Maize: Perspectives and Applications in India

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The cultivation of maize in India is compared to that in other countries. The consumption pattern of maize in India including maize starch industry is reviewed and the need for additional production indicated. Conservative estimates indicate that the present demand of about 10×10^6 t (metric tons) will more than double by the year 2005. The higher demand can be met if the yields are increased from the current low value of about 1.5 t/ha. Some states have already raised yields to about 3.5 t/ha and it should be possible, for the all-India average to reach this figure given the correct inputs.

1 Introduction

Maize, also known as corn or Indian corn in the USA, is a tall annual plant belonging to the grass family (*Gramineae*). It has a fibrous system and an erect stalk with a single leaf at each node and leaves in two opposite ranks. Maize is a cross pollinated species and is monoecious, that is, it has separate male (tassel) and female (ear) flowers located on the same plant. The ears grow to contain 300 to 1000 developed kernels arranged in rows along a rachis (cob).

Maize requires abundant sunlight for optimum yields. The rate of maturity is affected by day length, with short photoperiods favouring early flowering. However, maize has proved to be adaptable and there are cultivars adapted to climates from the tropics to the temperate regions, to altitudes from sea level to 3600 m, and to a growing period of 42 to 400 days [1].

It is generally agreed that maize originated in Mexico, from where it spread northwards to Canada and southwards to Argentina. Following European discovery of the "Americas", maize moved to Europe, Africa, and Asia. Most modern maize races are derived from prototypes developed by early agriculturists of Mexico and Central and South America. The maize that dominates the "corn-belt" of the USA and several other countries today, was a post-colonial discovery in the USA: The late maturing Virginia Gourdseed and the early maturing Northeastern flints were crossed. The crosses were repeated several times during the westward migration across the United States. Out of these mixtures eventually emerged the "dents", described as the most productive race of maize found anywhere in the world.

2 Maize Production

2.1 The world scenario

The production of maize in some countries is shown in Tab. 1. The USA, by far the largest producer of maize, produced about 41 % of the world production in 1996–97. The history of the maize cultivation in the USA is an example of what can be achieved in the field of agriculture if end users, growers, and research organisations pool their talent for the common good. As the demand for maize increased, research inputs went into raising yields. The yield increased from 1.61 t/ha in 1926 to 4.66 in 1966. The yields obtained today are about 8 t/ha. The projections are that the yields will reach about 8.5 t/ha by the year 2005. Tab. 2 shows the progressive increase in maize production over the years. The increased production has been met mainly by improved yields rather than increased average under maize.

Tab. 1. Production of maize in some countries in 1995 [2, 3].

Country	Production (10^6 t)	Yield (t/ha)
United States	236.0	7.98
China	117.0	4.92
European Union	34.0	7.82
Argentina	13.5	4.30
India	9.4	1.57
Romania	9.5	
South Africa	9.5	2.63
Canada	6.7	7.04
Egypt	4.9	6.36
Hungary	5.6	
Thailand	4.0	3.10
Russia	2.4	3.06

China is the second largest producer of maize, having produced 117.0×10^6 t in 1996–97, which was 20.4 % of the world total. The yield per hectare is 4.9 t. The yields of maize in Canada are close to those in the USA. In Mexico, however, the yields are much lower, probably due to the fact that maize in Mexico has traditionally been grown for use in foods. White maize is generally preferred. The average yield

Tab. 2. Maize production in the United States from 1926 to 1996 [2].

Year	Area under maize harvested (1000 ha)	Average yield (t/ha)	Total maize production (1000 t)
1926	33,700.9	1.61	55,245
1936	27,451.6	1.17	32,642
1946	31,732.1	2.33	75,140
1956	26,255.4	2.97	79,223
1966	23,068.4	4.65	107,230
1976	28,938.1	5.52	161,629
1986	27,886.3	7.49	211,285
1996	29,602.2	7.98	238,661

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of maize in the countries of the European Union is about the same as that in the United States and Canada. The yields in Russia and countries of the former Soviet Union are lower. Barring Egypt, where the current yields are about 6.3 t/ha, the yields in Asian and African countries are low. Taiwan and South Korea have yields of about 4 t/ha which are higher than those in other Asian countries.

2.2 The Indian scenario

India produced about 9.4 × 10^6 t of maize in 1997, the average yield being 1.57 t/ha. The changes in the production of maize in India over the years are given in Tab. 3. There is a large difference in the yields in various states, with Andhra Pradesh and Karnataka showing the highest yields (Tab. 4). The average yield for the entire country at present is about 1.6 t/ha, the lowest yield being 0.68 in Assam, and the highest being 3.63 in Karnataka. However, the area under maize in Karnataka is small. Among the states which have a large area under maize cultivation but where the yields are low, are Rajastan and Gujarat. In Rajastan, which has the second largest area under maize cultivation (907,000 ha), the yield is only 0.89 t/ha, the second lowest among the states surveyed. Madhya Pradesh, which ranks third in the area under cultivation, ranks twelfth in yield with a yield of 1.34 t/ha. Gujarat also has a considerable area under maize, ranking fifth among the states surveyed (378,000 ha). However, in yield it ranked near the bottom, at position 15, with a yield of 0.99 t/ha.

There is probably not one single reason for the low maize yields in India. Lack of inputs, both in terms of technical knowledge as well as physical inputs, such as quality seed and nutrients, have hampered the attainment of higher yields.

Tab. 3. Average annual maize production in India [4].

	Area (1000 ha)	Production (1000 t)	Yield (t/ha)
1970–1980	5,823	6,173	1.05
1980–1990	5,841	7,461	1.27
1990–1996	5,979	9,157	1.53

Tab. 4. Breakdown of area, production, and yield of maize according to state, April, 1995-March, 1996 [5].

State	Area (10^6 ha)	% of total area	Production 10^6 t	% of total production	Yield (kg/ha)
Madhya Pradesh	0.86	14.3	1.15	12.2	1,343
Uttar Pradesh	1.07	17.8	1.47	15.6	1,376
Rajastan	0.91	15.1	0.81	8.6	891
Bihar	0.72	12.0	1.25	13.2	1,739
Karnataka	0.33	5.5	1.20	12.7	3,634
Andhra Pradesh	0.31	5.2	0.79	8.4	2,549
Himachal Pradesh	0.31	5.2	0.66	7.0	2,146
Gujarat	0.38	6.3	0.37	3.9	991
Jammu and Kashmir	0.30	5.0	0.47	5.0	1,586
Punjab	0.17	2.8	0.31	3.3	1,795
Maharashtra	0.23	3.8	0.34	3.6	1,455
Orissa	0.16	2.7	0.20	2.1	1,215
West Bengal	0.05	0.8	0.11	1.2	2,376
Others	0.21	3.5	0.31	3.2	–
All India	6.01	100.0	9.44	100.0	1,570

The growth of the poultry industry has possibly given maize cultivation a significant boost, and the significant increases seen in the southern states of India are probably a result of this. A considerable quantity, estimated at 80 % of the maize produced, is cultivated in non-irrigated areas and depends on adequacy of rainfall. This may be an additional reason for the lower yields. Being unsure of his source of water the farmer is possibly unwilling to invest in quality inputs.

To achieve an increase in the production of maize an increased availability of quality seed would be required, suited to various climatic conditions. The farmer will have to be educated regarding the causes of the low outputs and the advantages of purchasing quality seeds, rather than retaining part of his previous crop for seed. This is not easy, as it involves changing practices that have been common for decades. Possibly that is the reason why the highest yields are in those areas where maize was not traditionally cultivated. And finally, the farmer should be convinced that he will be able to market his produce at a remunerative price. Growth in the user industry sector, both feed and processing industry will increase demand for quality grain and assure the farmer of adequate returns.

Maize grown in India is mainly flint: a certain amount of dent race is also available. Both white and yellow maize are cultivated. The maize grown in the southern states, which have the highest yields, is generally flint or yellow dent corn, with relatively bold grain. The maize from states such as Rajastan is usually small grained, both yellow and white flint. These types need less inputs for a "successful" crop. No waxy or high amylose maize is cultivated in India at present, and the chances of such cultivation in the immediate future are small. Cultivation will depend on the user industries for these unique starches growing to a level which makes cultivation and processing viable. Considering the large consumption by the poultry industry, and the high value of oil, cultivation of high-lysine and high-oil rice variants may be an interesting option to consider. Work has been done on high-oil varieties in India [6], but there are no indications of any attempts to commercialise these.

3 Maize Utilization

3.1 USA and Europe

Besides its major use as a feed ingredient, both for livestock and poultry, maize is also used in the production of food and industrial products. Most of the maize going into food and industrial uses is processed either by the wet-milling or dry-milling industries. International, a large proportion of the primary products of these industries, such as starch or corn meal, are further converted into products such as maize-derived sweeteners, snacks, pet feeds, etc. Some of these are used as feedstock for the production of other materials such as lysine, ethanol, and citric acid. Many find applications in various industrial processes such as the manufacture of paper and textiles.

In the United States, a major part of the maize produced is used for feed. Tab. 5 gives a breakdown of maize utilization in the past, at present, and projections for the future. As can be seen, a growing amount is used for industrial purposes and it is this sector which is showing the maximum growth. While Tab. 5 records data since 1982 only, the data are more impressive if a longer time frame is considered. For 25 years, corn refining in the United States has grown at a stunning rate, from an annual grind of 177,000 in 1970 to 35.4 × 10^6 t in 1995. Of the 201 × 10^6 t of corn produced in the USA in

Tab. 5. USA maize utilisation and projections for the future*.

	Maize utilisation (10^6 t)					
	1982/83	1987/88	1991/92	1996/97	1997/98	2003/04
Domestic use	1,477.2	1,644.1	1,723.3	1,974.8	2,054.0	2,118.73
Feed, residual	1,244.5	1,305.8	1,327.6	1,478.9	1,512.6	1,543.12
Fuel alcohol	38.1	75.9	108.3	170.9	204.7	237.32
HFCS**	58.2	97.4	106.7	125.7	127.6	124.37
Seed	4.1	4.6	5.4	5.7	6.0	5.99
Food, other	132.3	160.3	175.3	193.5	203.0	208.20
Exports	495.6	467.0	431.1	509.5	594.1	669.50
Total use	1,972.8	2,111.1	2,154.4	2,484.2	2,648.1	2,788.23

* Data adapted from U. S. Feed Grains Council, 1995 [3].
** High-fructose corn syrup.

1995, 7.5 % was used in ethanol production, 6.5 % for production of high-fructose corn syrup, 3.4 % for starch, and 3.2 % for corn syrup and dextrose production. This means that 20.6 % of the corn crop was used by corn refiners in 1995. Just 20 years ago, only 5 % of the corn crop was used by corn refiners. A major reason for this increase is the growing demand for maize-based sweeteners, especially high-fructose corn syrup, and the growth of the fuel alcohol industry.

More recent data on the maize consumption pattern in Europe could not be sourced. In 1992, of the $28{,}276 \times 10^6$ t of maize imported into the European Union 78 % was used in feeds [7]. It should be noted that in Europe only 52 % of the starch produced is derived from maize [8]. Of the 6.1×10^6 t of starch consumed, 53 % was consumed as hydrolysates, 30 % as native starch, and 17 % as modified starch [9].

3.2 India

In India, most of the maize cultivated is used for feeds. *Dias* and *Mehta* reported that 55 % goes to the feed industry [10]. A more recent survey including both poultry and other feed manufacturers indicates that the feed industry consumes 4.8×10^6 t of maize per annum, or 52 % of the available maize.

Of the remaining, 35 % of the harvested maize is used as a direct food, usually in the form of unleavened bread (*Rotis*, similar to the better known *chappatis* made from wheat flour), though consumption in other forms (corn-on-the-cob, as corn kernels) has also increased. The remaining quantity is used as seed, as an adjunct in brewing, and by the wet milling industry. The wet milling industry consumes about 6.5 % (645,000 t/a) of maize produced. Products of the wet milling industry are starch (168,000 t) glucose syrup (110,000 t), and other hydrolysis products (93,000 t). It should be noted that in India, starch is also produced from tapioca [10].

4 The Future of Maize Cultivation in India

As indicated earlier, the average yield of maize in India is much lower than that in the USA and several other countries. It is apparent that there is scope for large increases in production if yields are raised. This has already happened in states such as Karnataka where the average yield is higher than the all India average. Several factors exist which would have an impact on whether the farmer will adopt improved agricultural practices to increase yields and, hence, production:

- An assured market should exist for the additional quantities of maize available, either indigenously or abroad.
- The farmer should be confident that his income will not be eroded due to the additional inputs needed for better yields.
- The high yielding varieties should have characteristics that make them suitable for the particular application. This is particularly true for maize used for direct human consumption.
- Seeds of high yielding varieties and other agricultural inputs should be available to the farmer in adequate quantities and at the right time.

Indications are that there will be an increased demand for maize, both for feed production as well as for processing into industrial and food products. A quantitative assessment of this increased demand is indicated below.

4.1 The feed industry

As stated above, the feed industry consumes 52 % of the maize grown in India. The amount of feed produced in India is estimated at 37×10^6 t, comprising 30×10^6 t of cattle feed, 6×10^6 t of poultry feed, and 1×10^6 t of other feeds [11]. Estimates indicate that the demand for animal feed will increase by 25 % in the next five years from the current 36×10^6 t to 45×10^6 t. These estimates are based on existing minimum nutritional intake being provided to livestock in India. However, based on scientific estimates, the feed requirements should reach 82×10^6 t by the year 2005. The increased demand would be higher in the poultry sector, where scientific production methods are gradually replacing the ad hoc measures of the past. This increased demand for feed would mean that by the year 2005 the feed industry would need about 15×10^6 t of maize.

The CII-McKinsey report, FAIDA (Food and Agriculture Integrated Development Action) [13], states that the poultry production will quadruple in size, growing from Rs. $7{,}500 \times 10^8$ to Rs. $30{,}000 \times 10^8$ by the year 2005. The poultry sector has been identified as having the third highest growth potential after wheat-based and milk-based products. It should be noted that the cost of poultry keeping in India is much higher than in the United States, China, and Brasil [13]. *De Boer* and *Pandey* [14] are of the opinion that the high costs are mainly driven by high maize prices. This has to be contradicted, as the maize prices in India and elsewhere are about the same. Besides feed costs, other factors such as the feed efficiency ratio should also be considered, and the poultry industry is in a position to rectify these. The increasing use of enzymes as feed supplements is a pointer in this direction. Be that as it may, the increased demand for eggs and poultry

meat will need additional quantities of maize, and this can be achieved only through higher yields.

4.2 The maize starch industry

The maize starch industry in India is expected to grow in the next few years because the user industries are growing rapidly. Also, user industries have upgraded technologies and products and this has resulted in the need for additional quantities of starch, as well as for starches with novel functionalities. An example of a user industry whose demand for starch is anticipated to change is the paper industry. Until a few years ago, the paper industry in India was regulated by the Government of India, and there were no incentives to improve the quality of paper. With liberalization and increasing purchasing power, the demand for quality paper has increased. Also the higher demand for paper has necessitated an increased import of waste paper, most, if not all, of which has been manufactured by the alkaline sizing process. This will compel Indian manufacturers to go in for alkaline sizing, or in the least, neutral sizing, to avoid the difficulties the residual calcium carbonate would pose in acid sizing. This would result in the need for additional quantities of starch, especially modified starches.

Traditionally, the Indian paper industry used very little starch. Use has increased in recent years, but the demand is still far short of what it should be. *Ritter* and *Forkel* [15] have estimated that in 1994 the German paper industry used 270,000 t of starch to produce 14,457,000 t of paper, that is, 18.7 kg/t of paper produced. Using this as a yardstick to gauge the potential for starch utilization by the paper industry in India, at current paper production levels of 3.5×10^6 t/a the annual requirement for starch, both native and modified, should be 65,500 t instead of the current utilisation of 20,000 t. Paper production by the year 2010 has been estimated at 9.7×10^6 t/a (corresponding to an annual growth rate of 7 %) which would need 180,000 t of starch, corresponding to 285,000 t of maize [16]. This is a conservative estimate, as changing lifestyles and increased consumerism will be reflected in a much higher growth rate for the paper industry. The per capita paper consumption in India (3.6 kg) is much lower than that of other Asian countries (China 14 kg, Indonesia 10 kg, Thailand 27 kg, and Malaysia 61 kg), and there is no reason to believe that there will not be a rapid spurt in demand [17].

A spurt in demand for starch-derived products by the food industry may also be expected. Maize is used by the food sector both as a direct food ingredient, and in the form of starch and starch-derived sweeteners. There will be an increased demand in both sectors. In the sector of direct food ingredients the recent introduction of maize-based snacks in India could be a forerunner of other such products. Maize-based snacks have the advantage over traditional lentil-based snacks and potato-based snacks in that they are less expensive, and this will result in the faster growth of the snacking habit. Corn-based breakfast cereals would also show some growth but the total quantities will not be significant.

The demand by the food industry for starch, both native and modified, as well as for starch-based sweeteners, is expected to grow with the growth of the processed food industry. The quantity of maize needed to produce the former will be lower than that needed to produce the increased quantum of starch-based sweeteners that will be required.

The confectionery industry as well as the soft drink and beverage industries have been classified in the "activate" quadrant in the McKinsey report [13]. This is the quadrant with the greatest potential and consists of high volume products with high growth rates. The quadrant is expected to grow to $\$ 1{,}500 \times 10^6$ in 2005 from the current $\$ 275 \times 10^6$. The big and largely untapped market lies in mass-market products which could eventually account for 80 % of the total market. The growth in consumption will result in the growth of the value-added food market trebling from $\$ 21.4 \times 10^9$ to $\$ 62.5 \times 10^9$ by 2005 [14].

It is difficult to quantitate the increased demand for starches and starch-derived products in foods. In many cases the increases for individual items may be small, but when considered as a whole, the total figure will be considerable. An example is the sugar confectionery industry which is expected to have a growth rate of 35 %. Also, the annual per capita consumption of biscuits has gone up from 462 g in 1978 to 900 g in 1992. Total annual production is estimated at 1×10^6 t with an annual growth rate of 7 % for general varieties and 20–40% for cream and fancy varieties of biscuits. The value of the bakery market is expected to be $\$ 2.8 \times 10^6$ by 2005. Another example are tomato products, the market of which is estimated at 18,000 t. Of this 15,000 t is the market for tomato sauces. The sauce market is growing at a rate of 20 % per annum. While the use of starch-derived products in tomato sauces is not permitted at present, there are indications that the rules under The Prevention of Food Adulteration Act (India) may soon be amended.

Although there will be a significant growth in the demand for maize-derived products in the food industry, especially for the starch hydrolysates, the impact would be greater if the sugar market was deregulated and depoliticised, in which case high-fructose corn syrup would be a viable alternative [18]. However, with the increased demand for sweeteners by the growing food industry (confectionery, icecream, soft drinks, etc.), and the possibility of increasing production being small, it is possible that high-fructose corn syrup may become a reality in India. India is one of the largest sugar producers in the world, next only to the EU and Brasil, and the per capita consumption, though lower than in countries such as the United States, is much higher than that in China [19].

The brewing industry in India is growing at a rate of 15 % [18]. From the current demand of about 25,000 t of maize needed to produce 5×10^6 hL of beer, the brewing industry will need 105,000 t by the year 2005. If the industry switches to starch syrups from flaked corn the demand will be slightly higher.

Another area where the demand for starches and starch-derived products will witness an increased demand is the pharmaceutical industry. India's drug markets are growing at 15 % per year, the growth rates are amongst the highest in the world. Current per capita expenditures on drugs are only $\$ 3$ per year but are expected to rise as the economy is liberalised. Total investment is estimated at $\$ 345 \times 10^6$ [20].

In the USA and elsewhere, a significant amount of the starch produced from maize milled by wet millers is used as the starting material for other chemicals. Production of alcohol and high-fructose corn syrup have been the main drivers in the increased grinding of maize in the United States in recent years. A significant amount of the maize is used to manufacture fuel ethanol. This market is regulated and subsidised and in principle would not be economically viable against petrol. In India, this is not an option because of high costs and limited bagasse availability. However, there are several other opportunities for the utilisation of starch and starch hydrolysates as chemical feedstock. In the United States large quantities of amino acids such as methionine, glutamic acid and lysine are produced from starch hydroly-

Tab. 6. Estimates of maize consumption by the wet milling industry (1000 t).

	Native starch		Modified starch		Starch hydrolysate*		Total	
	1998	2005	1998	2005	1998	2005	1998	2005
Textile	132	182	29	42	0	0	161	224
Paper	14	21	18	26	0	0	32	47
Pharmaceuticals	9	18	3	7	73	133	85	158
Chemicals/fermentation	29	78	0	0	36	78	65	156
Confectionery	0	0	0	0	147	217	147	217
Other food	18	46	11	15	35	37	64	98
Other non-food	19	24	16	20	57	138	92	182
Total	221	369	77	110	348	602	603	1082

* Starch hydrolysates include glucose syrup, dextrose monohydrate, and sorbitol. All values are of maize equivalent at average yields obtained in India at present.

sates as are xanthan gum, erythritol, citric acid, lactic acid, and polydextrose, to name a few. The starch-based products are also used in fermentation media used in the manufacture of antibiotics. Though some of these have a limited market in India at present, it is likely that some would, in the not-to-distant future, have a sufficient market to make manufacture in India viable. The amino acids lysine and methionine, commonly used in feeds, are cases in point. In the case of citric acid, this production is already a reality [21] and requires the output of grinding 140,000 t/a of maize. With the rapid change in the industrial environment, such additional capacities may fructify soon. Hydrolysates are also being used in India for the manufacture of antibiotics such as penicillin. One Indian manufacturer has also announced setting up a plant to produce monosodium glutamate (MSG) [22].

Our estimates for maize utilization by the wet milling industry at present and in the year 2005 are given in Tab. 6. The estimates for the year 2005 are considered conservative, and it is anticipated that the actual demand for starch products will be much higher than indicated.

4.3 Maize as a direct food

The quantum of maize that is used as a direct food ingredient is larger than that in Europe or the United States but is similar to (if not lower) that in South and East Africa. However, unlike the latter, the food applications in India are varied. Maize flour is used to make unleavened breads (*rotlas*), which are eaten mainly in a few Northern states, such as the Punjab, especially in the winter. By and large, other than in the Punjab, maize breads are more commonly consumed by the less affluent people. It has not been possible to estimate the amount of maize used in this application. Maize flour is often added to "gram" (*Cicer arietinum*, chickpea) flour (*besan*) used in the manufacture of traditional Indian snacks. The addition of maize flour is perceived to improve the organoleptic properties of the final snack, by imparting it a desireable crispness. However, the main reason for such addition is to reduce cost due to the increasing price of chickpea, and to make traditional snacks affordable to the masses. The Prevention of Food Adulteration Act (India) does not permit such addition to *besan* marketed as such. However, it can be added to ready-to-use snack mixes. Also, as a large proportion of traditional *besan* snacks are produced at "tea stalls" or other roadside eateries seen all over India, the addition can be done at this stage. It is not possible to quantify the amount of maize used for this purpose, it is perceived to be large and increasing. About 3×10^6 t of *besan* are produced annually.

Another mode of direct consumption of maize is as roasted corn-on-the-cob. The cobs are roasted on an open charcoal fire by roadside vendors, and are available in most parts of the country. Here again, no statistics are available for the amount of maize consumed in this manner. Maize also goes into the manufacture of corn flakes, as well as snacks. Recently, Mexican style snacks and foods have been introduced in India and are gaining acceptance, though the volumes at present are small.

5 Conclusions

From the above, it is evident that there will be an increased demand for maize in India in the future. There are two options by which this increased demand could be met: one is to import maize, the second being an increase in production. To meet the growing demand for maize, the yields will have to be improved as there is little scope for increasing the area under cultivation (unless the area used for cultivation of sorghum is sown with maize). With proper inputs this does not seem to be a diffucult task as the states with large areas under maize have low yields. If the average yield rises from the 1995–96 level of 1.55 to 2.55 t/ha, the total production will increase to 15×10^6 t. At an average yield of 3.63 t, the production will increase to 21×10^6 t, more than double of what it is today. It is important to note that the improved yield levels envisaged are much lower than the yield levels in Europe and the United States. What is, therefore, needed is the easy availability of quality seeds and other inputs and the transfer of technical expertise from the academic institutions to the farmer. The seed companies have a large role to play, and it is surprising that their effort has not been greater than what it has been, considering their self-interest in selling quality seeds. There is a body of opinion that believes that often the seed companies have had an adverse effect in that the mere purchase of quality seeds by the farmer does not guarantee higher yield. Higher yields are dependent on several inputs and unless the farmer implements these he will not obtain improved yields. Having invested in quality seeds, the absence of suitable returns will prejudice him from going in for such seeds again.

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