

# Use of World Vegetable Center breeding lines among seed companies in Asia in 2022



*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 tomato breeder Dr. Peter Hanson (second from left) talks to seed company staff during the tomato and pepper field day organized at IIHR in Bangalore, India on 9 May 2022.

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# 1 Key findings

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1. The APSA-WorldVeg consortium, which focuses on four vegetable species: tomato, chili and sweet pepper, bitter gourd, and tropical pumpkin—had 40 seed company members in 2022. Four seed companies joined the consortium for the first time in 2022. The number of members has been stable at around 40 since 2019.
2. There are 11 seed companies that are no longer consortium members but contribute to ongoing special projects. Most of these seed companies are likely to join the consortium again in future years. Including these, WorldVeg collaborates with 51 seed companies in Asia.
3. This study collected data on key performance indicators by sending a customized Excel spreadsheet to 60 seed companies; 41 of these filled out the form. Since 2017 we have received 129 completed questionnaires from 53 different seed companies, which provide a unique dataset to monitor the use of WorldVeg germplasm over time.
4. In 2022, the WorldVeg genetic resources unit processed 2,326 seed requests from consortium members, 61% of these were for pepper seed. Since the start of the consortium in 2017, WorldVeg has shipped 10,456 seed samples to seed companies, 94% of which to locations in Asia.
5. 25 seed companies are currently using WorldVeg-developed pepper germplasm in their breeding programs, 24 are using tomato germplasm, 15 are using bitter gourd germplasm, and 10 are using pumpkin germplasm. This extensive and increasing use of WorldVeg germplasm in commercial breeding programs will promote future impact.
6. Consortium members had at least 158 vegetable varieties on the market in 2022 that were wholly or partially based on WorldVeg germplasm. The number of varieties based on WorldVeg germplasm has steadily increased since 2018.
7. Seed sales of WorldVeg-related varieties increased from an estimated 14.5 tons in 2018 to 50.0 tons in 2022. This is based on the quantity reported by seed companies with the true amount likely to be higher.
8. This quantity of seed is enough to potentially plant 257,000 ha under WorldVeg-related varieties and benefit 703,000 farm households in Asia.
9. Tomato accounts for most of the observed impact, followed by pepper. Seed sales of bitter gourd are growing fastest.

## 2 Recommendations

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1. There continues to be a need to develop new attractive special projects every year to maintain and expand consortium membership. While WorldVeg launched three new projects in 2020, only one new project was launched in 2021 and none in 2022. This requires additional effort. WorldVeg needs more information from seed companies to develop relevant projects.
2. Effort is also still needed to promote the consortium to seed companies in Bangladesh, the Philippines, Malaysia, Vietnam, and China as these countries are currently not well represented in the consortium. Depending on the budget availability, a Breeding Tour can be considered to arrange WorldVeg breeders to give presentations and share WorldVeg breeding updates with the support from the local seed associations in above countries to promote the visibility of consortium.

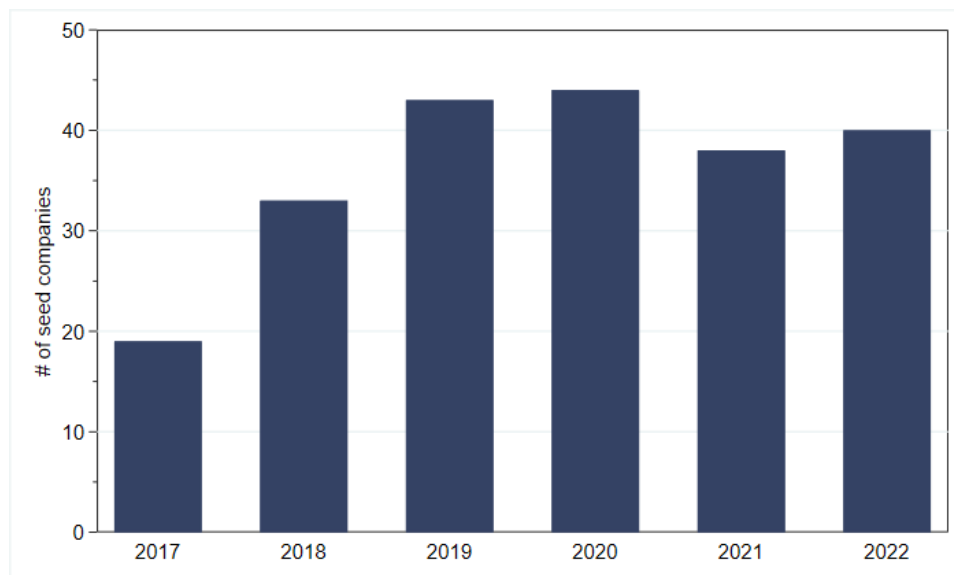
### 3 Consortium membership

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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.

The consortium had 40 members in 2022, slightly up from 38 members in 2021 (**Figure 1**). Over time, consortium membership appears to have stabilized at around 40 members. Eight companies joined the consortium in 2022—four of which had been a member in the past and rejoined the consortium and four companies were new members (**Table 1**). At the same time, six companies left the consortium in 2022. An exist survey was sent to these six companies in November 2022. Reasons provided were (a) difficulties in seed importation for non-DSIR (Department of Scientific Industrial Research) accredited companies in India; and (b) reduced research activities because of the COVID-19 pandemic. Two companies from Sri Lanka were also affected by the financial crisis in their country. However, four of the six companies rejoined the consortium in 2023.

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**. No new special projects started in 2022. 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. A requirement that to join a project, a company must be a consortium member in the year the project is launched was introduced in 2020. Companies are encouraged to remain consortium members in the subsequent years of the special project.



**Figure 1** Consortium membership 2017-2022

**Table 1** Seed companies that joined or left the consortium in 2022

Seed company name	Country	Previous membership
<u>Companies that joined in 2022:</u>		
1. Ch. Khair Din & Sons (CKD Seeds & Fertilizer)	Pakistan	2019-2020
2. Chung Kuan Seed Co., Ltd.	Thailand	2020
3. Sakata Seed Corporation	Japan	2018-2020
4. Noble Seeds	India	2017-2018
5. PT. Tani Murni Indonesia	Indonesia	New member
6. Saitama Genshu Ikuseikai Co., Ltd.	Japan	New member
7. Starke Ayres (Pty) Ltd.	South Africa	New member
8. Zenith Hybrid Seeds Private Limited	India	New member
<u>Companies that left in 2022:</u>		
1. Comienzo Agri Science Ltd. (previously Sattva Seeds) #	India	2018-2021
2. Kalash Seeds Private Limited #	India	2018,2020-2021
3. Landmark Agro Seeds Pvt. Ltd. #	Sri Lanka	2020-2021
4. Onesh Agri Pvt. Ltd.	Sri Lanka	2019-2021
5. Enza Zaden Asia Sdn Bhd #	India	2017-2019, 2021
6. Gemini Seeds Pvt. Ltd.	India	2021

Notes: # joined again in 2023

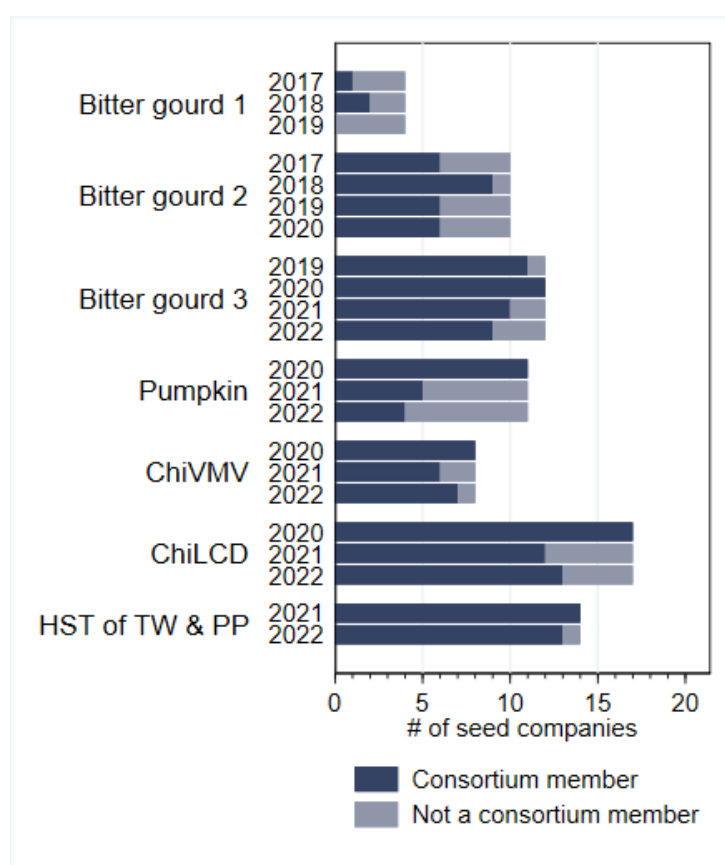
**Table 2** Special projects launched until 2022

Project names <sup>a</sup>	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	7/2020-6/2023 <sup>b</sup>	8
6. ChiLCD	7/2020-6/2024 <sup>b</sup>	17
7. HST of TW & PP	8/2021-7/2024	14

<sup>a</sup> 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 World Vegetable Center tropical pumpkin lines and F1 hybrids for sustainable pumpkin 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. <sup>b</sup> Project periods were amended because of delays in conducting the trials related to COVID-19 and seed shipments.

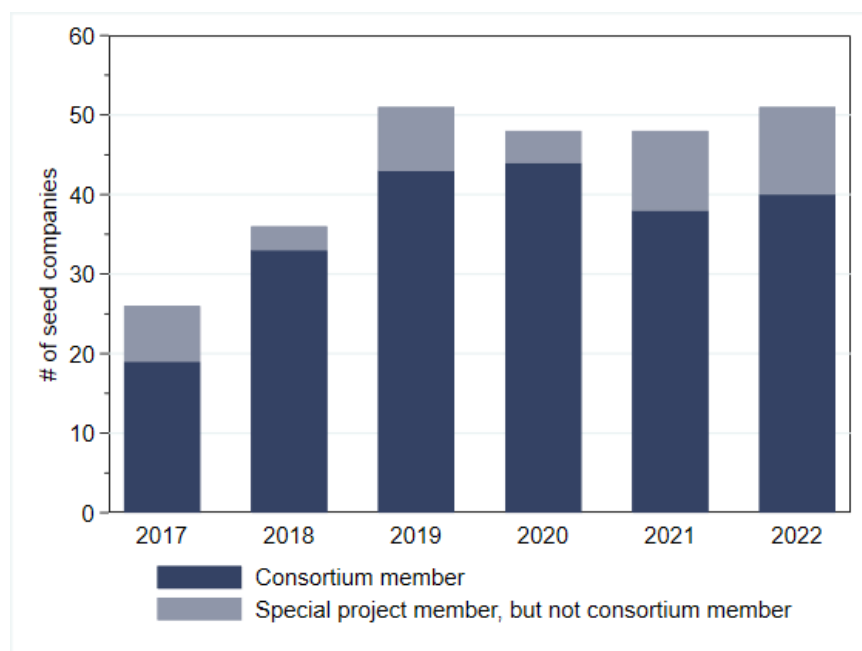
**Figure 2** shows that seed companies were indeed a consortium member in the year the project started, but some dropped out in the second year of the project. In the case of the pumpkin project this was even 6 of the 11 project members. In 2022, there were 11 companies that were part of special projects but were not a member of the consortium (**Figure 3**). When adding these 11 companies to the 40 consortium members, then WorldVeg collaborated with 51 seed companies in 2022 (3 more than in 2021).

In 2022, 20 consortium members (50%) came from India, 3 each from Indonesia, Taiwan, and Thailand (**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 40-42% since 2019 (**Figure 4**).



**Figure 2** Membership of special projects, 2017-2022

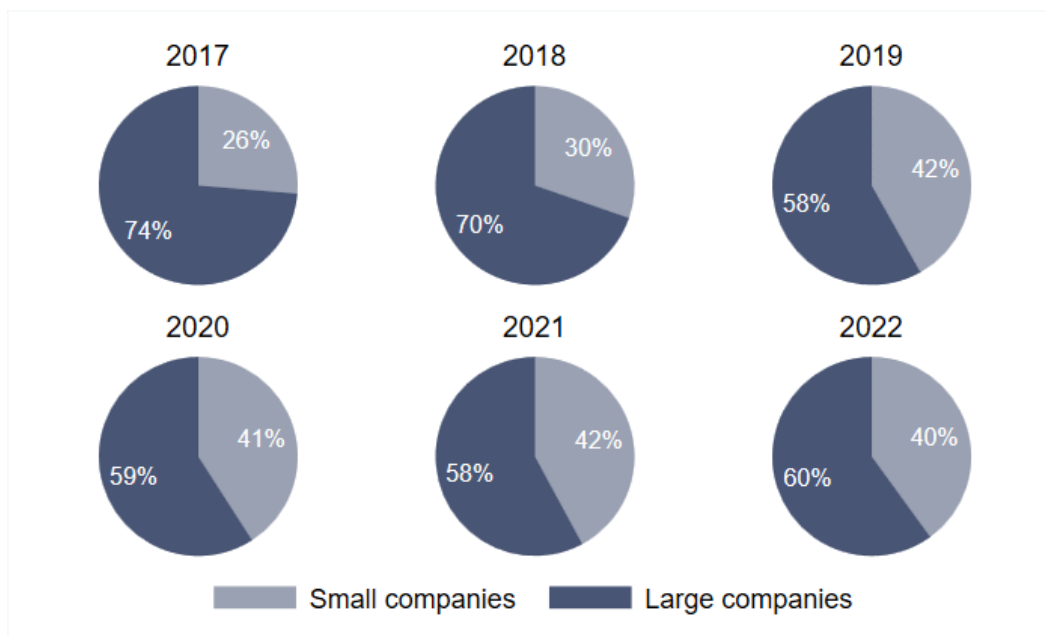




**Figure 3** Membership of the consortium and of special projects, 2017-2022

**Table 3** Distribution of consortium members by registered location and year

Asia:	2017	2018	2019	2020	2021	2022
– China	0	0	3	0	0	0
– Hong Kong, China	1	1	1	1	1	1
– India	8	20	21	23	23	20
– Indonesia	2	2	2	1	2	3
– Japan	1	4	3	3	1	3
– Malaysia	0	1	1	0	1	1
– Pakistan	0	0	2	2	1	2
– Singapore	1	1	0	0	0	0
– South Korea	1	0	0	0	1	1
– Sri Lanka	0	0	1	2	2	0
– Taiwan	0	1	3	3	2	2
– Thailand	2	1	3	5	2	3
– Viet Nam	0	0	0	1	0	0
Outside Asia:						
– Brazil	0	0	1	0	1	1
– France	0	0	0	0	1	1
– South Africa	0	0	0	0	0	1
– Netherlands	3	2	2	2	0	1
– USA	0	0	0	1	0	0
Total	19	33	43	44	38	40



**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 60 (current and past) consortium members. No major changes were made to the data collection method used in 2020 and 2021. Email requests

were sent during March and April 2023 and companies were given two weeks to return the data sheet. Reminders were sent afterwards. By mid-April 2023, we had received data from 41 seed companies (**Table 4**). In total, 53 seed companies have provided data at any time since 2017, which is 73% of all past and present members (73 seed companies). Of all members in 2022, only 5 companies have never provided data.

**Table 4** Questionnaire response per year

Year of survey	Companies that provided data
2017	14
2018	11
2019	4 <sup>a</sup>
2020	23
2021	36
2022	41
Any year	53

**Note:** <sup>a</sup> No survey was conducted in 2019.

Some companies that responded to the 2023 survey not just provided data for 2022 but also for previous years, which added 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 2022 then we replaced it with the data provided for 2021, or else with the data for 2020 or earlier. Combining the data points gives an estimate of the impact for 2022 based on data for 53 seed companies. As seed companies tend to exit and rejoin the consortium, we do not limit our analysis to current members but include all 53 companies for which we have data.

**Table 5** Number of companies that provided data on key performance indicators for particular years

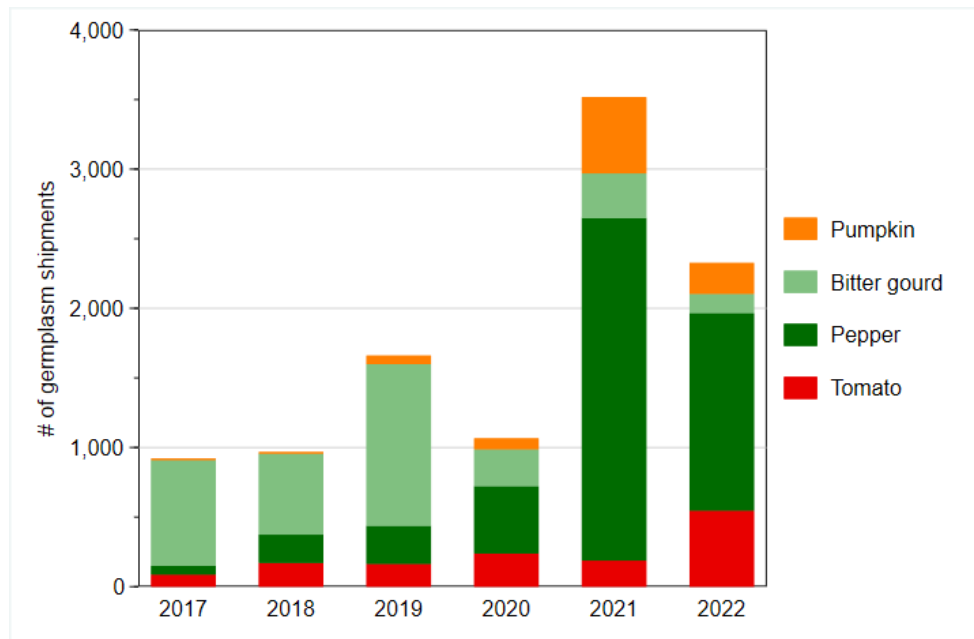
Year	Tomato	Pepper	Bitter gourd	Pumpkin
2017	27	27	28	26
2018	32	30	31	29
2019 <sup>a</sup>	11	12	11	11
2020	35	35	34	32
2021	41	41	40	39
2022	37	36	35	34
Any year	50	50	49	48

**Note:** Figures are different from those in Table 4 as some companies provided data for multiple past years. <sup>a</sup> 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 10,456 seed shipments have been sent. Large seed shipments in 2021 and 2022 were associated with two special projects on chili pepper launched in 2020.

The geographical distribution of the seed shipments shows that 62% were sent to South Asia, 32% to East or Southeast Asia and 6% to companies with a registration address outside Asia (**Table 6**).



**Figure 5** Germplasm shipments to past and current consortium members, 2017-2022

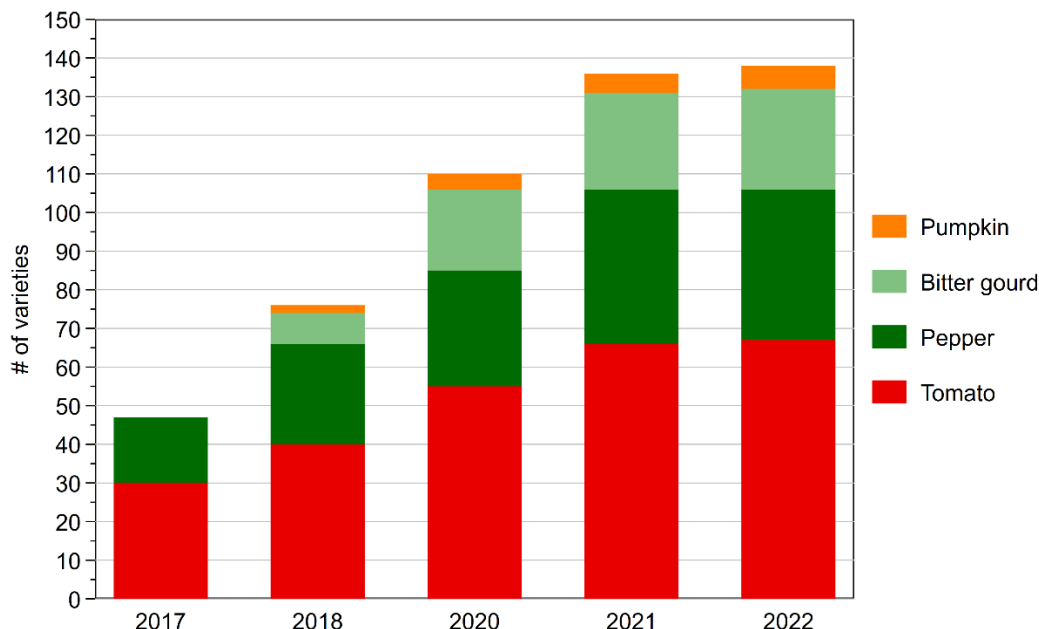
**Table 6** Distribution of germplasm shipments by region, sum of shipments over 2017-2022

Region	Tomato	Pepper	Bitter gourd	Pumpkin	Total
South Asia	708	2,792	2,539	410	6,449
East and Southeast Asia	550	1,605	664	517	3,336
Rest of the world	142	504	25	-	671
Total	1,400	4,901	3,228	927	10,456

## 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 138 in 2022 (**Figure 6**). Companies brought new varieties based on WorldVeg germplasm on the market, but part of the increase is also because more companies respond to our data request.



**Figure 6** Vegetable varieties sold in Asia that contain WorldVeg-developed germplasm, 2017-2022 (number of respondents varies by year as shown in Table 4).

When combining the data for all 53 seed companies that provided data at any point since 2017, then we count a total of 158 varieties containing WorldVeg-developed germplasm (up from 127 in 2021). In total these companies sold 2,050 varieties of bitter gourd, pepper, pumpkin, and tomato and hence 7% of the varieties contain WorldVeg-developed germplasm in their pedigrees. The contribution is largest for tomato and bitter gourd, where 10-11% of all varieties sold contain WorldVeg germplasm while this is 6% for pepper.

WorldVeg-developed bitter gourd germplasm is increasingly found in commercial varieties. The total number of WorldVeg-related bitter gourd varieties was 33 in 2022, up from 23 reported in 2021 and 13 in 2020. It is likely that the growth in WorldVeg-related varieties will continue in the coming years as more companies are using WorldVeg breeding lines in their vegetable breeding programs.

## 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 (as shown in the bottom row). 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 three 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 18 companies with at least 24 seed companies using WorldVeg tomato breeding lines in their breeding program (**Table 7**). Of the 758 tomato varieties sold by 49 seed companies, 75 contained WorldVeg germplasm (10%). About 15.6 tons of tomato seed was sold of these varieties (up from 14.2 tons reported in 2021), which is 14% of total tomato seed sales. This seed is enough to plant 130,000 ha of tomato and reach about 419,000 farm households (**Table 11**).

For **pepper**, varieties based on WorldVeg germplasm were sold by at least 14 seed companies with 25 seed companies using WorldVeg pepper lines in their breeding program (**Table 8**). We have data for 49 seed companies, which jointly sold 185 tons of pepper seed and 15.5 tons of this (8%) is based on WorldVeg germplasm. This is potentially enough to plant 103,200 ha of pepper and benefit 234,500 farm households (**Table 11**). This is substantially more (+91%) than reported last year.

For **bitter gourd**, we were able to confirm 33 WorldVeg-related bitter gourd varieties in 2022 (up from 23 varieties reported last year), which shows a steady increase in WorldVeg-related varieties considering there were none in 2017. We estimate that 18.0 tons of bitter gourd seed were sold in 2022—enough to plant 20,600 hectares and benefit 41,100 farm households (**Table 11**). This is four times more than we reported last year.

For **pumpkin**, we could confirm that at least four seed companies have commercialized WorldVeg pumpkin varieties while 10 companies are using WorldVeg material in their breeding programs (**Table 10**). We could confirm 6 commercial pumpkin varieties based on WorldVeg material. Seed sales of these varieties were 0.9 tons in 2022, which is less than the 1.3 tons reported last year (–26%). This is because one company reported lower sales. We estimate that 3,100 ha is currently planted to WorldVeg pumpkin varieties, benefiting about 7,800 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 future as varieties get scaled.

Overall, the results show that seed sales of WorldVeg-related varieties increased from 14.5 tons in 2018, 24.7 tons in 2020, and 27.6 tons in 2021 to 50.0 tons in 2022. These seed sales in 2022 are enough to potentially benefit 703,000 farm households in Asia (+34% from 2021 levels) (**Table 11, Figure 7**).

**Table 7** Use of WorldVeg tomato germplasm by consortium members, 2017-2022

Tomato	2017	2018	2020	2021	2022	2017-2022
<b>Number of companies:</b>						
Selling WorldVeg-related varieties	10	13	15	15	16	18
Using WorldVeg lines in breeding	15	9	15	23	24	24
<b>Number of varieties:</b>						
Varieties, all	348	505	447	632	658	758
Varieties, WorldVeg-related	30	40	55	66	67	75
% of varieties WorldVeg-related	9%	8%	12%	10%	10%	10%
<b>Quantity of seed sales:</b>						
Seed sales, all varieties (tons)	61.4	58.5	76.4	95.0	72.2	111.3
Seed sales, WorldVeg (tons)	9.0	7.9	10.8	10.7	11.5	15.6
Seed sales, WorldVeg (%)	15%	14%	14%	11%	16%	14%
# of companies reporting	26	31	34	40	36	49

**Table 8** Use of WorldVeg pepper germplasm by consortium members, 2017-2022

Pepper	2017	2018	2020	2021	2022	2017-2022
<b>Number of companies:</b>						
Selling WorldVeg-related varieties	7	8	12	14	13	14
Using WorldVeg lines in breeding	12	7	12	23	25	25
<b>Number of varieties:</b>						
Varieties, all	369	575	572	727	567	747
Varieties, WorldVeg-related	17	26	30	40	39	44
% of varieties WorldVeg-related	5%	5%	5%	6%	7%	6%
<b>Quantity of seed sales:</b>						
Seed sales, all varieties (tons)	87.9	103.4	122.0	169.3	148.5	184.8
Seed sales, WorldVeg (tons)	6.2	9.5	7.5	6.2	15.4	15.5
Seed sales, WorldVeg (%)	7%	9%	6%	4%	10%	8%
# of companies reporting	26	30	34	39	36	49

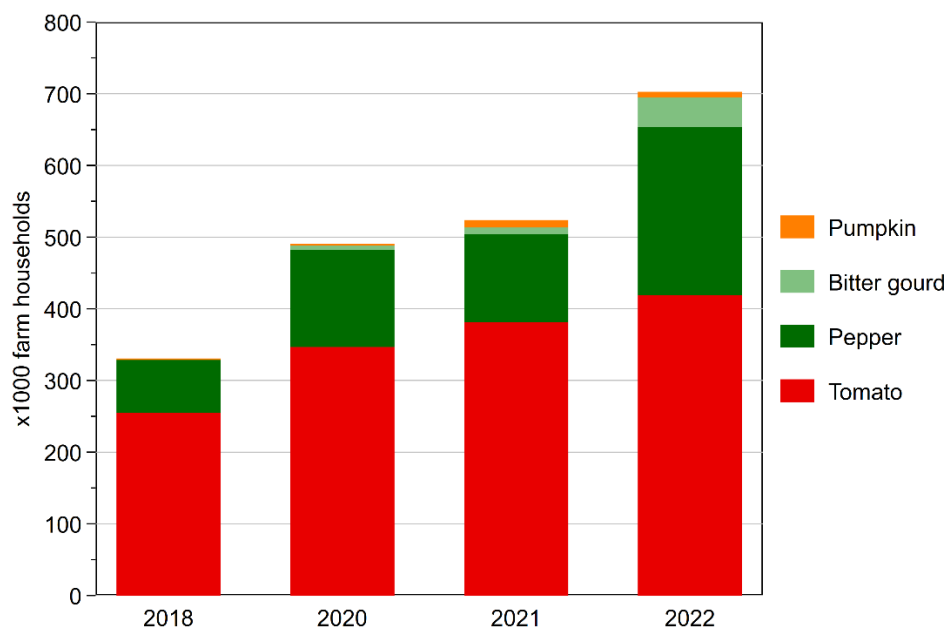
**Table 9** Use of WorldVeg bitter gourd germplasm by consortium members, 2017-2022

Bitter gourd	2017	2018	2020	2021	2022	2017-2022
<b>Number of companies:</b>						
Selling WorldVeg-related varieties	0	3	9	8	6	9
Using WorldVeg lines in breeding	6	5	13	21	15	21
<b>Number of varieties:</b>						
Varieties, all	91	176	223	262	275	312
Varieties, WorldVeg-related	0	8	21	25	26	33
% of varieties WorldVeg-related	0%	5%	9%	10%	9%	11%
<b>Quantity of seed sales:</b>						
Seed sales, all varieties (tons)	190.4	220.8	254.2	256.3	239.1	250.9
Seed sales, WorldVeg (tons)	9.5	9.6	12.3	15.7	16.0	18.0
Seed sales, WorldVeg (%)	5%	4%	5%	6%	7%	7%
# of companies reporting	28	31	35	40	35	49

**Table 10** Use of WorldVeg pumpkin germplasm by consortium members, 2017-2022

Pumpkin	2017	2018	2020	2021	2022	2017-2022
<b>Number of companies:</b>						
Selling WorldVeg-related varieties	0	1	2	2	3	3
Using WorldVeg lines in breeding	5	4	7	8	10	10
<b>Number of varieties:</b>						
Varieties, all	27	83	120	198	223	233
Varieties, WorldVeg-related	0	2	4	5	6	6
% of varieties WorldVeg-related	0%	2%	3%	3%	3%	3%
<b>Quantity of seed sales:</b>						
Seed sales, all varieties (tons)	72.7	136.5	215.5	263.5	206.6	215.0
Seed sales, WorldVeg (tons)	0.0	0.2	0.3	1.3	0.9	0.9
Seed sales, WorldVeg (%)	0%	0%	0%	0%	0%	0%
# of companies reporting	26	29	33	39	34	48





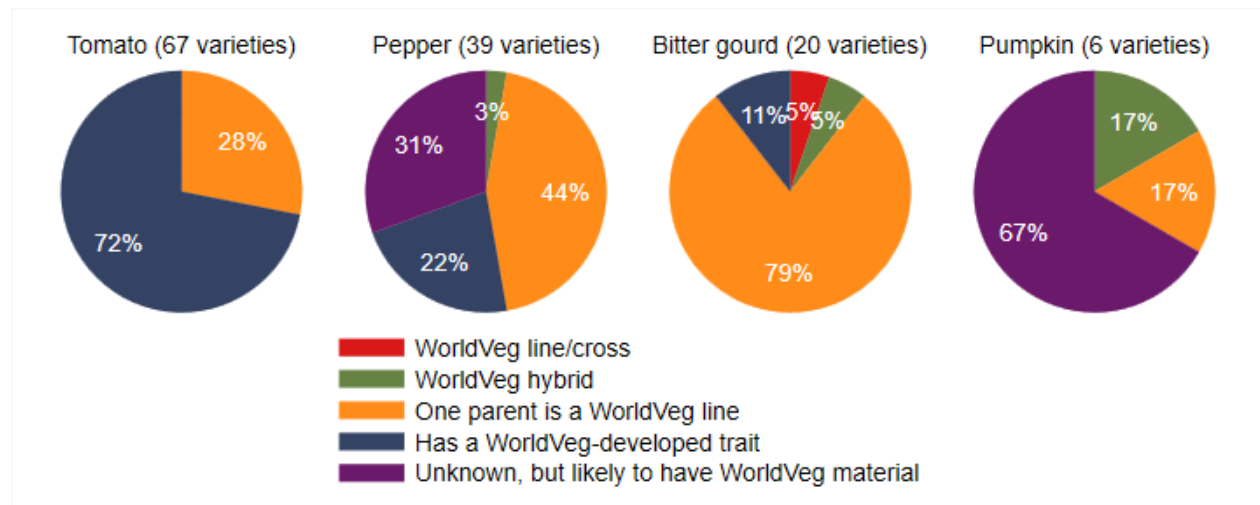
**Figure 7** Farm households potentially reached by WorldVeg-related vegetable varieties in Asia, 2018-2022 (number of respondents varies by year as shown in Table 4).

**Table 11** Area under WorldVeg-developed germplasm and farmers reached, 2018-2022.

	2018	2020	2021	2022
<b>Tomato:</b>				
– Seed sales with WorldVeg germplasm (kg)	9,471	12,896	14,184	15,597
– Area potentially planted (1000 ha)	79	108	118	130
– Farmers potentially reached (1000s)	255	347	381	419
<b>Pepper:</b>				
– Seed sales with WorldVeg germplasm (kg)	4,903	8,941	8,099	15,478
– Area potentially planted (1000 ha)	33	60	54	103
– Farmers potentially reached (1000s)	74	136	123	235
<b>Bitter gourd:</b>				
– Seed sales with WorldVeg germplasm (kg)	0	2,598	4,086	17,992
– Area potentially planted (1000 ha)	0	3	5	21
– Farmers potentially reached (1000s)	0	6	9	41
<b>Pumpkin:</b>				
– Seed sales with WorldVeg germplasm (kg)	172	289	1,264	933
– Area potentially planted (1000 ha)	1	1	4	3
– Farmers potentially reached (1000s)	1	2	11	8
<b>All crops:</b>				
– Seed sales with WorldVeg germplasm (kg)	14,546	24,724	27,633	50,000
– Area potentially planted (1000 ha)	112	171	181	257
– Farmers potentially reached (1000s)	330	491	524	703

## 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 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 tomato varieties and 44% of pepper varieties are derived from a particular WorldVeg breeding line as a parent for a hybrid. Regarding bitter gourd, of the 20 commercial varieties for which we have data, 79% are hybrids with one parent supplied by WorldVeg. For pumpkin, of 6 commercial varieties reported in 2022, four have WorldVeg germplasm as background material. The pumpkin project started in 2020 and the use of WorldVeg germplasm will increase in future years.



**Figure 8** Method of use of WorldVeg germplasm in commercial varieties, 2022 data

## 8 Traits

Of the 39 seed companies that completed this module of the questionnaire, 24 and 25 companies use WorldVeg tomato and pepper material in their breeding programs, respectively, while 14 use bitter gourd material and 10 use pumpkin material (**Table 12**). This use will 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.

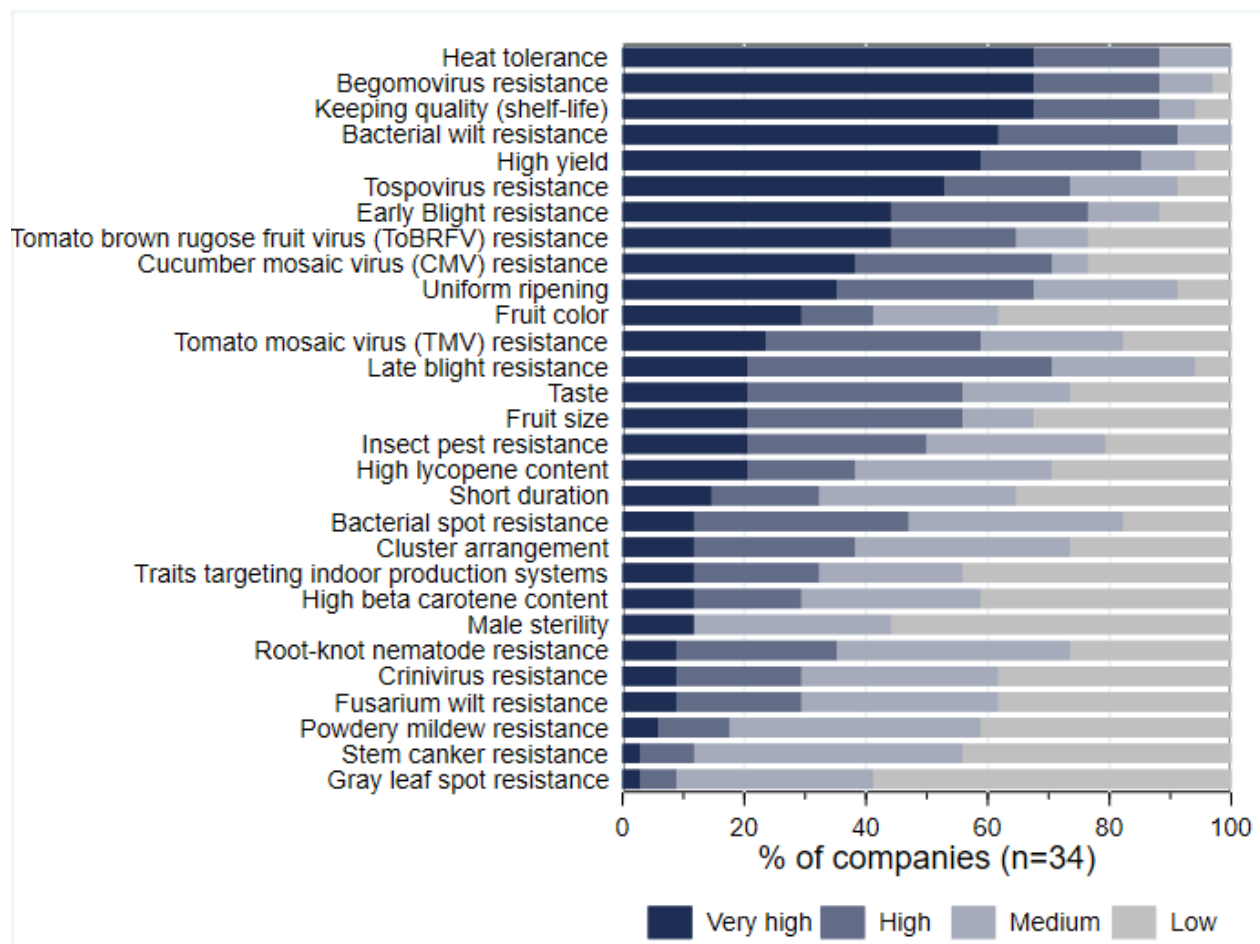
**Table 12** Number of companies using WorldVeg-developed traits, 2022

Variable	Tomato	Pepper	Bitter gourd	Pumpkin
Using WorldVeg germplasm in breeding	24	25	15	10
Incorporated WorldVeg germplasm in varieties	19	17	7	4

**Note:** based on the responses from 39 seed companies.

## 8.1 Tomato

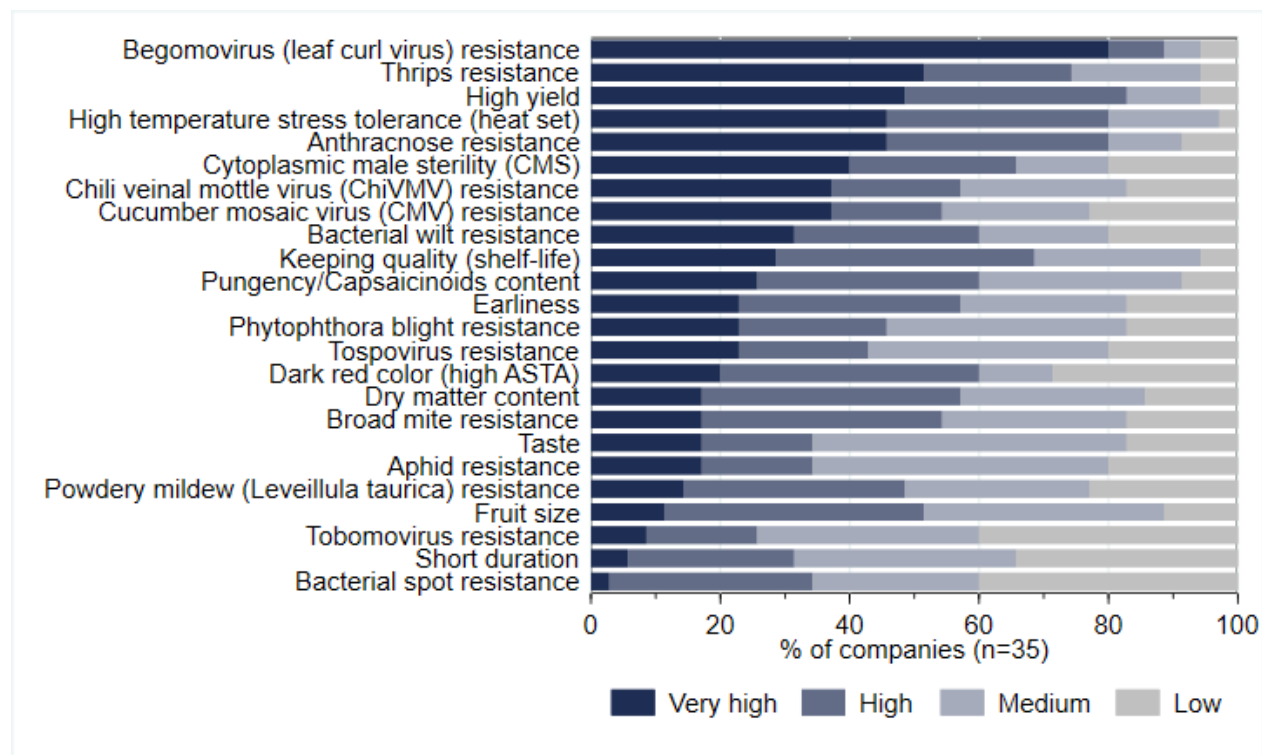
For tomato, the questionnaire included 29 different traits and respondents had to indicate for which traits WorldVeg germplasm was used as a source. It showed that WorldVeg tomato germplasm was mostly used by seed companies as a source of Bacterial wilt (*Ralstonia solanacearum*) resistance, Begomovirus resistance (Tomato yellow leaf curl virus, Tomato leaf curl New Delhi virus, and others), late blight (*Phytophthora infestans*) resistance and heat tolerance. For each of the 29 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), tospovirus resistance, Early Blight (*Alternaria solani*) resistance, and Cucumber mosaic virus (CMV) resistance. This is largely the same as was reported last year.



**Figure 9** Priority traits for tomato

## 8.2 Pepper

For pepper, the questionnaire listed 24 traits (**Figure 10**). Companies mostly use WorldVeg pepper germplasm for traits such as high yield, anthracnose (*Colletotrichum* spp.) resistance, heat stress resistance, cytoplasmic male sterility (CMS), Chili veinal mottle virus (ChiVMV) resistance, bacterial wilt (*Ralstonia solanacearum*) resistance, and fruit size. Key traits that companies would like WorldVeg to additionally work on include thrips resistance, Cucumber mosaic virus (CMV) resistance, bacterial wilt resistance, and shelf-life. This priority setting is different from previous years as thrips is ranked second and yield is third while these two traits had a lower priority in previous years. A few respondents mentioned crinivirus resistance and rootknot nematode resistance, which were not listed among the 24 traits in the questionnaire.

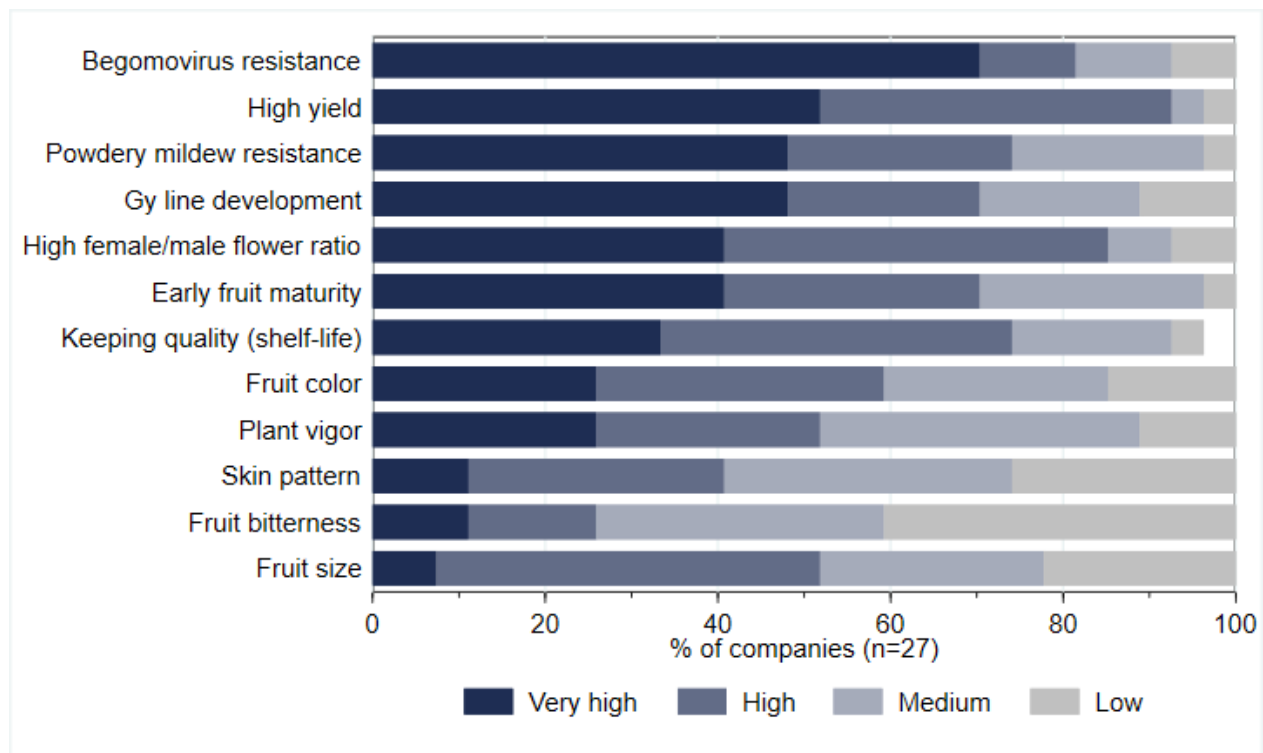


**Figure 10** Priority traits for pepper

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

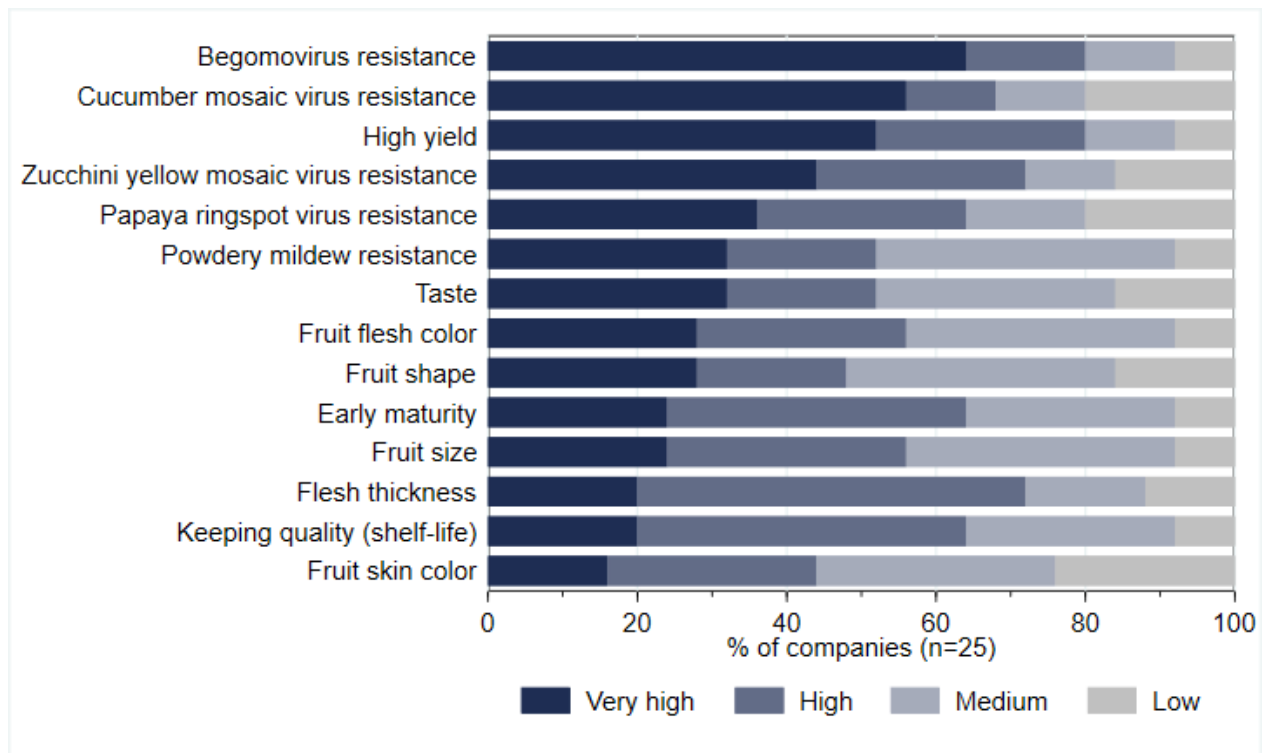
For bitter gourd, the questionnaire listed 12 different traits (**Figure 11**). The most important traits sourced from WorldVeg material and used in commercial breeding programs include Begomovirus resistance, high yield, powdery mildew (*Podosphaera xanthii*) resistance, high female/male flower ratio, and fruit color. In addition to these, companies would like WorldVeg to prioritize work on Gy line development, early maturity, and shelf-life. Several respondents asked WorldVeg to particularly work on downy mildew resistance, which was a trait not listed in the questionnaire. Others requests were Polero virus resistance, gummy stem blight resistance, parthenocarpy, and fruit fly resistance – each requested by at least two respondents. Single requests were made for: CAVYV, Cercopsora resistance, heat set, leaf hopper tolerance, multipistilate flowering pattern, plant rejuvenation, thrips tolerance (including thrips parvispinus), and young fruit yellow resistance/fruit yellowing.



**Figure 11** Priority traits for bitter gourd

## 8.4 Pumpkin

For pumpkin, the questionnaire listed 14 different traits (**Figure 12**). WorldVeg pumpkin germplasm was popular in breeding programs as a source of taste, fruit flesh color, early maturity, flesh thickness, fruit skin color but also various other traits. Seed companies would like WorldVeg to prioritize begomovirus resistance, Cucumber mosaic virus resistance, high yield, and Zucchini yellow mosaic virus resistance, Papaya ringspot virus resistance, and powdery mildew (*Podosphaera xanthii*) resistance. There were a few requests for traits not listed in the questionnaire, including: day insensitive, gummy stem blight resistance, nematodes resistance, pumpkin beetle tolerance, seed quality and quantity, and small seed cavity.



**Figure 12** Priority traits for pumpkin

## Annex 1: Membership data

**Table A1.** Past and present members of the APSA-WorldVeg Consortium, 2017-2022

Company	Country	Category	2017	2018	2019	2020	2021	2022	Data points
Acscn HyVeg Pvt. Ltd.	India	Large	0	0	1	1	0	0	0
Advanta Seed (United Phosphorus Limited Group)	India	Large	0	1	1	1	0	0	0
Ajeet Seeds Pvt. Ltd.	India	Large	0	0	0	0	0	0	3
Ankur seeds Pvt.ltd	India	Large	0	1	0	0	0	0	1
BHN Seed	USA	Small	0	0	0	1	0	0	2
Beijing Bannerseeds Oriental Agriculture Development Co. Ltd.	China	Small	0	0	1	0	0	0	0
Certus Seeds	Pakistan	Small	0	0	0	1	1	1	2
Ch. Khair Din & Sons (CKD Seeds & Fertilizer)	Pakistan	Small	0	0	1	1	0	1	1
Chakra Seeds, Bharat Nursery Pvt. Ltd.	India	Small	0	0	0	1	1	1	1
Chia Tai Co.	Thailand	Large	0	0	1	1	1	1	4
Chung Kuan Seed Co., Ltd.	Thailand	Small	0	0	0	1	0	1	0
Clover Seed Co., Ltd.	Hong Kong, China	Small	1	1	1	1	1	1	5
Comienzo Agri Science Limited (previously Sattva Seeds Pvt. Ltd.)	India	Small	0	1	1	1	1	0	2
Degao Vegetable Seed and Seedling Research Institute	China	Small	0	0	1	0	0	0	0
East-West Seed International Limited	Thailand	Large	1	1	1	1	1	1	5
Enza Zaden Asia Sdn Bhd	India	Large	1	1	1	0	1	0	2
Feltrin Sementes Ltda	Brazil	Small	0	0	1	0	1	1	2
Flotech Seeds Co., Ltd.	Thailand	Small	0	0	0	1	0	0	0
Gemini Seeds Pvt. Ltd.	India	Small	0	0	0	0	1	0	0
Genting Green Sdn Bhd	Malaysia	Small	0	0	0	0	1	1	2
HM. Clause India Pvt. Ltd.	India	Large	1	1	1	1	1	1	3
I & B Seeds Private Limited	India	Large	1	1	1	1	1	1	4
Indo-American Hybrid Seeds (India) Pvt. Ltd.	India	Large	0	0	1	1	0	0	3
JK Agri Genetics Ltd.	India	Large	1	1	1	0	0	0	1
Kagome Co., Ltd.	Japan	Large	0	1	1	0	0	0	1
Kalash Seeds Private Limited	India	Large	0	1	0	1	1	0	2

Company	Country	Category	2017	2018	2019	2020	2021	2022	Data points
Kaneko Seeds Co., Ltd.	Japan	Large	0	0	0	1	0	0	2
Kaveri Seed Company Limited	India	Large	0	1	0	1	1	1	4
Known-You Seed Co., Ltd.	Taiwan	Large	0	0	1	1	0	0	4
Kumar Bioseeds and Agro Products Pvt. Ltd. (KF Bioplant Pvt. Ltd.)	India	Small	1	1	0	0	0	0	3
Landmark Agro Seeds (Private) Limited	Sri Lanka	Small	0	0	0	1	1	0	2
Laxmi Inputs	India	Small	0	0	0	1	0	0	2
Loc Troi Joint Stock Company	Viet Nam	Large	0	0	0	1	0	0	0
Mahindra Agri Solutions Ltd.	India	Small	1	1	1	0	1	1	1
Mahyco Private Limited / Sungro Seeds Pvt. Ltd.	India	Large	0	1	1	1	1	1	2
Mehr Muhammad Din and Sons	Pakistan	Small	0	0	1	0	0	0	0
Monsanto Holdings Pvt Ltd	India	Large	0	0	1	1	1	1	2
Monsoon Foods	India	Small	0	0	0	0	1	1	0
Musashino Seed Co., Ltd.	Japan	Small	0	1	0	0	0	0	0
Namdhari Seeds Pvt. Ltd.	India	Large	0	1	1	1	1	1	4
Nath Bio Genes (India) Ltd.	India	Large	0	0	1	1	1	1	1
Nethra Enterprises Pvt. Ltd.	India	Small	0	1	0	0	0	0	1
Noble Seeds	India	Large	1	1	0	0	0	1	4
Nong Woo Bio	South Korea	Large	0	0	0	0	1	1	0
Nongwoo Seed India Pvt Ltd	India	Small	1	1	1	1	1	1	4
Nova Genetic/Technisem	France	Small	0	0	0	0	1	1	1
Nu Genes Pvt. Ltd.	India	Small	0	0	0	1	0	0	0
Nunhems Bv (BASF/Monsanto)	Netherlands/India	Large	1	1	1	1	1	1	3
Nuziveedu Seeds Ltd.	India	Large	0	0	0	1	1	1	2
Onesh Agri Pvt. Ltd.	Sri Lanka	Small	0	0	1	1	1	0	2
PT. BISI International Tbk	Indonesia	Large	1	1	1	0	1	1	3
PT. East West Seed Indonesia (EWINDO)	Indonesia	Large	1	1	1	1	1	1	6
PT. Tani Murni Indonesia	Indonesia	Small	0	0	0	0	0	1	1
Rallis India Limited (Metahelix Life Sciences Pvt. Ltd.)	India	Large	0	1	1	1	1	1	0
Rijk Zwaan	India	Large	1	1	1	1	1	1	2
Ruchi Hi-rich Seeds Pvt. Ltd.	India	Small	0	0	1	0	0	0	0
Saitama Genshu Ikuseikai Co., Ltd.	Japan	Large	0	0	0	0	0	1	1
Sakata Seed Corporation	Japan	Large	0	1	1	1	0	1	2
Seedworks International Pvt. Ltd.	India	Large	1	1	1	1	1	1	4



Company	Country	Category	2017	2018	2019	2020	2021	2022	Data points
Semillas Fito India Pvt. Ltd.	India	Small	0	0	0	1	0	0	0
Shouguang Yinong Horticulture Co., Ltd.	China	Small	0	0	1	0	0	0	0
Shriram Bioseed Genetics (A Division of DSCL)	India	Large	1	0	1	1	1	1	2
Sing-Flow Seed Co., Ltd.	Taiwan	Small	0	1	1	1	1	1	3
Starke Ayres (Pty) Ltd.	South Africa	Large	0	0	0	0	0	1	1
Syngenta India Limited	India	Large	1	1	1	1	1	1	2
Takii & Company, Ltd.	Japan	Large	1	1	1	1	1	1	4
Tierra Seed Science Pvt. Ltd.	India	Small	0	0	1	0	0	0	1
Tokita Seed India Private Limited	India	Small	0	1	1	1	1	1	1
United Genetics India Pvt.Ltd.	India	Small	0	1	1	0	0	0	0
VNR Seeds Pvt. Ltd.	India	Large	0	1	0	0	0	0	3
Welcome Crop Science Pvt., Ltd.	India	Small	1	0	1	1	0	0	0
Your Chain Seed Co., Ltd.	Taiwan	Small	0	0	1	1	1	1	3
Zenith Hybrid Seeds Private Limited	India	Small	0	0	0	0	0	1	0

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