MT/ha)
China	3,677,697	17,263,668	4.7
USA	192,190	4,785,000	24.9
France	78,000	2,463,667	31.6
Turkey	106,932	2,350,000	22.0
Italy	68,920	2,007,287	29.3
Germany	65,067	1,972,660	30.3
Japan	46,800	930,767	19.9
Chile	34,439	863,333	25.1
South Korea	41,282	651,654	15.8
New Zealand	15,873	557,000	34.0
The Netherlands	13,625	476,667	35.0

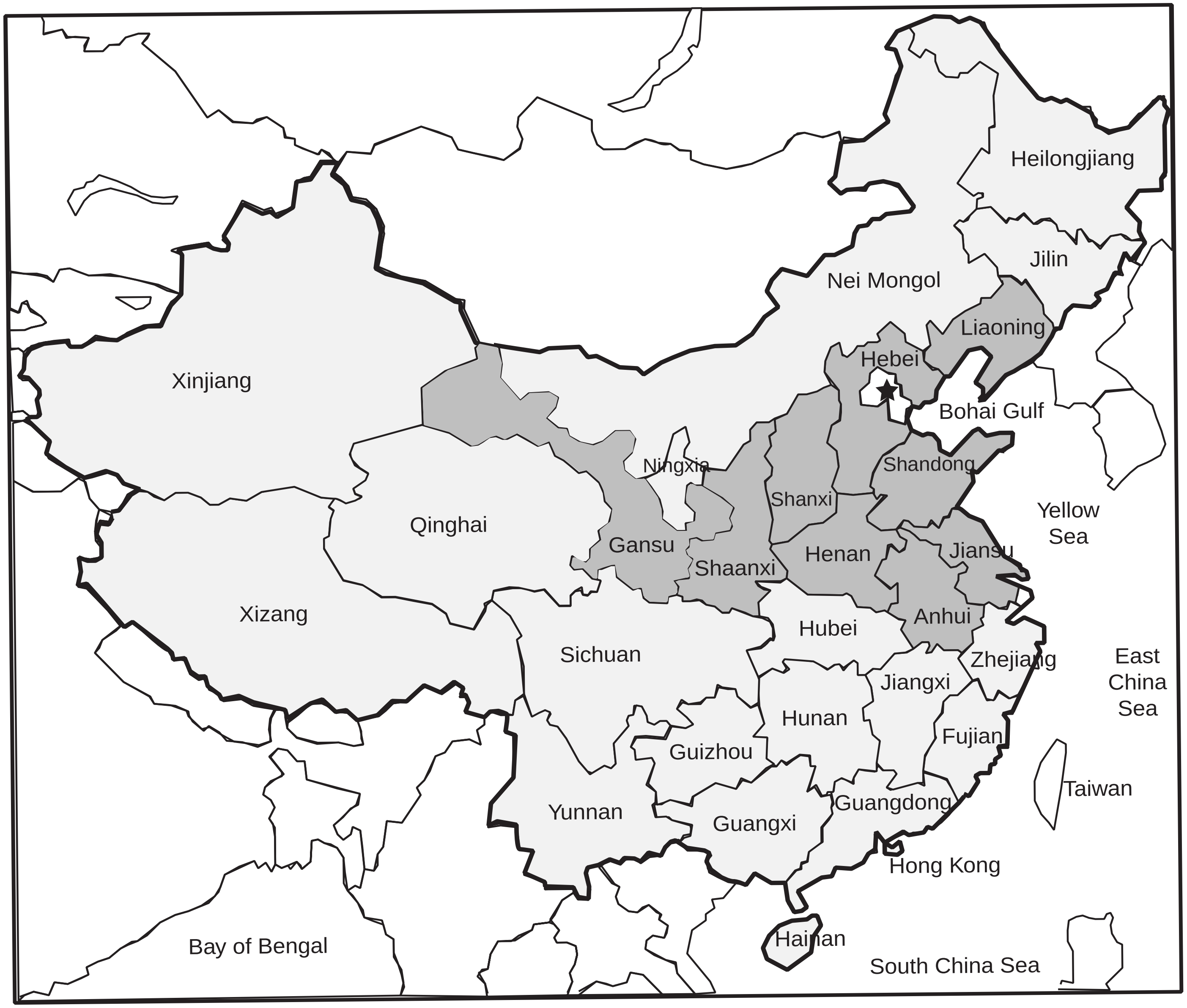

Figure 1. **The map of China shows the nine most important apple producing provinces (shaded). The greatest production occurs in the Bohai Gulf region in the provinces of Shandong, Hebei and Liaoning.**