

Use of World Vegetable Center breeding lines among seed companies in Asia in 2021



Annual Program Evaluation Report

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World Vegetable Center

The World Vegetable Center, an international nonprofit institute for vegetable research and development, mobilizes resources from the public and private sector to realize the potential of vegetables for healthier lives and more resilient livelihoods. WorldVeg's globally important genebank, improved varieties, production, and postharvest methods help farmers increase vegetable harvests, raise incomes in poor rural and urban households, create jobs, and provide healthier, more nutritious diets for families and communities.

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Front cover: WorldVeg pepper breeder Dr. Derek Barchenger (in the middle) talks to seed company staff at the annual meeting of the APSA-WorldVeg vegetable breeding consortium at WorldVeg headquarters in Shanhua, Taiwan on 16 May 2019.

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1 Key findings

1. The APSA-WorldVeg consortium had 38 members in 2021, which is slightly down from 44 members in 2020. Yet, some seed companies participating in special projects did not renew their membership (membership is only compulsory in the first year of the special project) and if including these then the consortium had 48 members in 2021—the same number as in 2020.
2. The study collected data on key performance indicators by sending a customized Excel spreadsheet to 69 seed companies (past and current members); 36 seed companies returned the form. In comparison, 23 companies provided data in 2020 and 11 in 2018. We now have data for 45 seed companies at some point in time, which allows for a more complete estimation of our impact.
3. In 2021, the WorldVeg genetic resources unit processed 3,243 seed requests. This was substantially higher than previous years (e.g., 1,065 in 2020 and 1,660 in 2019) with 72% of seed requests in 2021 made for pepper.
4. Twenty-three seed companies are currently using WorldVeg-developed tomato and pepper germplasm in their breeding programs, 21 are using bitter gourd germplasm, and 8 are using pumpkin germplasm.
5. The data show a continuous increase in the number of vegetable varieties on the market that contain WorldVeg-developed germplasm, from 47 varieties in 2017, to 73 in 2018, to 96 in 2020, and 120 in 2021.
6. Seed sales of WorldVeg-related varieties increased from 14.5 tons in 2018 to 24.7 tons in 2020 to 27.6 tons in 2021. These seed sales in 2021 are enough to potentially plant 181,000 ha under WorldVeg-related varieties and benefit 524,000 farm households in Asia.
7. Tomato accounts for most of the observed impact, followed by pepper. However, the largest growth in impact since 2017 is observed for bitter gourd and pumpkin.

2 Recommendations

1. To encourage seed companies to remain a member of the consortium for the full duration of special projects, we should consider requiring continuous consortium membership for new special projects, and offering multi-year membership at a discount (e.g., 5 or 10% discount for a 3-year membership). Companies that have not renewed their consortium membership could be send a friendly reminder before the annual workshop. If they have not renewed after the workshop then they could be asked to complete a brief exit survey to understand why they did not renew their membership.
2. Developing new attractive special projects every year is important to maintain and expand membership. While WorldVeg launched three new projects in 2020, only one new project was launched in 2021. This requires additional effort.
3. Effort is also needed to promote the consortium to seed companies in Bangladesh, the Philippines, Vietnam, Indonesia, Thailand and Malaysia as these countries are currently not well represented in the consortium.

3 Consortium membership

The Asia Pacific Seed Association (APSA) – World Vegetable Center Vegetable Breeding Consortium was established in 2017 for the purpose of enabling greater impact of the WorldVeg vegetable breeding programs. The consortium has an annual membership term from January 1 to December 31. Companies can join any time during the year.

In 2021, nine new companies joined the consortium—five of which had already been a member before 2020 but did not join in 2021, and four were new to the consortium (**Table 1**). At the same time, 15 companies left the consortium. Some dropped out because the COVID-19 pandemic created financial uncertainty for their business and they tried to save costs. Hence, while actual membership dropped from 44 members in 2020 to 38 members in 2021 (**Figure 1**), it likely to increase again in the future.

One of the benefits of consortium membership is the possibility to join special projects. Seven special projects have been launched to date and are listed in **Table 2**. The first bitter melon project was launched in 2016 before the start of the consortium. Previously, companies joining a special project were not always part of the consortium. Only in 2000 we introduce a requirement that to join a project, a company must be a consortium member in the year the project is launched. Companies are encouraged to remain consortium member in the subsequent years of the special project.

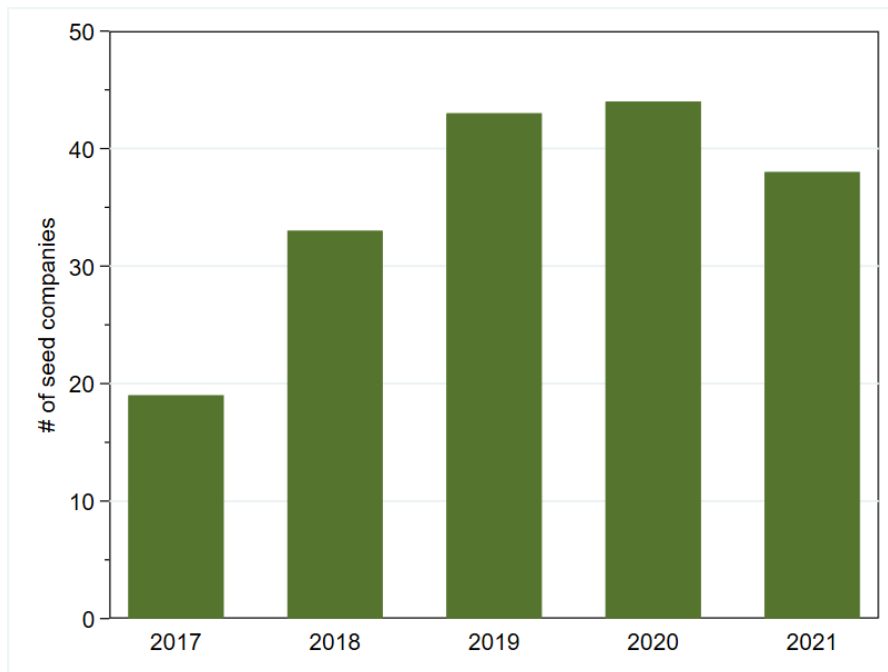


Figure 1 Consortium membership 2017-2021

Table 1 Seed companies that joined or left the consortium in 2021

Seed company name	Country	Previous membership
<u>Companies that joined in 2021:</u>		
1. Enza Zaden Asia Sdn Bhd	India	2017-2019
2. Mahindra Agri Solutions Ltd.	India	2017-2019
3. PT. BISI International Tbk	Indonesia	2017-2019
4. Feltrin Sementes Ltda	Brazil	2019
5. Nong Woo Bio	South Korea	2017
6. Gemini Seeds Pvt. Ltd.	India	New member
7. Genting Green Sdn Bhd	Malaysia	New member
8. Monsoon Foods	India	New member
9. Nova Genetic/Technisem	France	New member
<u>Companies that left in 2021:</u>		
1. Acsen HyVeg Pvt. Ltd.	India	2019, 2020
2. Advanta Seed (United Phosphorus Limited Group)	India	2018, 2019, 2020
3. BHN Seed	USA	2020
4. Ch. Khair Din & Sons (CKD Seeds & Fertilizer)	Pakistan	2019, 2020
5. Chung Kuan Seed Co., Ltd.	Thailand	2020
6. Flotech Seeds Co., Ltd.	Thailand	2020
7. Indo-American Hybrid Seeds (India) Pvt. Ltd.	India	2019, 2020
8. Kaneko Seeds Co., Ltd.	Japan	2020
9. Known-You Seed Co., Ltd.	Taiwan	2019, 2020
10. Laxmi Inputs	India	2020
11. Loc Troi Joint Stock Company	Viet Nam	2020
12. Nu Genes Pvt. Ltd.	India	2020
13. Sakata Seed Corporation	Japan	2018, 2019, 2020
14. Semillas Fito India Pvt. Ltd.	India	2020
15. Welcome Crop Science Pvt., Ltd.	India	2017, 2019, 2020

Table 2 Special projects launched until 2021

Project names ^a	Project period	No. of participating seed companies
1. 1st Bitter gourd	4/2016-3/2019	4
2. 2nd Bitter gourd	4/2017-3/2020	10
3. 3rd Bitter gourd	4/2019-3/2022	12
4. Pumpkin	7/2020-6/2023	11
5. ChiVMV	7/2020-6/2022	8
6. ChiLCD	7/2020-6/2023	17
7. HST of TW & PP	8/2021-7/2024	14

^a Project full names: **1st bitter gourd project**: Private seed sectors support to AVRDC's global cucurbit breeding program; **2nd bitter gourd project**: Broadening the narrow genetic base of commercial bitter gourd cultivars by exploiting the genetic diversity of WorldVeg's breeding lines; **3rd bitter gourd project**: Genetically diverse and superior bitter gourd lines and F1 hybrids of World Vegetable Center for sustainable bitter gourd breeding gains and enhanced profitability of smallholder farmers; **Pumpkin project**: Genetically diverse and superior bitter gourd lines and F1 hybrids of World Vegetable Center for sustainable bitter gourd breeding gains and enhanced profitability of smallholder farmers; **ChiVMV project**: Multi-location evaluation of chili lines carrying different combinations of pvr and Cvr genes for resistance to *Chili veinal mottle virus*; **ChiLCD project**: Chili leaf curl disease in Asia: Diversity and resistance; **HST of TW & PP project**: Heat stress tolerance of tomato & pepper.

Figure 2 shows that seed companies were indeed a consortium member in the year the project started, but some dropped out in the second year of the project. In the case of the pumpkin project this was even 6 of the 11 project members. In 2021, there were 10 companies that were part of several projects but were not a member of the consortium (**Figure 3**). When adding these 10 companies to the 38 consortium members, then WorldVeg collaborated with 48 seed companies in 2021, which was the same as in 2020.

In 2021, 22 consortium members (57%) came from India, 2 each from Indonesia, Taiwan, Thailand and Sri Lanka (**Table 1**). Membership is divided into small/start-up and medium/large companies with the threshold being 100 employees. The share of small companies has been constant at 41-42% over 2019-2021 (**Figure 4**).

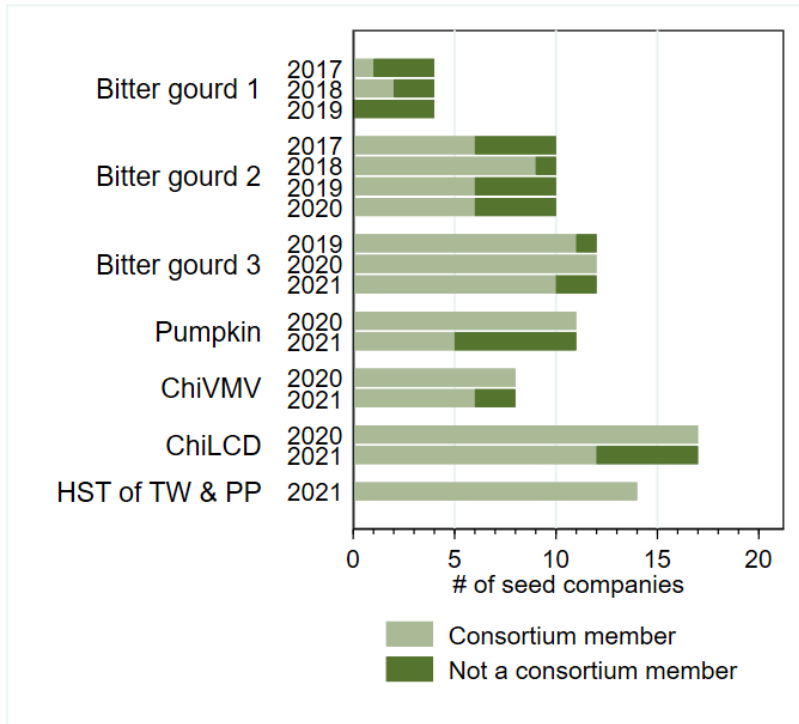


Figure 2 Membership of special projects, 2017-2021

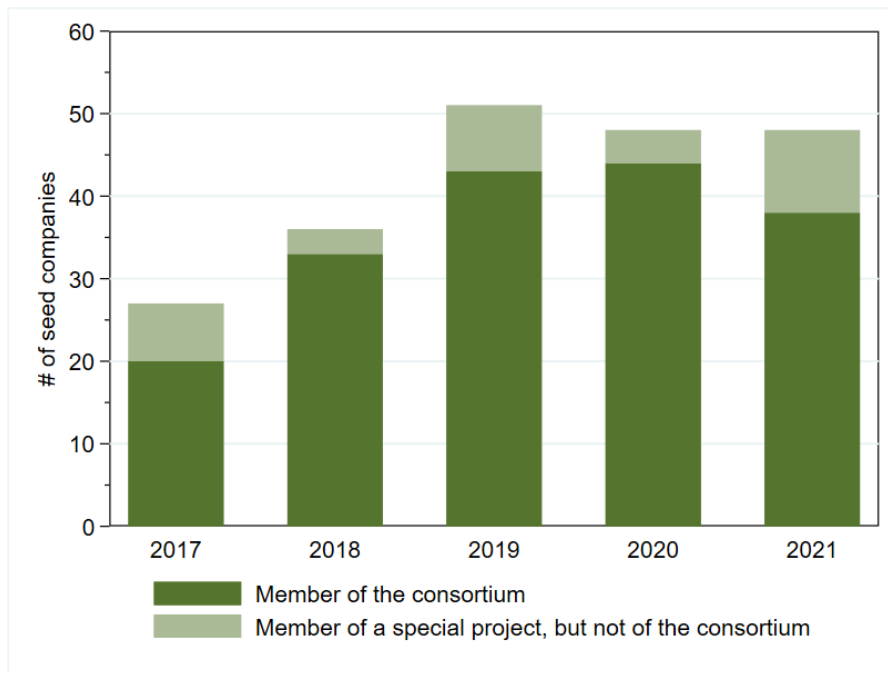


Figure 3 Membership of the consortium and of special projects, 2017-2021

Table 3 Distribution of consortium members by registered location and year

Country/territory	2017	2018	2019	2020	2021
Asia:					
– China	0	0	3	0	0
– Hong Kong, China	1	1	1	1	1
– India	8	20	21	23	22
– Indonesia	2	2	2	1	2
– Japan	1	4	3	3	1
– Malaysia	0	1	1	0	1
– Pakistan	0	0	2	2	1
– Singapore	1	1	0	0	0
– South Korea	1	0	0	0	1
– Sri Lanka	0	0	1	2	2
– Taiwan	0	1	3	3	2
– Thailand	2	1	3	5	2
– Viet Nam	0	0	0	1	0
Other:					
– Brazil	0	0	1	0	1
– France	0	0	0	0	1
– Netherlands	3	2	2	2	1
– USA	0	0	0	1	0
Total	19	33	43	44	38

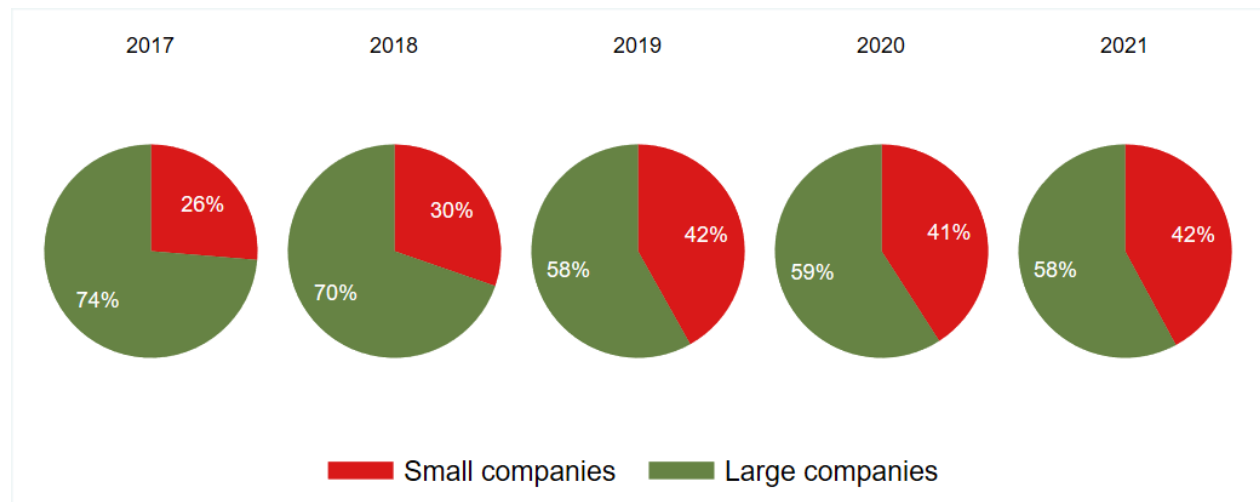


Figure 4 Composition of the consortium in terms of small vs. large companies

4 Data collection and questionnaire response

The objective of this study is to track the use of WorldVeg-developed breeding lines and hybrids of tomato, pepper, bitter melon and tropical pumpkin by seed companies in Asia and estimate their use by farmers.

The three key performance indicators used are:

- (1) The number of seed companies that are using WorldVeg-developed breeding lines in their breeding programs.
- (2) The number of varieties currently sold in Asia that contain WorldVeg-developed breeding lines.
- (3) The quantity of seed sold in Asia of varieties containing WorldVeg-developed germplasm.

The third indicator is used to estimate the area planted to WorldVeg-related varieties using an average seed rate; and, from this, to estimate the number of farm households that are using WorldVeg-developed germplasm assuming an average planted area per farmer.

A second objective of the study is to identify the breeding priorities of consortium members to inform WorldVeg breeding programs.

Data were collected by email using a standard Excel data entry sheet sent to the voting representative and registered contact person of 38 current and 31 past consortium members. No major changes were made to the data collection method used in 2020. All email requests were sent on 15-16 February 2022 and companies were given two weeks to return the data sheet. Reminders were sent afterwards.

By late-March 2022, we had received data from 36 seed companies (**Table 3**). This is substantially better than in 2020 when we received data from 23 seed companies. In total, 45 seed companies have provided data at any time since 2017, which is 65% of all past and present members.

Table 4 Questionnaire response per year

Year of survey	Companies that provided data
2017	14
2018	11
2020	23
2021	36
Any year	45

Note: No survey was conducted in 2019.

Some companies that responded to the 2022 survey not just provided data for 2021, but also for previous years, which added additional data points as shown in **Table 5**. However, not every company has provided data for every year, which makes it difficult to identify trends, also as membership changes over time. Therefore, to estimate the current use of WorldVeg germplasm,

we took the most recent data point provided by each company and assumed that this reflects the current situation. So, if a company did not provide data for 2021 then we replaced it with the data provided for 2020, or else with the data for 2019 or earlier. Combining the data points in such way gives an estimate of the impact for 2021 based on data for 45 seed companies. As seed companies tend to exit and rejoin the consortium, we do not limit our analysis to current consortium members, but include all companies for which we have data.

Table 5 Companies that provided data on key performance indicators for particular years

Year	Tomato	Pepper	Bitter gourd	Pumpkin
2017	24	23	24	23
2018	28	26	26	25
2019 ^a	9	9	9	9
2020	31	29	29	28
2021	36	35	35	35
Any year	44	44	43	43

Note: Figures are different from those in Table 4 as some companies provided data for multiple past years. ^a No survey was conducted in 2019.

5 Seed shipments

Consortium members can order consortium exclusive lines as well as any other (non-exclusive) lines or genebank accessions. **Figure 5** shows the number of seed shipments processed by the WorldVeg genebank per year. Since 2017, a total of 7,855 seed shipments have been sent. Seed shipments were particularly high in 2021 with 3,243 shipments, 72% of which were shipments of pepper seed and 16% of pumpkin seed. The high number of distributions of pepper could be associated with the two pepper-oriented projects launched in 2020.

The geographical distribution of the seed shipments shows that 62% were sent to South Asia, 34% to companies with a registration address outside Asia and only 4% to companies in East or Southeast Asia (**Table 6**).

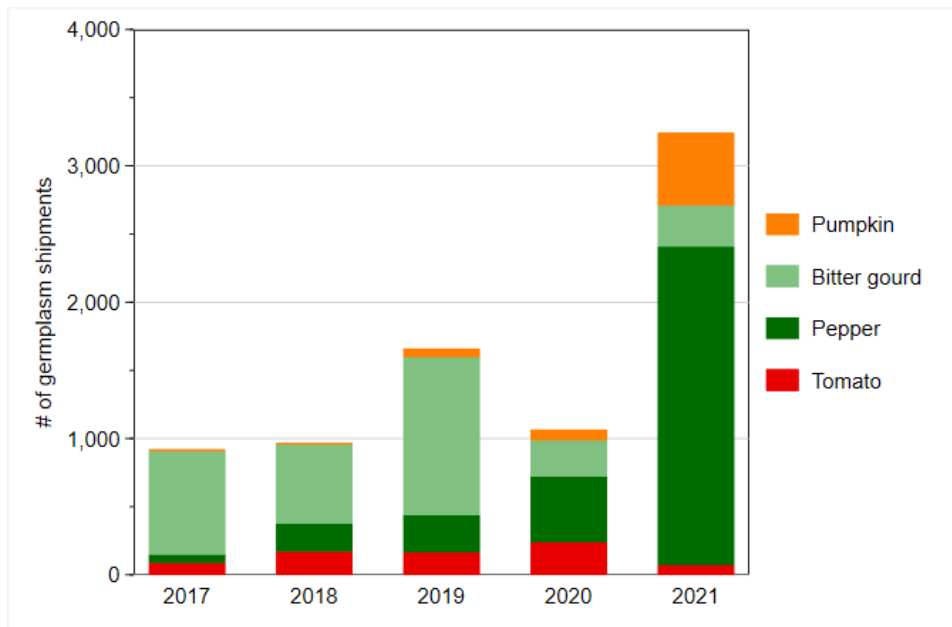


Figure 5 Germplasm shipments to past and current consortium members, 2017-2021

Table 6 Distribution of germplasm shipments by region, sum of shipments over 2017-2021

Region	Tomato	Pepper	Bitter gourd	Pumpkin	Total
South Asia	412	1,714	2,445	306	4,877
East and Southeast Asia	57	250	13	-	320
Rest of the world	266	1,395	613	384	2,658
Total	735	3,359	3,071	690	7,855

6 Key performance indicators

6.1 Varieties incorporating WorldVeg-developed germplasm

The data show a continuous increase in the number of vegetable varieties on the market that contain WorldVeg-developed germplasm, from 47 varieties in 2017, to 71 in 2018, to 94 in 2020, and 120 in 2021 (**Figure 6**). Part of this increase is because companies bring new varieties based on WorldVeg germplasm on the market, but part is also because more companies responded to the questionnaire.

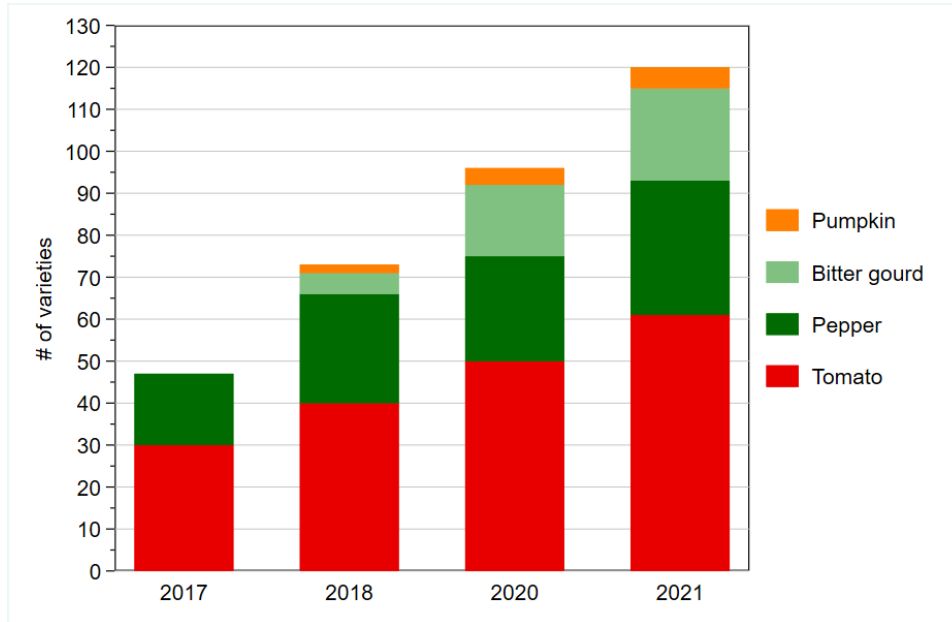


Figure 6 Vegetable varieties sold in Asia that contain WorldVeg-developed germplasm as reported by 45 seed companies, 2017-2021

When combining the data for all 45 seed companies that provided data at any point since 2017, then we count a total of 127 varieties containing WorldVeg-developed germplasm. In total these companies sold 2,081 varieties of bitter gourd, pepper, pumpkin and tomato and hence 6% of the varieties contain WorldVeg-developed germplasm in their pedigrees. The contribution is largest for tomato and bitter gourd, where 8% of all varieties sold contain WorldVeg germplasm.

There is clear evidence that WorldVeg-developed bitter gourd and pumpkin germplasm is increasingly found in commercial varieties of these crops. The total number of WorldVeg-related varieties was 23 for bitter gourd (up from 13 varieties reported last year) and 8 for pumpkin in 2020 (up from 4 varieties last year).

It is likely that the growth in WorldVeg-related varieties will continue in the coming years as an increasing number of companies is using WorldVeg breeding lines in their vegetable breeding programs. For instance, only 6 companies were using WorldVeg bitter gourd lines in their

breeding in 2017, but this was 21 companies in 2021; and 12 companies were using pepper breeding lines in 2017, but this had increased to 23 companies in 2021.

6.2 Volume of seed sales with WorldVeg germplasm

Table 7 to **Table 10** show the key performance indicators for each crop and each year. The years are not strictly comparable as the sample of companies changes over time. The data generally show an increasing trend for the three performance indicators. **Table 11** compares the impact estimates for 2021 to the impact estimates reported in the two previous M&E reports. It is important to emphasize that these data underestimate the true use of WorldVeg material as not all companies disclosed their sales data.

For **tomato**, varieties based on WorldVeg germplasm were sold by 14 companies with 23 seed companies using WorldVeg tomato breeding lines in their breeding program (**Table 7**). Of the 811 tomato varieties sold by 44 seed companies, 66 contained WorldVeg germplasm (8%). About 14.2 tons of tomato seed was sold of these varieties, which is 11% of total tomato seed sales. This seed is enough to plant 118,000 ha of tomato and reach about 381,300 farm households (**Table 11**).

For **pepper**, varieties based on WorldVeg germplasm were sold by 12 seed companies with 23 seed companies using WorldVeg pepper lines in their breeding program (**Table 8**). We have data for 44 seed companies, which jointly sold 190 tons of pepper seed and 8.1 tons of this (4%) is based on WorldVeg germplasm. This is potentially enough to plant 54,000 ha of pepper and benefit 122,700 farm households (**Table 11**). This is slightly down from the 135,500 reported in 2020 as some WorldVeg-related varieties were replaced in the market.

For **bitter gourd**, there were 23 WorldVeg-related bitter gourd varieties in 2021 (up from 0 in 2017 and 5 in 2018) that amassed sales of 4.1 tons in 2021 (**Table 9**). There are 9 seed companies that have commercialized WorldVeg bitter gourd varieties with another 12 companies that are using our material in their breeding program but have not yet released varieties. An estimated 4,700 ha is planted to WorldVeg bitter gourd varieties in 2021, benefitting about 9,300 farm households (**Table 11**). This is an increase of 57% over 2020 levels.

For **pumpkin**, two seed companies have commercialized WorldVeg pumpkin varieties, although a total of 8 companies are using our material in their breeding program (**Table 10**). At present, there are 5 commercial pumpkin varieties based on WorldVeg material out of a total of 201 commercial varieties recorded. Seed sales of WorldVeg pumpkin varieties were 1.3 tons in 2021 (up from 0.3 tons in 2020, which is a threefold increase). We estimate that 4,200 ha is currently planted to WorldVeg pumpkin varieties, benefitting about 10,500 farm households (**Table 11**).

For both pumpkin and bitter gourd, it is important to keep in mind that these programs started only in 2010 whereas the tomato and pepper programs started in 1973 and 1984, respectively. The impact of these new programs is likely to pick up in the next years as seed production is gaining momentum.

Overall, the results show that seed sales of WorldVeg-related varieties increased from 14.5 tons in 2018 to 24.7 tons in 2020 to 27.6 tons in 2021. Seed sales in 2021 are enough to potentially benefit 524,000 farm households in Asia (**Table 11, Figure 7**).

Table 7 Use of WorldVeg tomato germplasm by consortium members, 2017-2021

Tomato	2017	2018	2020	2021	2017-2021
Number of companies:					
Selling WorldVeg-related varieties	10	13	14	13	14
Using WorldVeg lines in breeding	15	9	23	23	23
Number of varieties:					
Varieties, all	343	498	439	623	811
Varieties, WorldVeg-related	30	40	50	61	66
% of varieties WorldVeg-related	9%	8%	11%	10%	8%
Quantity of seed sales:					
Seed sales, all varieties (tons)	61.2	58.1	84.1	92.5	127.2
Seed sales, WorldVeg (tons)	9.0	7.9	10.0	10.4	14.2
Seed sales, WorldVeg (%)	15%	14%	12%	11%	11%
# of companies reporting	24	28	31	36	44

Table 8 Use of WorldVeg pepper germplasm by consortium members, 2017-2021

Pepper	2017	2018	2020	2021	2017-2021
Number of companies:					
Selling WorldVeg-related varieties	7	8	10	11	12
Using WorldVeg lines in breeding	12	7	23	23	23
Number of varieties:					
Varieties, all	353	561	565	715	778
Varieties, WorldVeg-related	17	26	25	32	33
% of varieties WorldVeg-related	5%	5%	4%	4%	4%
Quantity of seed sales:					
Seed sales, all varieties (tons)	85.9	101.6	128.0	148.5	189.7
Seed sales, WorldVeg (tons)	6.2	9.5	6.6	5.7	8.1
Seed sales, WorldVeg (%)	7%	9%	5%	4%	4%
# of companies reporting	23	26	29	35	44

Table 9 Use of WorldVeg bitter gourd germplasm by consortium members, 2017-2021

Bitter gourd	2017	2018	2020	2021	2017-2021
Number of companies:					
Selling WorldVeg-related varieties	0	2	8	8	9
Using WorldVeg lines in breeding	6	5	21	21	21
Number of varieties:					
Varieties, all	86	170	218	252	282
Varieties, WorldVeg-related	0	5	17	22	23
% of varieties WorldVeg-related	0%	3%	8%	9%	8%
Quantity of seed sales:					
Seed sales, all varieties (tons)	95.4	209.8	336.8	189.6	351.4
Seed sales, WorldVeg (tons)	0.0	0.6	2.9	4.0	4.1
Seed sales, WorldVeg (%)	0%	0%	1%	2%	1%
# of companies reporting	24	26	29	35	43

Table 10 Use of WorldVeg pumpkin germplasm by consortium members, 2017-2021

Pumpkin	2017	2018	2020	2021	2017-2021
Number of companies:					
Selling WorldVeg-related varieties	0	1	2	2	2
Using WorldVeg lines in breeding	5	4	8	8	8
Number of varieties:					
Varieties, all	27	83	119	197	210
Varieties, WorldVeg-related	0	2	4	5	5
% of varieties WorldVeg-related	0%	2%	3%	3%	2%
Quantity of seed sales:					
Seed sales, all varieties (tons)	72.7	136.5	214.4	250.5	271.0
Seed sales, WorldVeg (tons)	0.0	0.2	0.3	1.3	1.3
Seed sales, WorldVeg (%)	0%	0%	0%	1%	0%
# of companies reporting	23	25	28	35	43

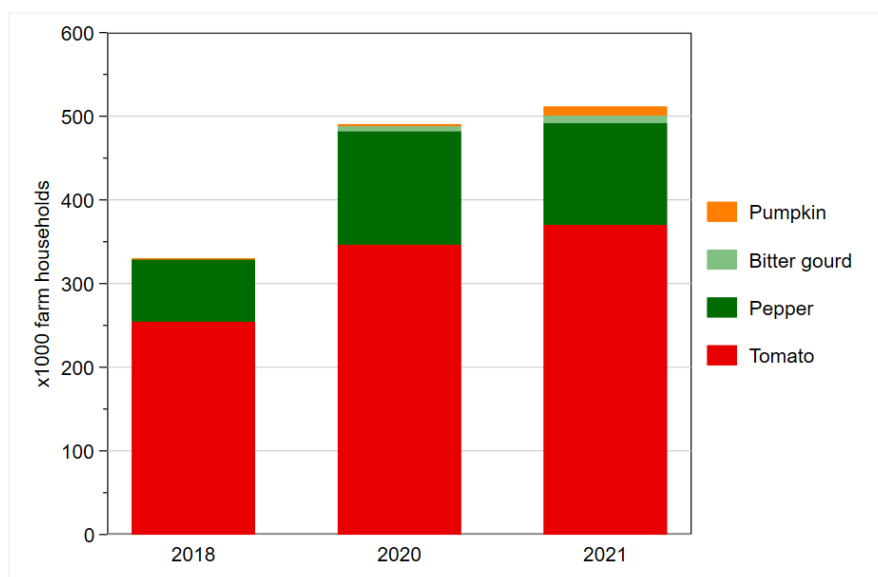


Figure 7 Farm households potentially reached by WorldVeg-related vegetable varieties in Asia, 2018-2021

Table 11 Estimated area under WorldVeg-developed germplasm and farmers reached, 2018-2021.

	2018	2020	2021
Tomato:			
– Seed sales with WorldVeg germplasm (kg)	9,471	12,896	14,184
– Area potentially planted (1000 ha)	79	108	118
– Farmers potentially reached (1000s)	255	347	381
Pepper:			
– Seed sales with WorldVeg germplasm (kg)	4,903	8,941	8,099
– Area potentially planted (1000 ha)	33	60	54
– Farmers potentially reached (1000s)	74	136	123
Bitter gourd:			
– Seed sales with WorldVeg germplasm (kg)	-	2,598	4,086
– Area potentially planted (1000 ha)	-	3.0	4.7
– Farmers potentially reached (1000s)	-	5.9	9.3
Pumpkin:			
– Seed sales with WorldVeg germplasm (kg)	172	289	1,264
– Area potentially planted (1000 ha)	0.6	1.0	4.2
– Farmers potentially reached (1000s)	1.4	2.4	10.5
All crops:			
– Seed sales with WorldVeg germplasm (kg)	14,546	24,724	27,633
– Area potentially planted (1000 ha)	112	171	181
– Farmers potentially reached (1000s)	330	491	524

7 Role of WorldVeg germplasm

Seed companies were asked to provide the names of varieties containing WorldVeg-developed germplasm and to indicate how WorldVeg germplasm was used using five standard options listed in **Figure 8**.

For tomato and to lesser extent pepper, seed companies have mostly used particular WorldVeg-developed traits such as bacterial wilt resistance, late blight resistance, and heat stress tolerance in tomato; and phytophthora wilt resistance and heat stress tolerance in pepper. About a quarter of the tomato varieties and 41% of pepper varieties used a particular WorldVeg breeding line as a parent for a hybrid. Regarding bitter gourd, of the 22 commercial varieties reported, 29% were hybrids that had both parents supplied by WorldVeg, 57% were hybrids with one parent supplied by WorldVeg, and 14% were WorldVeg lines directly released as varieties. For pumpkin, only 5 commercial varieties were reported in 2021 and 4 of these had WorldVeg germplasm as background materials and 1 was a WorldVeg hybrid. The pumpkin project started in 2020 and the use of WorldVeg germplasm will increase in future years.

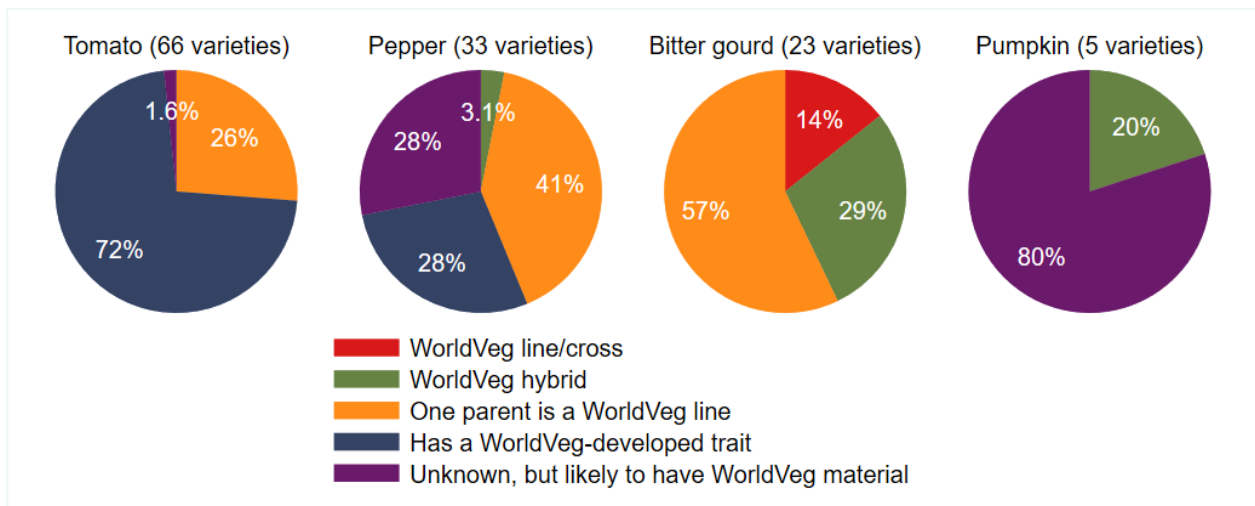


Figure 8 Role of WorldVeg germplasm in varieties containing WorldVeg-developed germplasm, 2021 data

8 Traits

Of the 36 seed companies that responded to the 2021 survey, 23 used WorldVeg tomato and pepper material in their breeding programs while 21 used bitter gourd material and 8 used pumpkin material (**Table 12**). This use of WorldVeg material in breeding programs is important as it is likely to increase the impact of the WorldVeg breeding programs in years to come. Next, we describe the key traits that companies have sourced from WorldVeg or would like WorldVeg to work on.

Table 12 Number of companies using WorldVeg-developed traits, 2021

Variable	Tomato	Pepper	Bitter gourd	Pumpkin
Using WorldVeg-developed traits in breeding program	23	23	21	8
Have incorporated particular WorldVeg-developed traits in current varieties	17	13	7	2

Note: based on the responses from 33 seed companies.

8.1 Tomato

For tomato, the questionnaire included 36 different traits and respondents had to indicate for which traits WorldVeg germplasm was used as a source. It showed that WorldVeg tomato germplasm was mostly used by seed companies as a source of:

- Bacterial wilt (*Ralstonia solanacearum*) resistance – used by 20 companies
- Begomovirus resistance (Tomato yellow leaf curl virus, Tomato leaf curl New Delhi virus, and others), bacterial wilt – used by 18 companies in their breeding program
- Late blight (*Phytophthora infestans*) resistance – used by 15 companies
- Heat tolerance – used by 12 companies
- High yield – used by 9 companies
- Tomato mosaic virus (TMV) resistance – used by 8 companies

For each of the 36 traits, respondents had to indicate the priority they would like WorldVeg to give to further developing these traits (very high, high, medium, or low), as shown in **Figure 9**. This is largely the same as the traits listed above with the additions of:

- Keeping quality (shelf-life)
- Early Blight (*Alternaria solani*) resistance
- Tospovirus resistance
- Cucumber mosaic virus (CMV) resistance

A few companies also mentioned other traits, not listed in the questionnaire:

- Fruit cracking
- Small blossom end-point

- Stem scar
- Firmness

We had added two questions about desired fruit color and fruit size, but only few companies answered this. Four companies from India responded “Deep red”, “Red”, and “Pink” and one company from Japan responded “Red, Pink”. In terms of fruit size, three companies from India indicated 100-130g, 120-150g, and 100-120g, one company from East Asia indicated 150-200g for beefsteak tomato, and one company outside Asia indicated “above 200g”.

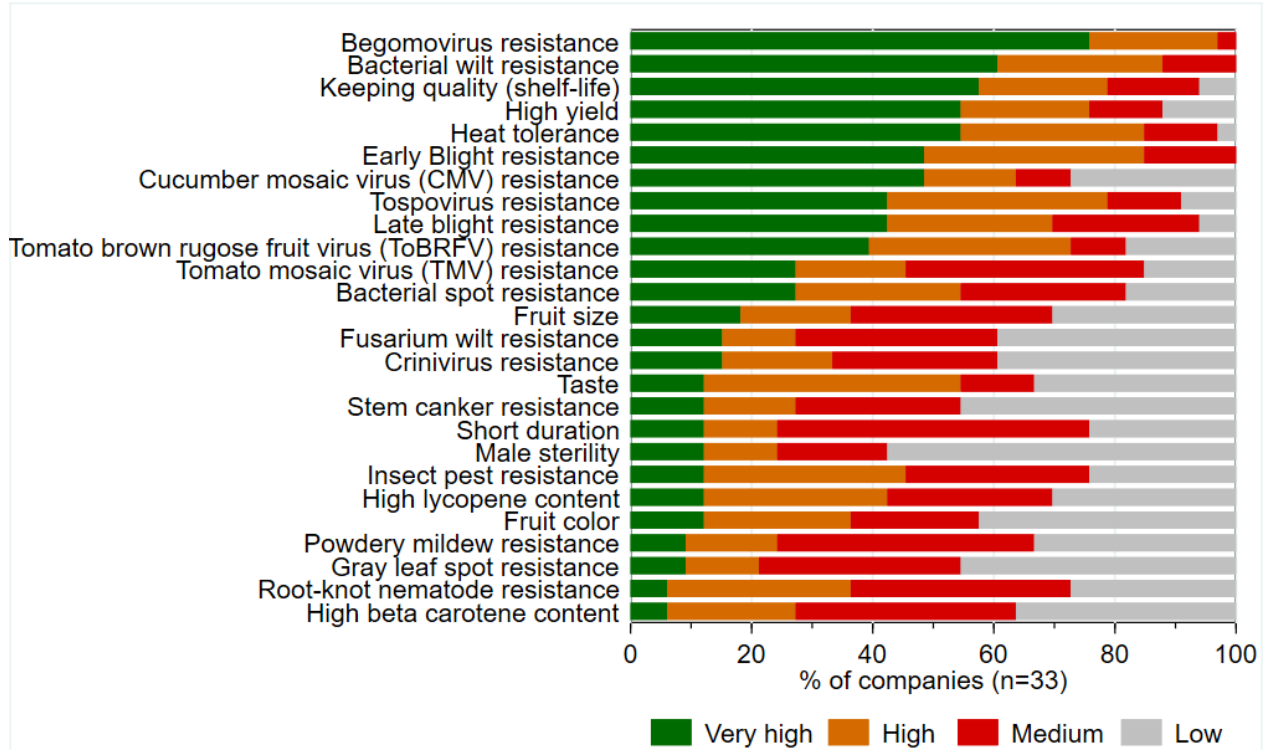


Figure 9 Priority traits for tomato

8.2 Pepper

For pepper, the questionnaire listed 20 traits. WorldVeg pepper germplasm was source of the following traits used in breeding programs:

- Anthracnose (*Colletotrichum* spp.) resistance – used by 13 companies
- High temperature stress tolerance (heat set) – used by 12 companies
- High yield – used by 11 companies
- Fruit size – used by 10 companies
- Cytoplasmic male sterility (CMS) – used by 9 companies
- Phytophthora blight (*Phytophthora capsici*) resistance – used by 9 companies
- Cucumber mosaic virus (CMV) resistance – used by 8 companies

- Bacterial wilt (*Ralstonia solanacearum*) resistance – used by 8 companies
- Dark red color (high ASTA) – used by 8 companies
- Chili veinal mottle virus (ChiVMV) resistance – used by 8 companies
-

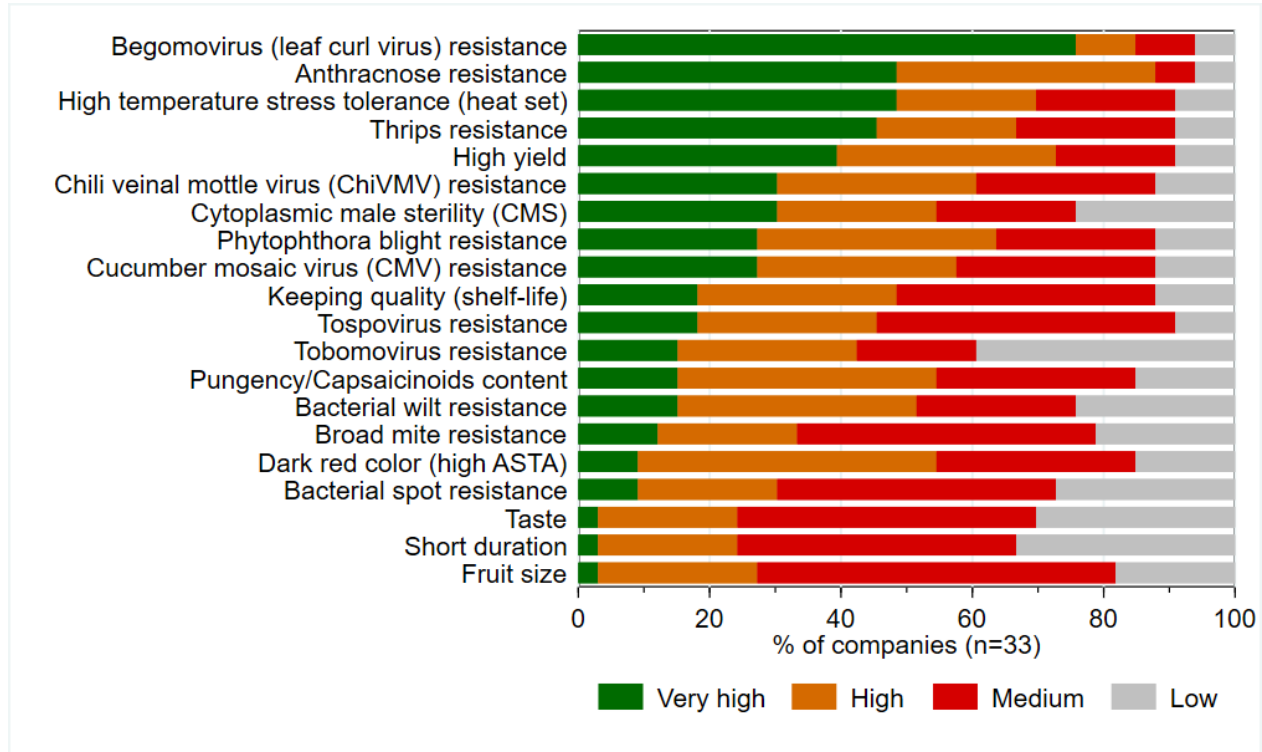


Figure 10 lists all traits and shows those that companies would like WorldVeg to prioritize for further development. Here the five most important traits are:

- Begomovirus (leaf curl virus) resistance – very high priority for 76% of companies
- Anthracnose (*Colletotrichum* spp.) resistance – very high priority for 48% of companies
- High temperature stress tolerance (heat set) – very high priority for 48% of companies
- Thrips resistance – very high priority for 45% of companies
- High yield – very high priority for 39% of companies

A few companies also mentioned other traits, not listed in **Figure 10**, including:

- Crinivirus resistance
- Root knot nematode (RKN) resistance

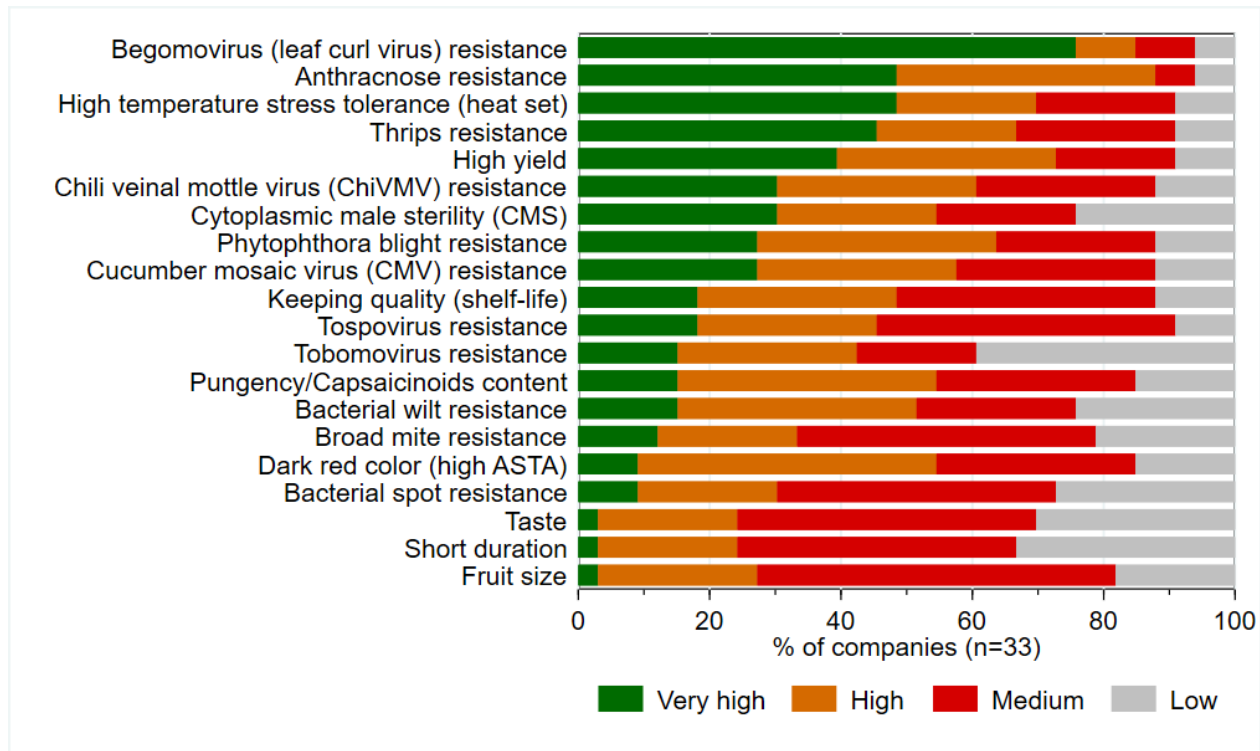


Figure 10 Priority traits for pepper

Notes on scientific names of plant diseases: Bacterial wilt (*Ralstonia solanacearum*); Phytophthora blight (*Phytophthora capsici*); Late blight (*Phytophthora infestans*); Anthracnose (*Colletotrichum* spp.); Early blight (*Alternaria solani*); Stem Canker (*Alternaria alternata*); Gray leaf spot (*Stemphylium solani*); Bacterial spot (*Xanthomonas*); Fusarium wilt (*Fusarium oxysporum* f. sp. *lycopersici*)

8.3 Bitter gourd

For bitter gourd, the questionnaire listed 12 different traits. The most important traits sourced from WorldVeg material included:

- Begomovirus resistance – used by 18 seed companies in their breeding program
- Powdery mildew (*Leveillula taurica*) resistance – used by 17 companies
- Fruit size – used by 15 companies
- High yield – used by 13 companies
- Fruit color – used by 13 companies
- Skin pattern – used by 12 companies
- Early fruit maturity – used by 11 companies
- High female/male flower ratio – used by 11 companies

Figure 11 ranks the breeding priorities. The five most important priorities included:

- Begomovirus resistance – very high priority for 67% of companies

- High yield – very high priority for 48% of companies
- Powdery mildew (*Leveillula taurica*) resistance – very high priority for 37% of companies
- Gy line development – very high priority for 37% of companies
- High female/male flower ratio – used by 11 companies – very high priority for 26% of companies

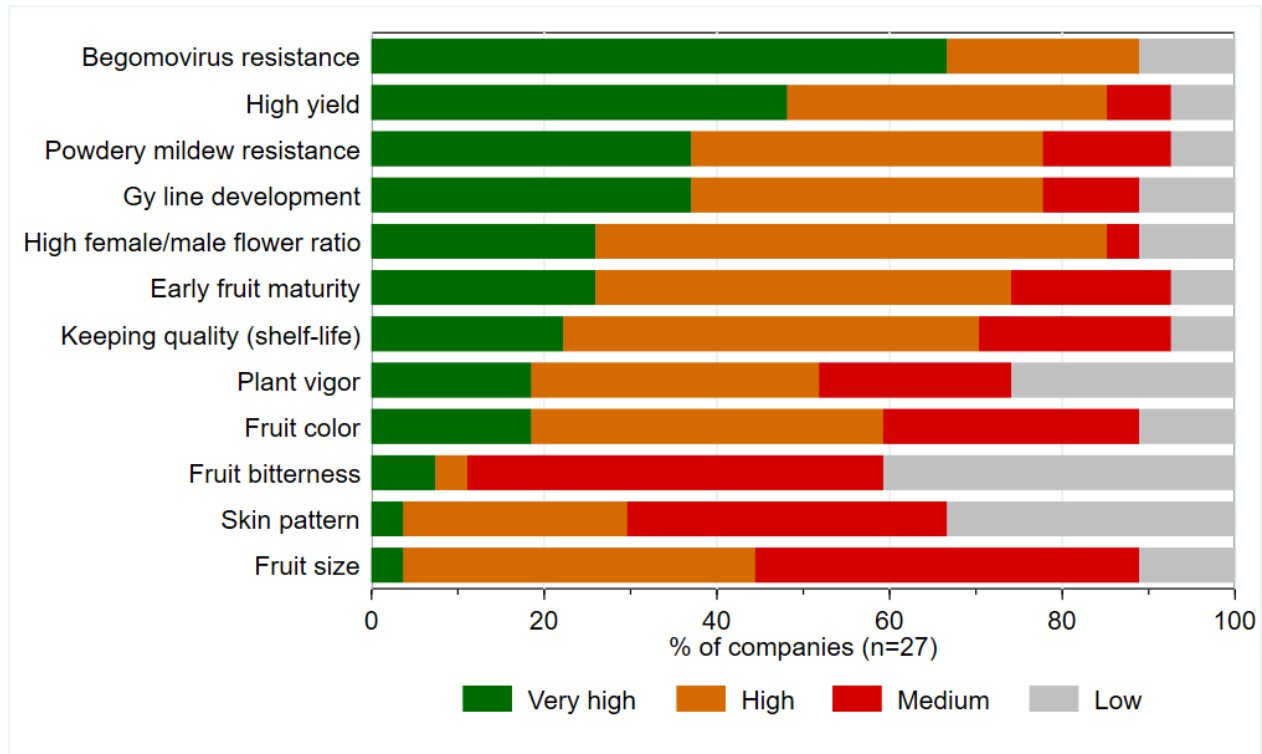


Figure 11 Priority traits for bitter gourd

A few seed companies suggested other traits that were not listed in our questionnaire, these being:

- CAVYV
- Cercospora resistance
- Downy mildew resistance
- Fruit blossom end
- Fruit fly (*Bactrocera* spp.)
- Fruit shape
- Gummy Stem Blight resistance
- Heat set
- Leaf hopper tolerance
- Multipistilate flowering pattern

8.4 Pumpkin

For pumpkin, the questionnaire listed 14 different traits. WorldVeg pumpkin germplasm was used as a source for the following traits:

- Fruit flesh color – used by 6 seed companies in their breeding program
- Early maturity – used by 6 companies
- High yield – used by 5 companies
- Taste – used by 5 companies
- Flesh thickness – used by 5 companies
- Fruit skin color – used by 5 companies
- Fruit shape – used by 5 companies
- Keeping quality (shelf-life) – used by 5 companies
- Powdery mildew (*Leveillula taurica*) resistance – used by 5 companies

It is interesting to note here that horticultural traits such as taste, shape, flesh and skin color and flesh thickness are relatively important here as compared to pest and disease resistance characteristics. Yet in terms of breeding priorities, companies rank disease resistance high, including (**Figure 12**):

- Begomovirus resistance – high priority for 62% of companies
- High yield – high priority for 52% of companies
- Cucumber mosaic virus resistance – high priority for 38% of companies

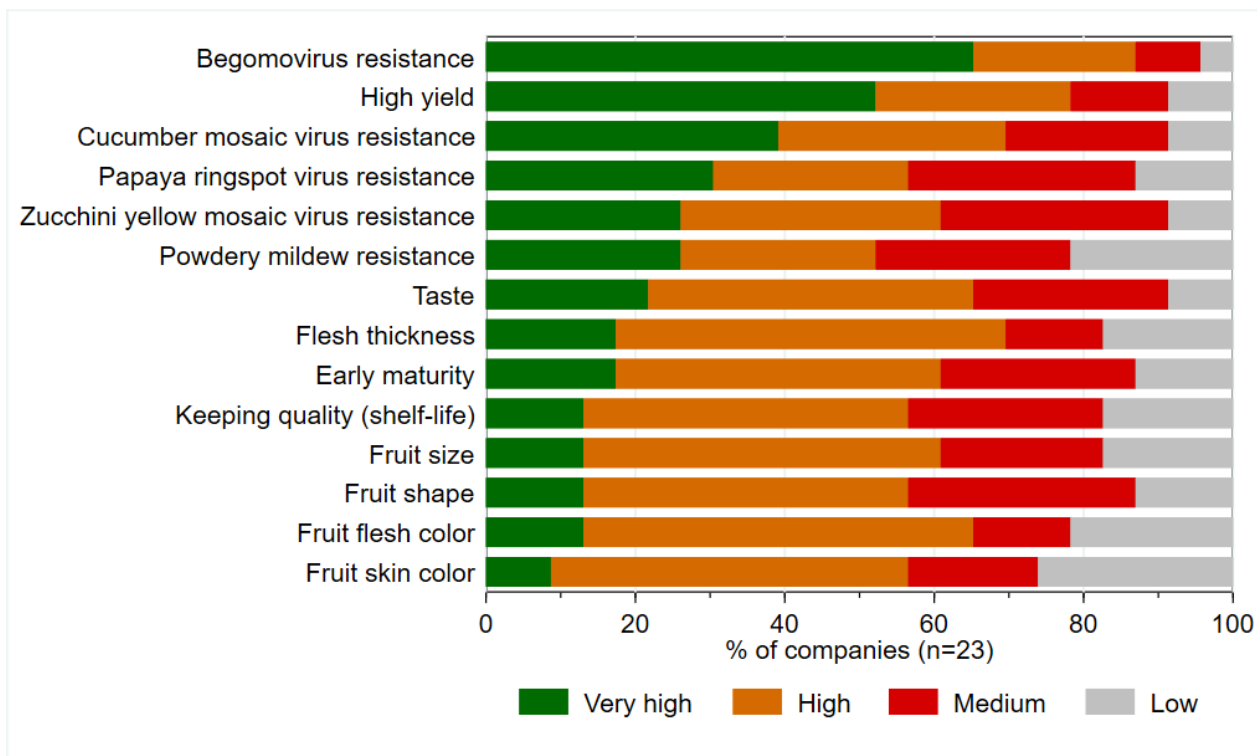


Figure 12 Priority traits for pumpkin

A few other characteristics that were mentioned but had not been listed in our questionnaire were:

- Gummy Stem Blight resistance
- Pumpkin beetle resistance
- Seed quality and quantity
- Day insensitive
- Small seed cavity

Annex 1: Membership data

Table A1. Members of the APSA-WorldVeg Consortium in 2021, including membership history

Company	Country / territory	Category	2017	2018	2019	2020	2021	Data points
Acsen HyVeg Pvt. Ltd.	India	Large	0	0	1	1	0	0
Advanta Seed (United Phosphorus Limited Group)	India	Large	0	1	1	1	0	0
Ajeet Seeds Pvt. Ltd.	India	Large	0	0	0	0	0	2
Ankur seeds Pvt.ltd	India	Large	0	1	0	0	0	0
BHN Seed	USA	Small	0	0	0	1	0	1
Beijing Bannerseeds Oriental Agriculture Development Co. Ltd.	China	Small	0	0	1	0	0	0
Certus Seeds	Pakistan	Small	0	0	0	1	1	1
Ch. Khair Din & Sons (CKD Seeds & Fertilizer)	Pakistan	Small	0	0	1	1	0	0
Chakra Seeds, Bharat Nursery Pvt. Ltd.	India	Small	0	0	0	1	1	0
Chia Tai Co.	Thailand	Large	0	0	1	1	1	3
Chung Kuan Seed Co., Ltd.	Thailand	Small	0	0	0	1	0	0
Clover Seed Co., Ltd.	Hong Kong	Small	1	1	1	1	1	4
Comienzo Agri Science Limited (previously Sattva Seeds Pvt. Ltd.)	India	Small	0	1	1	1	1	2
Degao Vegetable Seed and Seedling Research Institute	China	Small	0	0	1	0	0	0
East-West Seed International Limited	Thailand	Large	1	1	1	1	1	4
Enza Zaden Asia Sdn Bhd	India	Large	1	1	1	0	1	2
Feltrin Sementes Ltda	Brazil	Small	0	0	1	0	1	2
Flotech Seeds Co., Ltd.	Thailand	Small	0	0	0	1	0	0
Gemini Seeds Pvt. Ltd.	India	Small	0	0	0	0	1	0
Genting Green Sdn Bhd	Malaysia	Small	0	0	0	0	1	1
HM. Clause India Pvt. Ltd.	India	Large	1	1	1	1	1	1
I & B Seeds Private Limited	India	Large	1	1	1	1	1	3
Indo-American Hybrid Seeds (India) Pvt. Ltd.	India	Large	0	0	1	1	0	2
JK Agri Genetics Ltd.	India	Large	1	1	1	0	0	1
Kagome Co., Ltd.	Japan	Large	0	1	1	0	0	1
Kalash Seeds Private Limited	India	Large	0	1	0	1	1	1
Kaneko Seeds Co., Ltd.	Japan	Large	0	0	0	1	0	1
Kaveri Seed Company Limited	India	Large	0	1	0	1	1	3
Known-You Seed Co., Ltd.	Taiwan	Large	0	0	1	1	0	3
Kumar Bioseeds and Agro Products Pvt. Ltd. (KF Bioplant Pvt. Ltd.)	India	Small	1	1	0	0	0	2
Landmark Agro Seeds (Private) Limited	Sri Lanka	Small	0	0	0	1	1	1
Laxmi Inputs	India	Small	0	0	0	1	0	1

Company	Country / territory	Category	2017	2018	2019	2020	2021	Data points
Loc Troi Joint Stock Company	Viet Nam	Large	0	0	0	1	0	0
Mahindra Agri Solutions Ltd.	India	Small	1	1	1	0	1	1
Mahyco Private Limited / Sungro Seeds Pvt. Ltd.	India	Large	0	1	1	1	1	1
Mehr Muhammad Din and Sons	Pakistan	Small	0	0	1	0	0	0
Monsanto Holdings Pvt Ltd	India	Large	0	0	1	1	1	0
Monsoon Foods	India	Small	0	0	0	0	1	0
Musashino Seed Co., Ltd.	Japan	Small	0	1	0	0	0	0
Namdhari Seeds Pvt. Ltd.	India	Large	0	1	1	1	1	3
Nath Bio Genes (India) Ltd.	India	Large	0	0	1	1	1	1
Nethra Enterprises Pvt. Ltd.	India	Small	0	1	0	0	0	1
Noble Seeds	India	Large	1	1	0	0	0	3
Nong Woo Bio	South Korea	Large	1	0	0	0	1	0
Nongwoo Seed India Pvt Ltd	India	Small	0	1	1	1	1	3
Nova Genetic/Technisem	France	Small	0	0	0	0	1	0
Nu Genes Pvt. Ltd.	India	Small	0	0	0	1	0	0
Nunhems Bv (BASF/Monsanto)	Netherlands /India	Large	1	1	1	1	1	2
Nuziveedu Seeds Ltd.	India	Large	0	0	0	1	1	1
Onesh Agri Pvt. Ltd.	Sri Lanka	Small	0	0	1	1	1	1
PT. BISI International Tbk	Indonesia	Large	1	1	1	0	1	2
PT. East West Seed Indonesia (EWINDO)	Indonesia	Large	1	1	1	1	1	5
Rallis India Limited (Metahelix Life Sciences Pvt. Ltd.)	India	Large	0	1	1	1	1	0
Rijk Zwaan	Netherlands	Large	1	1	1	1	1	1
Ruchi Hi-rich Seeds Pvt. Ltd.	India	Small	0	0	1	0	0	0
Sakata Seed Corporation	Japan	Large	0	1	1	1	0	2
Seedworks International Pvt. Ltd.	India	Large	1	1	1	1	1	3
Semillas Fito India Pvt. Ltd.	India	Small	0	0	0	1	0	0
Shouguang Yinong Horticulture Co., Ltd.	China	Small	0	0	1	0	0	0
Shriram Bioseed Genetics (A Division of DSCL)	India	Large	1	0	1	1	1	1
Sing-Flow Seed Co., Ltd.	Taiwan	Small	0	1	1	1	1	2
Syngenta India Limited	India	Large	1	1	1	1	1	2
Takii & Company, Ltd.	Japan	Large	1	1	1	1	1	3
Tierra Seed Science Pvt. Ltd.	India	Small	0	0	1	0	0	0
Tokita Seed India Private Limited	India	Small	0	1	1	1	1	0
United Genetics India Pvt. Ltd.	India	Small	0	1	1	0	0	0
VNR Seeds Pvt. Ltd.	India	Large	0	1	0	0	0	2
Welcome Crop Science Pvt., Ltd.	India	Small	1	0	1	1	0	0
Your Chain Seed Co., Ltd.	Taiwan	Small	0	0	1	1	1	2

Note: Data points refer to the number of years for which data were provided.