

Vegetable seed industry – Retrospect and prospects

The vegetable seed industry annual market value by late eighties was around ₹400 crore of which vegetable seeds was about ₹40 crore. The Government realized that the seed act needs change to allow Indian farmers to have access to seeds of highest quality and genetics from the developed world. This brought in the Open General License Act in 1989 that allowed import of seeds from abroad for testing and sale in India and allowed full research and development within private sector- recognized by DSIR. The changes this act brought about in vegetable seed sector and how it has impacted our farmer's productivity as well as total vegetable production will be detailed below under various crops where most research was focussed.

THE author has personally experienced the growth of the seed industry since over 50 years and seen its growth from being just producers and marketeers of publicly bred varieties to developing into full fledged research, product development, production, sales and marketing units comparable to the best in the globe. During those early days in late 60's and 70's the few companies like Sutton Seeds India, Pahuja, Mahyco and a few others, were the main seed companies known in the private sector cornering less than 5% of the total vegetable seed market in India. Most of the seeds were produced by the public sector companies like National Seeds Corporation (NSC) and several State Seed Corporations. In vegetables, seed replacement rates were less than 25% as farmers used to resow their own saved seeds. Seed quality, agronomy followed by farmers was not of a high standard and that meant low yields per unit area that were more or less similar to heavily populated countries like China and about half of what was obtained in USA and other developed nations. The industry, especially vegetables, has come a long way from those early days to the current. The first signs of more professionally based vegetable and flower seeds were seen by the establishment of Indo American Hybrid Seed Company in Bengaluru established by Late Padmashri Dr Manmohan Attavar and his partner Mr Krishna Bhat around 1972 when they introduced the tomato hybrid Karnataka and sweet pepper hybrid Bharat. Not only did they introduce these but also did an excellent extension work to introduce staked cultivation of tomato in commercial plots. In author's view that is a major milestone in vegetable industry and this coincided with his own journey into the vegetable crop improvement scenario in private sector as he joined Pioneer as Principal Vegetable Breeder after 17 years in IIHR, Bengaluru. Soon several other MNC's started

their own R&D as well and initially the market received the best hybrids from their parent companies which was followed by hybrids developed in-house. The key crops for in-house research initially were tomato, pepper, okra, tropical cauliflower and eggplant. Once success in these crops was apparent, other crops like cucumber, bitter gourd, etc. followed. East West seeds and few Indian companies like VNR focussed initially on gourds and cucumber and later added the main crops as well. About ten years back few companies like Rik Zwan, Enza Zaden, Syngenta also started to focus on high value products suitable for protected cultivation-- tomato, sweet pepper, cucumber being the key crops.

Vegetable Industry today

From 40 crore annual turnover in 1989 the vegetable seed industry reached an annual revenue of ₹5,000 cr plus. Among the top companies are five from India, with UPL Advanta at 4th, Namdhari seeds at 5th, Mahyco at 7th, VNR at 8th, RasiHyVeg at 9th and Kalash at 10th.



Fig. 1. Top 16 vegetable seed companies 2020/21
(Source: Author's estimates)

The annual sales revenues given in Fig 1 should be within a ± 10 percentile range. This is a great endorsement of the investor confidence in the potential of vegetable seeds as well as of the talent pool we have in India. Crop breeders, pathologists, seed production technologists, quality assurance and the sales and marketing personnel trained within the country or abroad are not only manning these departments within MNC's but also within Indian companies. The job opportunities in these areas have grown several folds since the OGL act in 1989 and the efforts of these personnel have helped improve both production and productivity by two to four folds in several crops. Admittedly the impact has been on major vegetable crops only, especially where hybrid vigour was possible because by marketing hybrids seeds, companies have an inherent protection of their IP's. These crops are Okra, Tomato, Hot and Sweet Pepper, tropical Cauliflower where breeding was taken up in India from germplasm development to hybrids. Other crops where hybrids are ruling the market are Cabbage, Watermelon, Melon, Bittergourd, Cucumber, Sweet Corn, Baby Corn, Beet Root and a few others. However, in these crops breeding is done abroad, and hybrids are tested in India to select the best for various markets. Focus on the crops where heterosis is not enough and hence OP varieties is the main advancement avenue haven't so far been addressed by the sector, e.g. legume vegetables. This is of late changing as the IP scenario is getting more robust. Crop wise key progress made by private sector is presented below.

Major milestones from private sector efforts in India on vegetables

With the advent of in-house research, each company recruited accomplished breeders to lead their crop breeding and established a clear target approach in their planning. The targets were fixed through discussions with the company's key sales and marketing teams and from that evolved what are known as Product market segments that have enough commercial value to support in-house research investment. This is one of the key success factors of the private sector as they found clear gaps in the crops where there was market potential and

delivered products on time bound plans. Focus was to collect germplasm from within the company's own and from various germplasm repositories around the globe and based on that developed a screening platform to select appropriate lines followed by recombinant breeding to create new lines, go through top crossing and combining ability tests to identify superior inbreds that became parents of successful hybrids in tomato, okra, peppers, tropical cauliflowers. Around 1993 (5 years after the OGL act) and beyond when hybrids from these in-house efforts in these crops started to roll out and found acceptance by farmers. Among these crops, cauliflower is the one that took the longest time. Initial tropical cauliflower hybrids were commercialized around 2005 but the real ground breakers are only 5 to 7 years old. Details of how market driven breeding is conducted under private sector can be found in the recently published book on 'Market Driven Plant Breeding for Practicing Breeders' by Aparna Tiwari et al. (2022). Crop wise impact analysis is presented below.

Tomato: After the initial success of hybrids like Rashmi, Rupali by IAHS, followed by NS 2535 by Namdhari Seeds several diseases especially the white fly transmitted virus, Tomato Leaf Curl Virus (ToLCV) became limiting factors. Novartis (Now Syngenta) introduced Avinash as the first ToLCV tolerant hybrid that had adult plant tolerance as well as good heat tolerance. This helped start the summer segment of tomato in South & West India where sowing could be done in Jan/Feb and obtain fruits by May/June when farmers could realise the high cash value of ₹ 10 at farm gate around 1996/97. This was soon followed by the hybrid Abhinav by Syngenta around 2003 which was resistant to the virus ToLCV through a *Ty* gene and had good heat tolerance as well as highly firm fruits that could transport from Bengaluru to Kolkata by trucks. This is a milestone in tomato breeding in India and soon several hybrids with resistance to bacterial wilt, higher heat, better foliage disease tolerance and firm fruits were released. These advances made year-round cropping possible in India. The overall impact is that our average yields today have reached 25 t/ha vs 15 t/ha in 90's (FAO Stats data). In Fig 2, one can see the overall impact of the

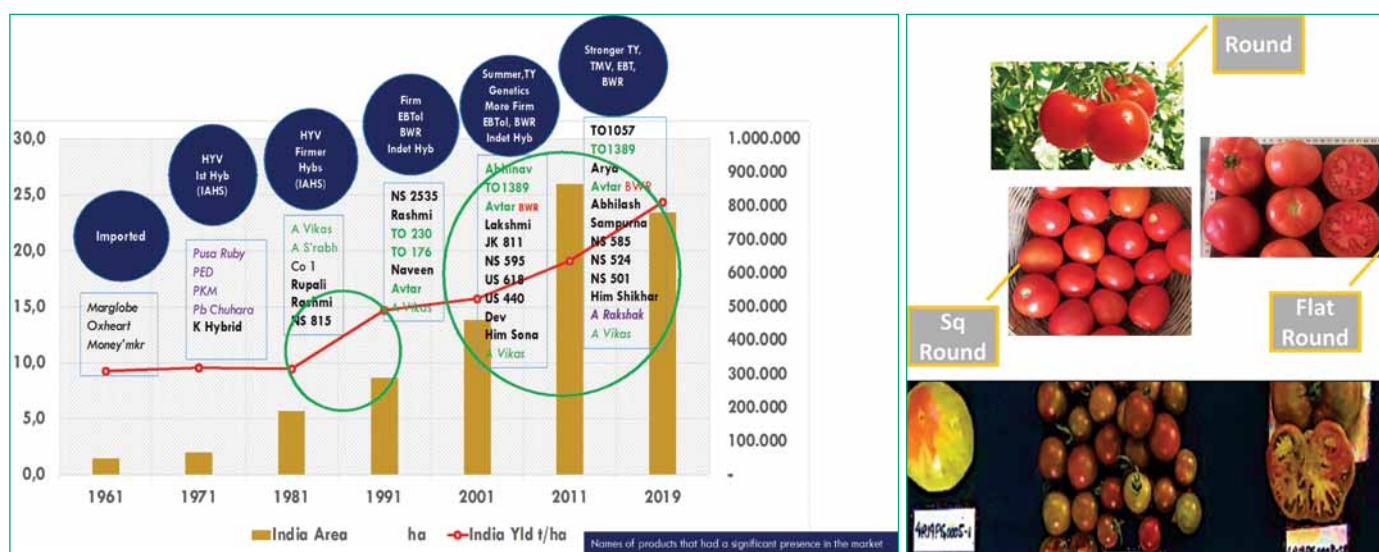


Fig. 2. Tomato area, productivity and important products 1961-2019 and product segments

private seed sector on the crop by way of yield, acreage and segmentation over last 5 decades and see the main products that held a good market share.

The author has also had a direct impact on this scenario as a breeder by developing the market leading variety Sel 22 (Arka Vikas) at IIHR, released by CVRC in 1987, which remained a national check for nearly two decades, to developing Hybrids in private sector like LIHB 230 and 7711 (Indeterminate and was the first bacterial wilt resistant hybrid from private sector) at Pioneer (Now BASF) and finally also Research Head under whom the first highly TY resistant, heat tolerant and very firm fruited Abhinav was developed at Syngenta. Today about 100 mt of hybrid tomatoes are sold in India. The names of varieties and hybrids that had a good commercial presence and the traits and technology that was required to introduce those are presented in detail in Fig 2. The real increase in productivity started from 1991 as the hybrids got entrenched in the market. But the big increases started from 2001 when the TY resistant hybrids were released which also led to increased acreage. Today around 8,00,000 ha are grown annually in India. As yield per unit area keeps increasing the area for tomato will ultimately either remain same or decline a bit. In the same figure one can see the transition from public sector to private sector after 90's and see the traits (blue circles) that have been continuously added since the 70's. The annual turnover of the crop in 2020-21 was ₹400 crore.

Okra: In the last five years, Okra has become the most valuable vegetable crop in India both in terms of increased popularity and high revenues for not only the seed sector but also the small farmer. The acreage per unit area yields have seen huge increases in last decade rising from 4.6 t/ha in 2011 to 6.8 t/ha in 2018 and 13.5 t/ha in 2021 as per FAO Stats. Hence the production increase has been largely due to genetic gain for yield and not just increased acreage (Fig 3).

From a seed revenue of ₹ 91 crore in 2011 the same has reached ₹750 crore in 2019. Estimated 2020-21 revenue was ₹1,000 cr. This transformation was started by the release of highly popular YVMV resistant

varieties like Parbhani Kranti by Drs Y S Nerkar and N D Jhambale from Parbhani; Arka Anamika by Dr O P Dutta from ICAR-IIHR, Bengaluru and Varsha Uphaar by Dr B.S.Dhankar from HAU, Hisar. By 1990 the first hybrids of Okra, Vijay and Varsha by IAHS, Bengaluru appeared in the market that showed improved yields over OP's to around 20-25%. This was followed by a market leading hybrids Sun 40 and Sun 8 by the author in 1994. Hybrids by other private sector companies with significant market share kept on getting introduced, viz. MH 10 by Mahyco; SI 152 by Syngenta; Avantika by BioSeeds; Shakti by Nunhems; JK 7315 by JK Seeds; US 7109 by Seed Works etc during 2001 to 2014. Their popularity kept increasing because of their stable virus resistance and better yield over OP's. The game changer has been the release of the short internoded strongly virus resistant hybrids, like Radhika where good tolerance to the other important menace Okra Leaf Curl Virus (OLCV) was combined with YVMV by Advanta which has helped increase yields over previous hybrids by about 20%. The spread to the smallest farmer, who grow 80% of our food, has been relatively easy as no changes in their agro-techniques were needed for them to adopt the new hybrid/s. Fig 3 also summarizes the transition and progress in the crop from 1961 to 2019. One of the key factors for success by private sector has been the selection of early generations under hot spots within the country followed by multilocation hybrid evaluation across the country to help reject nonstable hybrids. In Fig 3 one can also see the pod segment potential, green and purple already in the market. Seven ridge types and baby okra are also in pipeline.

Hot and sweet peppers: Among peppers, impact in peppers from private sector has been on Hot Pepper (Chillies) while on Sweet Pepper (Simla Mirch) the impact is more on hybrids for protected culture. The two main segments in hot pepper have been the Dry and Fresh Green and over time a dual segment has also emerged where farmers harvest green chillies a few times and then leave the rest to dry on plant and harvest the red ripe and dry fruits for spices at the end. Product

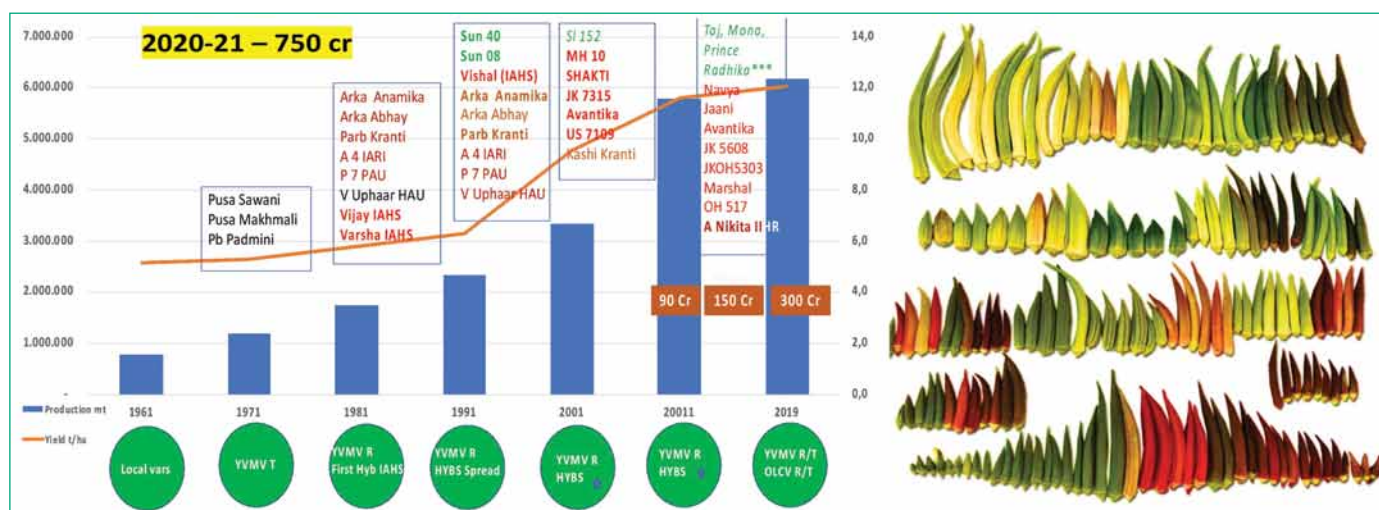


Fig. 3. Okra transition from OP 100% up to 80's to 80% hybrids by 2020-21 and potential pod segments (Note: Green bold fonted hybrids developed by author & Green italics under authors leadership)



Fig. 4. Peppers (Dry and Green) area and yield of India 1990-2018 (Source: FAO and product segments)

market segmentation has been the way that breeders have addressed the improvements for the market. Top five segments that breeders have concentrated are 1. Red dry, short cylinder, 2. Dual Segment, 3. Red Dry Bydaggi Kaddi, 4. Red Dry Bydaggi Dabbi, 5. Green Fresh. Dry chillies as well as dual types are grown on a very large acreage of over 7,80,000 ha (stable over four decades). This year the acreage has again crossed 8,50,000 ha. Fresh green segment has grown from 4,750 ha to 9,634 ha as per FAO estimates (Fig 4). While yield per ha in dry segment has seen 2.5 times increase since 1990, yields in green segment have gone slightly down from 8.8 t/ha to 8.2 t/ha. Overtime market has diversified into finer segments in dry and fresh green chillies.

Over the last four decades the market has moved from open pollinated to hybrids and today over 80% area is covered by F1 hybrids. The top five products in the market are Yashwashini (Mahyco) in Red dry short slender segment, Mahy 456 (Mahyco) in Dual segment, HPH 5531 (Syngenta) in Byadgi Kaddi and Green fresh-dual, HPH 2043 (Syngenta) in Red dry Byadgi Dabbi and VNR 145 (VNR) in Green fresh. Major achievements in private sector have been improved fruit quality (Red dry colour and Surface, ASTA values), Intermediate tolerance to CLCV (chilli leaf curl virus), Quick drying, dry matter

content, plant ideotype-a sturdy plant structure for adverse weather, high pungency (capsaicin content) for Industry usage and yield and stability across environments.

Eggplant: Eggplant acreage has increased by 2.5 times since 1990 but the yields after a good increase in the first decade after OGL (Fig 5) have stagnated since. The period 1990 to 2001 saw the introduction of hybrids in several segments like Green Long and round, Purple long and round, the purple with white stripes (popularly known as Manjari Gota segment where Mahyco hybrid ruled the market for a long time), the green oval segment with the green and white stripes where hybrids from Ankur Seeds as well as Syngenta were very popular. The consumer segments in eggplant within the country are very different in each state and sometimes unique even within a district. An idea on the type of consumer demand can also be gauged from Fig 5. In eggplant it is the most varied among the three solanaceous crops. Hence the breeding programs are focussing on just the top 5 or 6 types as it is not possible to focus on all segments. As the yields of hybrids are ensuring a fair income for farmers and the diseases affecting the crops are not as severe as in other crops, focus has been on breeding high yielding hybrids with better glossy colour. In the Manjari Gota segment

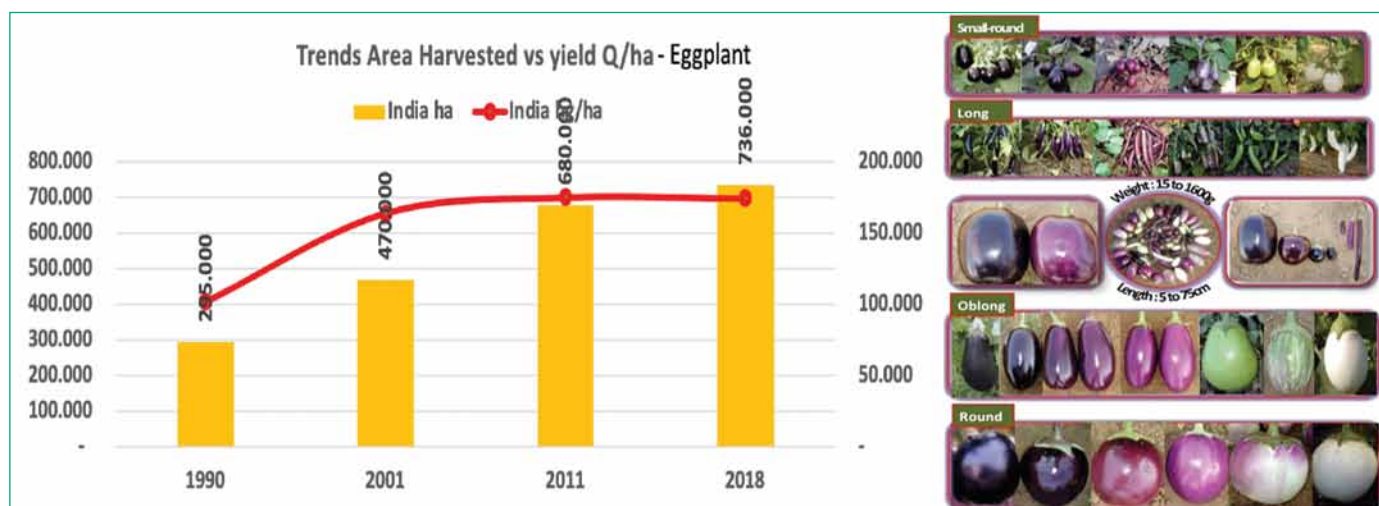


Fig. 5. Eggplant area and yield of India 1990-2018 (Source: FAO and product segments)



Fig. 6. Watermelon and Melon yields and acreage 1991-2019 (Source: FAO Stats and their key product segments)

the key trait is better shelf life and cooking quality.

Watermelon and melons: In Fig 6, one can see that in both crops' acreage has increased significantly in last decade. In watermelons this has also come with higher yields per unit area. In melons the yields have more or less remained stagnant though acreage has increased as more consumer acceptance for new more sugar and thicker fleshed hybrids came about. In the private sector in both these crops the impact on the market has been through imported hybrids from sources abroad. In authors estimate over 70% of the required seed quantity in India is met from imported seeds. The predominantly OP market has now been converted to over 85% hybrids. Key changes in watermelon have been from the large fruited 8 to 10 kg market of 90's to either 3-4 kg sizes and 5-6 kg types. The skin colour is either black or jubilee (light green with black stripes). The emphasis has been family size or what is also called ice box types. In 2020 seedless watermelon hybrid has been released by Syngenta bringing to our farmers and consumers a product that was already available to customers abroad since 2002 onwards. This has been possible by their ability to improve its tropical adaptation and transfer specific agronomic practices to the farmers without which a successful crop wasn't possible. In melons the main change has been through the introduction of thick fleshed, low cavity, high sugar honey dew as well as cantaloupes for the Indian market.

In these crops too, initial research is carried out

abroad but multilocation tests of hybrids is done within India to identify best adapted hybrids. Introduction of popular hybrids by the private sector in these two crops has seen sudden increase in both acreage as well as yield per unit area.

This progress will continue rapidly as disease resistance traits like powdery mildew, etc are being added. Of late melons under protected cultivation are being introduced under protected cultivation which will further boost the yields and quality of the products. Melons with TSS of 16/17% are available today. Top left melon is a product from Known You India Seeds, and is suitable for net house and polyhouse cultivation

Cucumber: Cucumbers too have moved predominantly into hybrids and is one of the biggest cucurbit crops in India and globally too. In India the bi colour in south and west mainly and the dark green beta alpha type in the north are the main segments. In addition, there are the light green "puneri kheera" in Maharashtra and the export-oriented gherkins. Hybrids in each segment and increased consumption since 2001 are impacting acreage (Fig 7).

However, the average yields seem to have stagnated as per FAO stats of 2018. The key reason is the predominance of diseases like powdery and downy mildew and the virus CMV that is still not available in all the hybrids. Protected cultivation is now increasing in the country and is now impacting yields. Companies like Rik Zwan, Enza Zaden

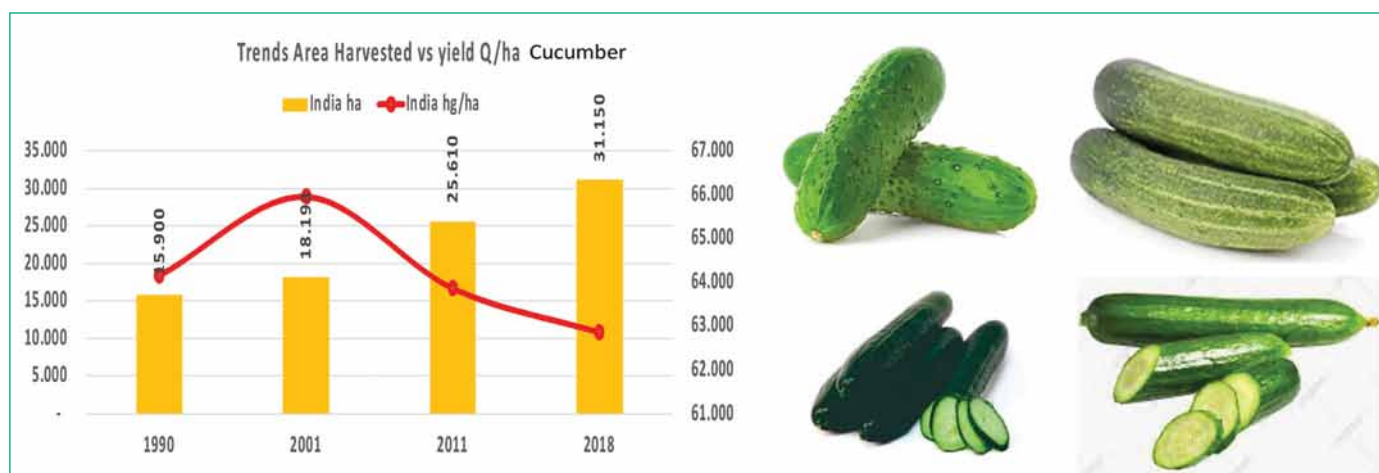


Fig. 7. Cucumber area and yield of India 1990-2018 (Source: FAO and few product segments)

are specifically catering to this segment. This is improving both yield and quality. In the open field East West Seeds, Rik Zwan, BASF, Chia Tai, H M Clause, Taki and Sakata are the main market leaders. Namdhari and VNR are also having market share among Indian companies. Key traits used in the commercial hybrids is incorporation of the gynoeious genetics especially in the protected cultivation segment. Besides helping in producing seedless cucumbers through parthenocarpy the eating quality of the products has improved significantly.

Gherkins (Fig 8) are mainly exported and the value of exports in 2021-22 was \$114m. BASF and Rik Zwan are the leading breeders of this segment. These are preserved in brine solution and exported. All are bred outside of India. Gherkin cultivation has generated a lot of rural employment in Karnataka where it is mostly grown.



Fig. 8. Gherkins

Vegetable Brassica–Cabbage and cauliflower: Both Cauliflower and Cabbage are now over 90% hybrids. In tropical Cauliflower the breeding locally in India by Syngenta, Advanta, VNR in private sector has had a huge impact on its acreage and yield. Today over 20 tonnes of seeds are sold, and Syngenta holds major market share of over 50% as per author's personal estimates. Significantly this work has led to extending the sowing window of February to July in North India for heat tolerant segment. Hybrid Syn 1522 from Syngenta is the clear market leader. This work at Syngenta and Advanta took over 10 years to reach the current stage. Not only do they develop curds under high temperature but have uniform curd size of 500 g to 600 g and nearly 10% plants yield curds that are white. In another transformation in this crop almost 100%

conversion to use of the cms system (Ogura cms-radish) in developing female parents has immensely improved seed production and quality of seeds. In brief tropical cauliflower research can be summed up as below:

- Excellent curd quality- firm, white, big sizes and 95% plus productive curds harvested
- An extended sowing window in range of 45-60 days maturity after transplanting
- Move genetics from SI to cms based in almost all hybrids from Pvt Sector
- Molecular markers for several traits have been developed including Rf and BLB
- Implementation of many new marker assisted selection techniques and also used in seed purity check (commercial F1's) with SNP's before supply to market
- Development of several villages for high quality seed production and rural employment
- Speed breeding by doing two seed seasons a year.
- Full range of hybrids in all segments tropical, sub-tropical and temperate are in the market. This has made year-round availability of both crops for consumers.
- Anti-pinking (of curds) trait to make sure curd remains white and not turn pink in stress.

For Tropical cabbage, temperate cauliflowers and cabbages seeds are still imported from far east companies based in Taiwan, Japan, China to meet our country's needs. Syngenta and AcSenHyveg are the only two companies having local cabbage research programs as per the knowledge of the author. The impact these improvements in these two crops on acreage and yields from 2011 can be seen from Fig 9. Recently Syngenta has also released the purple- and orange-coloured hybrids that have high nutritional quality.

Syngenta, Seminis, Sakata, Advanta are top four cauliflower companies who have introduced full range of hybrids starting from 45 to 100 days in different segments to address growers needs.

Other important contributions of vegetable breeding in private sector

F1 Hybrids in Dolichos and Cowpea: Ankur Seed

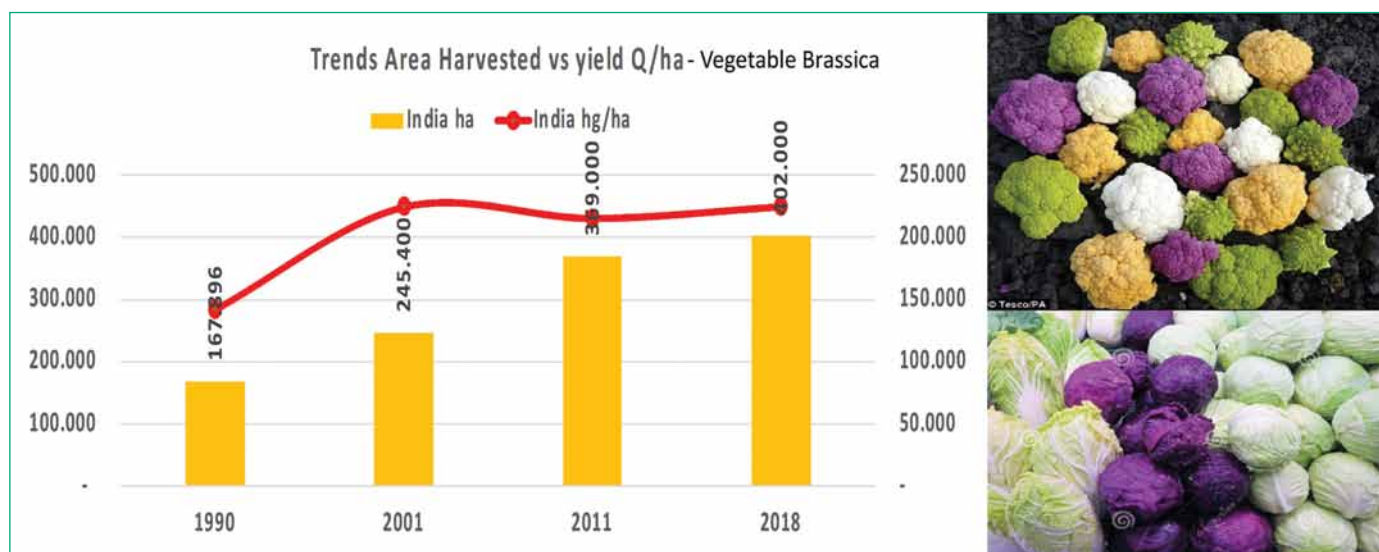


Fig. 9. Vegetable Brassica area and yield of India 1990-2018 (Source: FAO and key product segments)



Fig. 10. Dolichos and Cowpea hybrids using GMS system (Source: Dr Manoj Phalak, Ankur Seeds)

has recently released for the first time ever F1 hybrids in Dolichos and Cowpeas using genetic male sterility system (Fig 10).

Protected cultivation: Polyhouse, greenhouse and nethouse cultivation is gaining ground as it assures quality and yield in adverse conditons – high rains as well as high heat. Reduces water use significantly. Companies like Rik Zwan and Enza Zaden have research base in Netherlands for protected cultivation and are major suppliers of indoor crops, e.g Slicer and Gherkin Cucumbers and various types of Lettuce and large and cherry tomatoes. Rik Zwan is introducing Mid/high tech cultivation methods (Soil less/NFT), transferring knowledge to growers, stimulating, and supporting export, developing linkages between growers and chain partners, cooperation with partners: growers, chain partners and knowledge sharing with institutes and government. Cravo is introducing large scale protected cultivation green houses in India since last six years. These are based on retractable roofs that are controlled by a centralized computer system. Though initially expensive, this technology needs to be adopted by large FPO's as Cravo caters to very large structures. They have a couple of 100-acre projects going on in the country as of now.

New breeding tools

Since 2002 molecular markers have not only been developed in the private sector (tomatoes, peppers, brassica vegetables) but have been applied on a large scale. The author has been using in tomatoes since 2003 and was even responsible for opening the applied MAS lab in Pune under Syngenta in Pune (probably the first such applied lab in pvt sector) followed by a DH lab in Aurangabad in 2005. The DH lab is used by breeders for speeding homozygosity and thus product delivery in Hot Peppers and Cauliflowers. Today almost all the major players in the industry are using both MAS and DH as tools on a large scale on several crops by private sector breeders. MAS – Tomato, Peppers, Veg Brassica, Cucumbers, Melons and DH – Veg Brassica, Hot and

Sweet Peppers, Sweet Corn (a crop that has become very popular since 2003 when Syngenta introduced the hybrid Sugar 75), etc.

Male sterility in vegetables

The CMS system based on Ogura cms (Radish) is now routinely used in all Cauliflower, Cabbage, Broccoli breeding. This has replaced self-incompatibility-based hybrid development completely. Similarly, hot pepper hybrids are based on a CGMS system making hybrid seed production very efficient.

Hybrid seed production in India

India has now become not only a production hub for indigenous hybrids by the companies but also is a global hub for contract hybrid seed production in several crops-based Karnataka, Maharashtra, Gujarat and some sites in North. In several places these production plots are under protected cultivation which ensures global high standards of purity and quality seeds that are free of seed borne diseases. These efforts have improved economies in hundreds of villages and also generated huge employment potential for semi and skilled workers.

Gaps and future strategies

Having achieved great strides the author would like to address a few challenges that are now under consideration by the private sector and will need attention of the public sector too.

Vegetable consumption per capita: As seen in Fig 11, our per capita consumption of almost all vegetables is around 20% of Chinese population. It is even in the most popular vegetables like tomato, peppers, chillies, cabbages, watermelons and melons. We are better in dry chillies and Okra and equal in Onions. The author is sure that similar will be the scenario in all other vegetables too. Hence, we need to work towards diversifying our vegetable usage as well as increase their consumption to meet the daily requirement of 400 g plus per capita. We

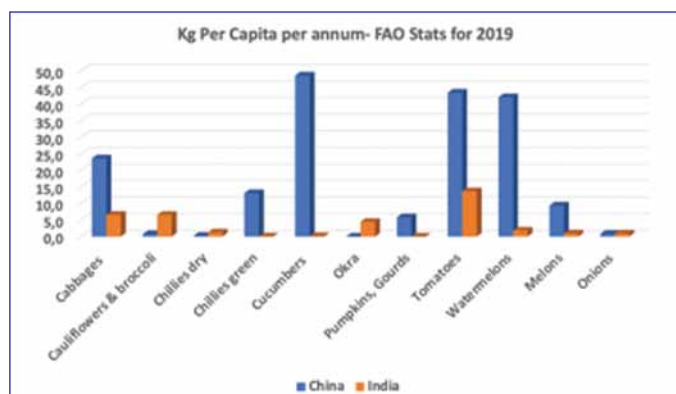


Fig. 11. Per capita consumption of vegetables, India vs China (Source: FAO stats-2019)

are at around 220 g today. This needs not only breeders attention but also extension agencies within private sector as well as government.

Productivity gap analysis: In Fig 12 are presented average yields of key vegetables over four decades to see how we have progressed and to see how we have progressed vs an equally populated country like China. This table is prepared based on FAO Stats and helps us to see progress as well as key gaps that need to be addressed. In the column % over 1990 we can see the best progress in Dry Chillies to the tune of 163% and 100% in Watermelon. Okra at 91%, Eggplants at 71%, Tomatoes at 55% Cauliflower at 35% increase over 1990 are the other best results. In 1990 we had 117% more yield over China in Melons but today we are at 64% of that. On an average our yields are 41% of China today. Cauliflower is the only crop where we are close to them and the reason is the huge improvement in cauliflower in India and of course also for the fact that China consumes low per capita cauliflower. Cucumbers, Beans Dry and Green are the worst off at around less than 25%. Fresh green Chillies too at 35% are much below. Beans are an excellent source of protein for vegetarian diets and private sector hasn't been involved in breeding of self-pollinating crops where

OP varieties are the main seeds sold. The reason is the fear of IP getting lost after putting in years of work and expenses. As the PVPFRA regime is strengthening it is surely an area that will now find more attention by private sector but also needs higher attention by public sector.

Nutritional quality breeding: The recent pandemic has increased the demand for vegetables as all consumers now are looking for them as very healthy. There is a lot of variability for nutritional quality traits in all vegetable germplasm. Private industry is moving towards breeding for nutritional quality. Recently Advanta has released a Purple Okra hybrid in the market that is high in flavonoids and antioxidants. Syngenta delivered seedless watermelon with high lycopene and also released purple and orange cauliflower hybrids having higher nutritional quality. At Tierra the author has bred high nutritional quality tomatoes in Indeterminate segment having 100 g fruits and 35-40 g fruits (Fig 13). The hybrids have significantly higher ascorbic acid, reducing sugar and lycopene content besides carrying TY and TMV genes that make them virus resistant. TS 4809 is a green shoulder one and TS 4813 has uniform green unripe colour and both are round fruited. TS 4810 and TS 4811 are in a new segment of snack tomato. Square oval, 35-40 g weight, very firm with over two weeks shelf life even on its red fruits. All four have high flavour/taste scores on organoleptic tests. All are indeterminate and will add new products in the market from this year. This work took over six years after a high flavour heirloom germplasm was crossed with high TY resistant line, followed by pedigree selection and heterosis breeding experiments.

Rootstock breeding: Bottle gourd is an excellent rootstock for wilt and cold tolerance and used in watermelon and melons successfully in countries abroad where grafted seedlings are sold. Tomatoes on bacterial and other wilt resistant stocks have started to be sold as grafted plants in many countries. In India, VNR and a

Crop	Yield kg/ha India					% of China	
	1990	2001	2011	2018	% Over 1990	% CN 1990	% CN 2018
Beans Dry	0.4	0.5	0.4	0.5	10%	28%	26%
Beans Green	3.0	2.8	2.8	2.8	-4%	32%	10%
Carrot & Turnips	14.0	14.7	15.2	15.6	11%	64%	34%
CFL & BROCC	14.2	18.0	18.3	19.2	35%	62%	98%
Chillies dry	0.9	1.2	1.6	2.3	163%	16%	34%
Chillies green	8.8	9.0	8.6	8.3	-6%	52%	35%
Cucumbers & Gherkins	6.4	6.6	6.4	6.3	-2%	43%	12%
Eggplants	10.2	16.4	17.5	17.4	71%	68%	41%
Melons	20.2	21.0	18.7	22.8	13%	117%	64%
Okra	6.2	9.5	11.6	11.9	91%	No Data in China	
Tomatoes	15.9	15.7	19.1	24.7	55%	63%	42%
WAM	12.5	13.1	21.3	25.0	100%	65%	60%
Average	9.4	10.7	11.8	13.1	45%	55%	41%

Fig. 12. Comparison of Yield/ha of vegetables in India and as % of China

Samples original name	Vitamin C (mg/100g fw Ascorbic acid equivalents)	Acidity (%)	Reducing Sugars (mg/g fw glucose equivalents)	Lycopene (mg/100g fw β -Carotene equivalents)
TS 4809	53	0,54	26,48	6,68
TS 4813	51	0,49	24,53	5,37
TS 4810	50	0,65	31,25	7,04
TS 4811	55	0,73	29,63	5,2
Commercial Chk	41	0,67	16,75	3,1



Fig. 13. Nutritional quality analysis of Tierra Agrotech Tomato Hybrids

few other companies are delivering such plants. In future, rootstock breeding needs to get higher focus.

Public Private Partnership projects: Although private sector in India has become part of several consortiums through APSA and World Vegetable Centre (WVC), Taiwan under which projects on tomato, chillies, cucurbits have been running since 2003 with great success. The germplasm and breeding lines are used by Private sector breeders to introgress in their lines and hence helped them develop new hybrids. WVC has conducted an independent survey among private sector breeders to know how their germplasm was utilized. A summary table from a study is presented in Table 1. It is recommended that a similar study be done by ICAR and Universities to gauge how their research is utilized by Private sector. The author mentions this as he is too many times asked that private sector doesn't reveal how they have utilized the germplasm from public sector in India. In authors' view public sector germplasm has certainly been used by private sector in their pedigree and back crossing programs and those projects lead to new pedigrees that become parents of their commercial hybrids. It is generally a 4 to 5 years process before a new hybrid becomes commercial. A study in the right way can help public sector to get good feedback on this issue.

This may help remove the trust deficit between the two sectors and lead to developing pre-breeding projects in mutual partnership. These projects will use wild relatives of each crop of importance to unearth new sources of biotic and abiotic resistance, higher nutritional quality; understand their genetics, discover molecular markers for these new traits and then these can get used by breeders to develop the hybrids and varieties of future. It is time for brainstorming on this very important aspect of crop improvement in vegetables and come up with action plans as quickly as possible.

Table 1. World Vegetable Centre germplasm in Private sector

WVC germplasm in Pvt sector hybrids 2014		
Parameters	Tomato	Chilli pepper
Hybrid seed containing World Vegetable Center germplasm (t/year)	11.0	15.0
Area reached ('000 ha)	65.5	100.0
Farm households reached ('000)	309	223

SUMMARY

In vegetable crops, the private sector has had an immense contribution to the farmers and consumers in India. They have done so by following targeted breeding and developed the downstream activities that involve germplasm development, Inbred and hybrid development, product development by setting up a robust testing platform, a parent seed department to handle increasing breeders' seeds of parents based on a business plan, a rock-solid seed production platform that involves a large organization and partnership with seed producing farmers. Once seeds are produced the sales and marketing departments then ensure that the seeds reach the market. The vegetable seed industry has given tremendous boost not only to employment but also to increased yields that ensured better income to our farmers. Let us look forward to bigger innovations in future hand in hand with the public sector.

For further interaction, please write to:

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If we can get people to focus on fruits and vegetables and more healthy foods, we will be better in terms of our health care situation

- Tom Vilsack

