

Use of World Vegetable Center breeding lines among seed companies in Asia in 2020

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APSA-WorldVeg Vegetable Breeding Consortium

World Vegetable Center

PUBLIC VERSION

31 March 2021

Table of Contents

1	Consortium membership	2
2	Data collection	5
3	Questionnaire response.....	6
4	Key performance indicators.....	7
5	Varieties	10
6	Traits	11
7	Summary of key findings.....	14
8	Recommendations	15
	Annex 1: Membership data.....	16

1 Consortium membership

The Asia Pacific Seed Association (APSA) - WorldVeg Vegetable Breeding Consortium (hereafter called the Consortium) started in 2017. Membership has increased every year from 19 members in 2017 to 44 members in 2020 (**Figure 1**). Current and past members are listed in **Annex 1**. In 2020, 23 consortium members (52%) came from India, 5 companies came from Thailand, 3 each from Japan and Taiwan, and 2 each from Pakistan and Sri Lanka (**Table 1**).

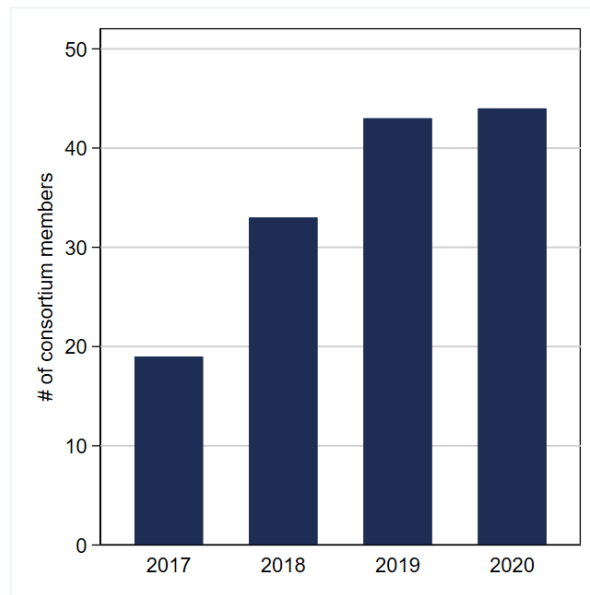


Figure 1. Development of consortium membership 2017-2020.

Membership is divided into small/start-up and medium/large companies with the threshold being 100 employees. The data show that the share of small companies has increased every year from 26% in 2017 to 48% in 2020 (**Figure 2**).

Consortium membership is annual for a calendar year and open to all APSA members. Small companies pay a membership fee of \$2,900 whereas large companies pay \$ 6,900. APSA members can join the consortium any time during the year but must pay the entire annual fee for that term. The membership renewal process leads to substantial year-on-year changes in consortium membership. Fourteen seed companies joined the consortium in 2020 (**Table 2**). Two of these companies had already been members in 2018, dropped out in 2019, and rejoined in 2020. Some of these new members joined the consortium in order to participate in the new pumpkin project that was launched in 2020.

On the other hand, 13 companies left the consortium in 2020. Some of these had joined in 2019, perhaps out of curiosity, but left when they realized that the WorldVeg breeding programs did not match their own product portfolio. Yet, several companies that left in 2020 had been members since the start of the consortium, including Enza Zaden, JK Agri Genetics, Mahindra Agri Solutions, and PT BISI International (**Table 3**). Some of these are likely to rejoin the consortium in future years. However, the reasons for their exit need to be identified. As a result of these yearly

changes, a total of 63 seed companies have been members of the consortium at some point in time since 2017 (**Annex 1**).

Data provided by the WorldVeg gene bank show that 24 of the 44 consortium members ordered breeding lines or genebank accessions in 2020. Members ordered a total of 138 genebank accessions and 382 breeding lines.

Table 1. Distribution of 2017-2020 consortium members by location

Location	2017	2018	2019	2020
Brazil	0	0	1	0
China	0	0	3	0
Hong Kong	1	1	1	1
India	10	20	21	23
Indonesia	2	2	2	1
Japan	1	4	3	3
Malaysia	1	1	1	0
Netherlands	1	1	1	1
Netherlands/India	1	1	1	1
Pakistan	0	0	2	2
Sri Lanka	0	0	1	2
Taiwan	0	1	3	3
Thailand	2	2	3	5
United States	0	0	0	1
Viet Nam	0	0	0	1
Total	19	33	43	44

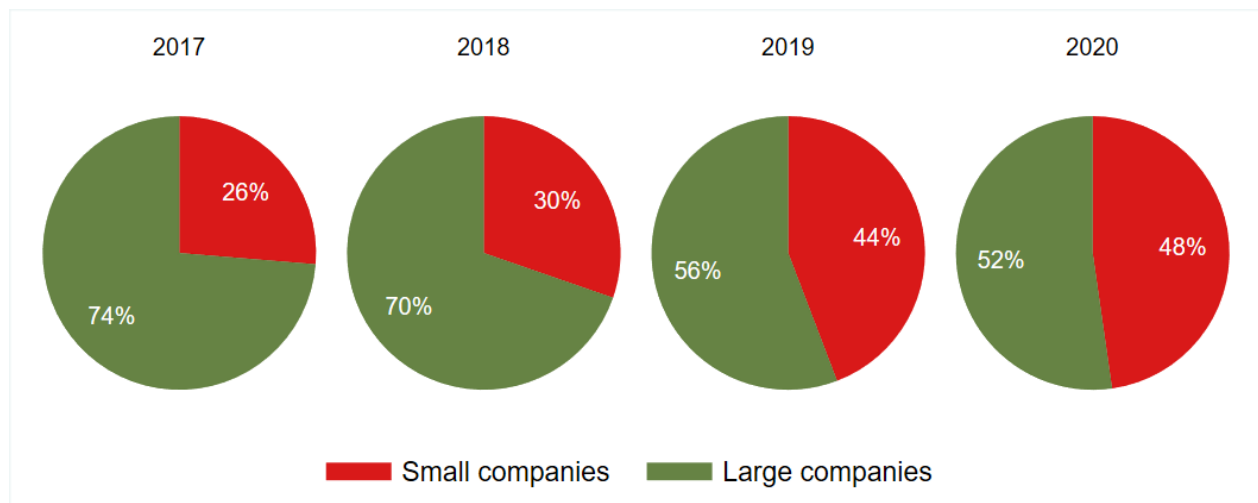


Figure 2. Composition of the consortium in terms of small vs. large companies.

Table 2. Seed companies that joined or left the consortium in 2020

Company name	Country	Previous membership
<u>Companies that joined in 2020:</u>		
1. BHN Seed	USA	
2. Certus Seeds	Pakistan	
3. Chakra Seeds, Bharat Nursery Pvt. Ltd.	India	
4. Chung Kuan Seed Co., Ltd.	Thailand	
5. Flotech Seeds Co., Ltd.	Thailand	
6. Kalash Seeds Private Limited	India	2018
7. Kaneko Seeds Co., Ltd.	Japan	
8. Kaveri Seed Company Limited	India	2018
9. Landmark Agro Seeds (Private) Limited	Sri Lanka	
10. Laxmi Inputs	India	
11. Loc Troi Joint Stock Company	Viet Nam	
12. Nu Genes Pvt. Ltd.	India	
13. Nuziveedu Seeds Ltd.	India	
14. Semillas Fito India Pvt. Ltd.	India	
<u>Companies that left in 2020:</u>		
1. Beijing Bannerseeds Oriental Agriculture Development Co. Ltd.	China	2019
2. Degao Vegetable Seed and Seedling Research Institute	China	2019
3. Enza Zaden Asia Sdn Bhd	Malaysia	2017, 2018, 2019
4. JK Agri Genetics Ltd.	India	2017, 2018, 2019
5. Kagome Co., Ltd.	Japan	2018, 2019
6. Mahindra Agri Solutions Ltd.	India	2017, 2018, 2019
7. Mehr Muhammad Din and Sons	Pakistan	2019
8. PT. BISI International Tbk	Indonesia	2017, 2018, 2019
9. Feltrin Sementes Ltda	Brazil	2019
10. Ruchi Hi-rich Seeds Pvt. Ltd.	India	2019
11. Shouguang Yinong Horticulture Co., Ltd.	China	2019
12. Tierra Seed Science Pvt. Ltd.	India	2019
13. United Genetics India Pvt. Ltd.	India	2018, 2019

2 Data collection

The objective of this study is to track the use of WorldVeg-developed breeding lines and hybrids of bitter melon, pepper, tropical pumpkin and tomato by seed companies in the APSA-WorldVeg consortium and estimate their use by farmers. A secondary objective is to identify the breeding priorities of consortium members to inform WorldVeg breeding programs.

The key performance indicators used are:

- (1) The number of varieties currently sold in Asia that contain WorldVeg-developed germplasm as a proportion of all varieties sold.
- (2) The quantity of seed sold in Asia of varieties containing WorldVeg-developed germplasm.

The second indicator is used to estimate the area planted to vegetables varieties developed from WorldVeg-derived germplasm 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.

Data were collected by Email using a standard Excel data entry sheet sent to the voting representative and registered contact person of each consortium member in 2020. The following changes were made to the data collection as compared to previous years:

1. The timing of the data was changed from October to January each year. This was done to link it to the consortium registration process and to refer to the last completed calendar year. As a consequence, no data collection took place in 2020, although four companies still sent in the data and these were included in this analysis.
2. Different from previous years, we used pre-filled Excel workbooks showing the data that were provided in previous years, which makes it easier for respondents to compare data over time. Yet, it required individualized communication to each company to ensure confidentiality of the data.
3. As the new data collection process is more time consuming, it was managed directly by WorldVeg instead of APSA. This also allowed us to immediately check the data and ask companies to correct or verify data if necessary.
4. To encourage timely feedback, we gave a US\$ 100 discount on the 2021 consortium membership fee to the first five companies that returned fully completed data forms.

All emails requests were sent in mid-January and companies were given two weeks to return the file. Reminders were sent afterwards.

3 Questionnaire response

By late-March 2021, we had received data from 23 seed companies (52% of the 2020 consortium members) as shown in **Table 3**. This response rate is below expectations, but much better than previous years. In total, 34 seed companies have provided data at any time since 2017, which is more than half of all past and present members.

Table 3 Questionnaire response per year.

Year	Number of companies that provided data	Proportion of consortium members that provided data
2017	14	0.74
2018	11	0.33
2019	4	0.09
2020	23 ^a	0.52
Any year	34	0.54 ^b

Note: ^a includes 2 past consortium members. ^b Calculated over 63 past and current members

Some companies in the 2021 survey, not just provided data for 2020, but also for previous years, which added further data points over time as shown in **Table 4**. However, not every company has provided data for every year, which makes it difficult to identify trends, also as membership changes over time. To estimate the total 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 2020 then we replaced it with their 2019, 2018 or 2017 data, if provided. The total number of data points is indicated in the bottom row of each table and shows that we have “current data” on key performance indicators for about 30 companies for each crop. As seed companies tend to exit and rejoin the consortium, we do not limit the analysis to current consortium members, but include all companies for which we have data.

Table 4 Number of companies that provided data on key performance indicators

Year	Bitter gourd	Pepper	Pumpkin	Tomato
2017	19	19	18	19
2018	16	17	15	19
2019	5	5	5	5
2020	21	21	19	22
Any year	31	31	29	32

Note: Figures for 2017 and 2018 are higher than shown in Table 4 as some companies that responded to the 2021 survey also provided data for past years.

4 Key performance indicators

4.1 Varieties incorporating WorldVeg-developed germplasm

The data show a gradual increase in the number of vegetable varieties on the market that contain WorldVeg-developed germplasm, from 32 varieties in 2017, to 50 in 2018, to 79 in 2020 (**Figure 2**). However, the trend may be confounded by changes in the sample of seed companies that are reporting on this indicator.

The combined data show that the 34 seed companies that provided data on the number of varieties sell a total of 1,084 varieties of bitter gourd, pepper, pumpkin and tomato. Of these, 86 varieties (8%) contain WorldVeg-developed germplasm in their pedigrees. The contribution of WorldVeg germplasm is largest for tomato, where 14% of all varieties sold contain WorldVeg germplasm. There is clear evidence that WorldVeg-developed germplasm of bitter gourd and pumpkin is increasingly found in commercial varieties of these crops. Seven seed companies reported selling WorldVeg-related bitter gourd and two companies reported selling WorldVeg-related pumpkin varieties and the total number of varieties was 13 for bitter gourd and 4 for pumpkin in 2020.

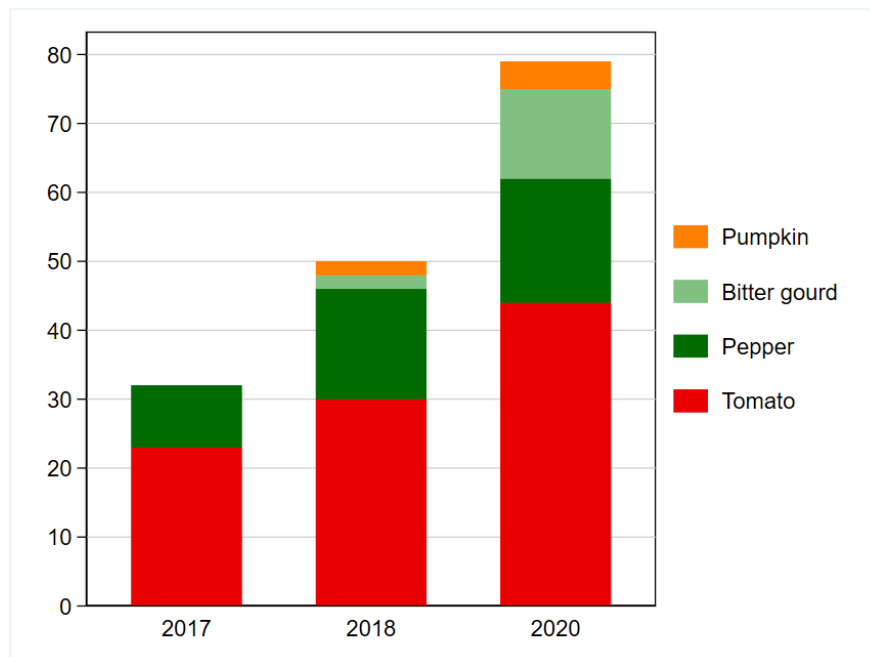


Figure 2. Current vegetable varieties sold in Asia that contain WorldVeg-developed germplasm as reported by 30 seed companies.

Table 5 Use of WorldVeg germplasm by consortium members, 2017-2020

A. Data for 2017	Bitter gourd (n=19)	Pepper (n=19)	Pumpkin (n=18)	Tomato (n=19)	Total
Number of varieties:					
Varieties, all	76	256	22	299	653
Varieties, WorldVeg-related	0	9	0	23	32
% of varieties WorldVeg-related	0%	4%	0%	8%	5%
Quantity of seed sales:					
Seed sales, all varieties (tons)	97.5	79.3	56.1	63.0	296.0
Seed sales, WorldVeg (tons)	0.0	6.2	0.0	8.8	15.0
Seed sales, WorldVeg (%)	0%	8%	0%	14%	5%
B. Data for 2018	Bitter gourd (n=16)	Pepper (n=17)	Pumpkin (n=15)	Tomato (n=19)	Total
Number of varieties:					
Varieties, all	141	340	75	285	841
Varieties, WorldVeg-related	2	16	2	30	50
% of varieties WorldVeg-related	1%	5%	3%	11%	6%
Quantity of seed sales:					
Seed sales, all varieties (tons)	195.2	65.2	127.5	32.1	420.0
Seed sales, WorldVeg (tons)	0.5	9.2	0.2	5.5	15.2
Seed sales, WorldVeg (%)	<1%	14%	<1%	17%	4%
C. Data for 2020	Bitter gourd (n=21)	Pepper (n=21)	Pumpkin (n=19)	Tomato (n=22)	Total
Number of varieties:					
Varieties, all	185	309	95	320	909
Varieties, WorldVeg-related	13	18	4	44	79
% of varieties WorldVeg-related	7%	6%	4%	14%	9%
Quantity of seed sales:					
Seed sales, all varieties (tons)	316.4	87.5	184.2	60.7	648.7
Seed sales, WorldVeg (tons)	2.6	6.5	0.3	9.1	18.6
Seed sales, WorldVeg (%)	1%	7%	<1%	15%	3%
D. Data for 2017-2020	Bitter gourd (n=31)	Pepper (n=31)	Pumpkin (n=29)	Tomato (n=32)	Total
Number of varieties:					
Varieties, all	203	386	107	388	1084
Varieties, WorldVeg-related	13	19	4	50	86
% of varieties WorldVeg-related	6%	5%	4%	13%	8%
Quantity of seed sales:					
Seed sales, all varieties (tons)	320.6	106.3	205.9	89.4	722.1
Seed sales, WorldVeg (tons)	2.6	8.9	0.3	12.9	24.7
Seed sales, WorldVeg (%)	1%	8%	<1%	14%	3%

Note: "WorldVeg" means varieties or seed sales of varieties that incorporate improved breeding lines from the World Vegetable Center.

4.2 Volume of seed sales with WorldVeg germplasm

The total seed sales of consortium members for the four crops included in the consortium has expanded rapidly from 296 tons in 2017 to 649 tons in 2020. This is the result of expanding seed sales, but also of more companies reporting their sales data.

Seed sales of varieties containing WorldVeg germplasm were 15.0 tons in 2017, 15.2 tons in 2018, and 18.6 tons in 2020. Combining the data provides a more meaningful estimate of the current vegetable seed sales in Asia that contain WorldVeg germplasm. We estimate that WorldVeg germplasm is used in 24.7 tons of vegetable seed sold in Asia per year (**Table 5D**). Of this, 21.8 tons is small-seeded (tomato and pepper) and 2.9 tons is large-seeded (bitter gourd and pumpkin).

These are the key findings per crop:

- **Bitter gourd** varieties based on WorldVeg germplasm were reportedly sold by 7 companies. These sold a total of 2,598 kg of bitter gourd seed in 2020 (**Table 6**). This is potentially enough to plant 2,969 ha under bitter gourd based on farmers' average seed rate in India. As the average farmer plants about 0.5 ha of bitter gourd, we estimate that 5,938 farmers used WorldVeg-related bitter gourd varieties.
- **Pumpkin** varieties based on WorldVeg germplasm were sold by 2 companies. These companies sold a total of 289 kg of pumpkin seed in 2020. This is enough to plant 963 ha of pumpkin and potentially benefits 2,400 small-scale farmers.
- **Pepper** varieties based on WorldVeg germplasm were sold by 8 companies, which sold a total of 8.9 tons of pepper seed in 2020. This is potentially enough to plant 59,600 ha and reaches an estimated 135,500 small-scale farm households. This is well-above our 2017-2018 data, which estimated a planted area of 32,700 ha, benefitting 74,300 farm households. Yet, we need to be careful interpreting a trend in these data because the sample of companies has expanded over time.
- **Tomato** varieties based on WorldVeg germplasm were sold by 11 companies, which sold a total of 12.9 tons of tomato seed in 2020. This is potentially enough to reach 108,000 ha and 347,000 small-scale farm households. This is substantially larger than the 2017-2018 data that showed that WorldVeg tomato germplasm was planted on 78,900 ha and benefitted 254,600 farm households. Again, we need to be careful interpreting a trend.

These estimates are likely to underestimate the actual use of WorldVeg germplasm as it is based on data provided by 34 companies out of a total of 63 past and present consortium members.

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 five years as seed production of recently released varieties gains momentum.

Comparing these estimates to those for 2018, we find a 48% increase in the area planted under WorldVeg varieties and in the number of farmers using WorldVeg-derived varieties (**Table 6**).

Table 6 Estimated area under WorldVeg-developed germplasm and farmers reached, 2017-2018.

	Bitter gourd	Pepper	Pumpkin	Tomato	Total
Assumptions:					
– Average seed rate (grams/ha)	875	150	300	120	
– Average planted area (ha/farmer)	0.50	0.44	0.40	0.31	
2021 study (using 2017-2020 data):					
– Seed sales with WorldVeg germplasm (kg)	2,598	8,941	289	12,896	24,724
– Area potentially planted (1000 ha)	2.969	59.6	1.0	107.5	171.0
– Farmers potentially reached (1000s)	5.938	135.5	2.4	346.7	490.5
2019 study (using 2017-2018 data):					
– Seed sales with WorldVeg germplasm (kg)	-	4,903	172	9,471	14,546
– Area potentially planted (1000 ha)	-	32.7	0.6	78.9	112.2
– Farmers potentially reached (1000s)	-	74.3	1.4	254.6	330.3
% change (2021 over 2019 study):					
– Farmers potentially reached (% change of most recent over previous period)	-	82%	68%	36%	48%

5 Varieties

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 3**.

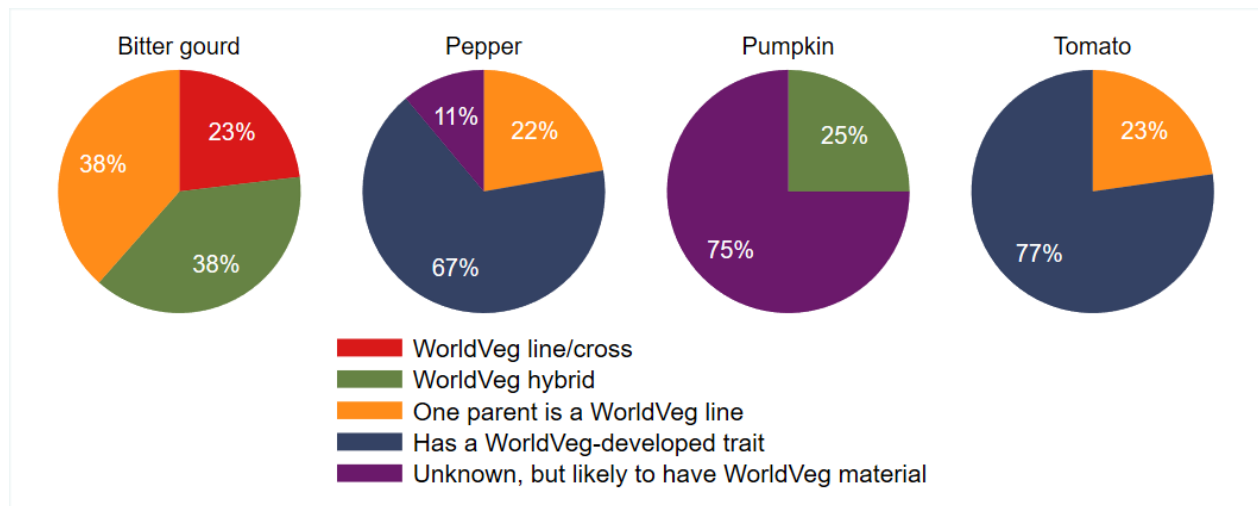


Figure 3. Role of WorldVeg germplasm in varieties containing WorldVeg-developed germplasm, 2020 data

For tomato and 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 varieties used a particular WorldVeg breeding line as a parent for a hybrid.

This is quite different for bitter gourd where the role of WorldVeg germplasm is more significant: of the 13 commercial varieties reported, 5 were hybrids that had both parents supplied by WorldVeg, 5 were hybrids with one parent supplied by WorldVeg, and 3 were WorldVeg lines directly released as varieties.

For pumpkin, only 4 commercial varieties were reported in 2020 and these were produced by only 2 seed companies. One seed company used WorldVeg germplasm as background materials to develop 3 hybrids. The pumpkin project started in 2020 and we expect, therefore, that the use of WorldVeg germplasm will increase in the next 2-3 years.

6 Traits

Of the 23 seed companies that responded to the 2020 survey, 13 were using WorldVeg bitter gourd lines in their breeding program, 12 were using pepper lines, 7 were using pumpkin lines, and 15 were using tomato lines (**Table 7**). This usage in the current breeding programs is important as it is likely to maintain and increase the future impact of the WorldVeg breeding programs.

Table 7 Number of companies using WorldVeg-developed traits, 2020

Variable	Bitter gourd	Pepper	Pumpkin	Tomato
Using WorldVeg-developed traits in breeding program	13	12	7	15
Have incorporated particular WorldVeg-developed traits in current varieties	7	7	2	9

Note: based on the responses of 21 seed companies.

Table 8 shows which WorldVeg-developed traits are currently used by consortium members in their breeding programs and which have already been incorporated in varieties currently sold. It also shows the priorities that seed companies attach to further development of the listed traits.

The following breeding priorities were identified for each WorldVeg breeding program:

- For **bitter gourd**, begomovirus resistance is clearly the most important priority as identified by seed companies. Other traits that companies would like WorldVeg to prioritize are high yield, powdery mildew resistance, and Gy line development followed by high female-to-male flower ratio and keeping quality. A few companies gave very high

priority to the traits gummy stem blight resistance, heat tolerance and downy mildew resistance, which were not included in our questionnaire.

- For **pepper**, anthracnose resistance and high yield were given the highest priority by seed company respondents, followed by heat tolerance, bacterial wilt resistance (*Ralstonia solanacearum*), and Phytophthora blight resistance (*Phytophthora capsici*). Some companies mentioned the importance of thrips resistance and high pungency, which were not included in our questionnaire.
- For **pumpkin**, the breeding priorities identified by seed company respondents included first and foremost begomovirus resistance followed by early maturity and high yield. Other priorities included powdery mildew resistance, fruit flesh color, cucumber mosaic virus resistance, fruit size/shape and zucchini yellow mosaic virus resistance.
- For **tomato**, the breeding priorities were clearly tomato yellow leaf curl virus (TYLCV) resistance and heat tolerance, followed by high yield, bacterial wilt resistance (*Ralstonia solanacearum*), and late blight resistance (*Phytophthora infestans*), early blight resistance (*Alternaria solani*) and keeping quality (shelf-life). A few companies mentioned the importance of firmness, nematode resistance, fruit cracking, stem scar, and blossom end rot, which were not included in our questionnaire.

In general, high yield ranks high among the priorities for all crops, but it is also noteworthy that heat tolerance ranks high for both tomato and pepper. Taste characteristics is given a lower rank than disease-resistance traits, and nutritional value usually ranks bottom of the list, with the exception of pumpkin where fruit flesh color (associated with a higher pro-vitamin A contents) is of relative importance.

Table 8 Traits used and traits prioritized in the company’s breeding programs, 2020

A. Bitter gourd	Used in varieties	Used in breeding program	Level of priority (proportion of 16 companies)			
			VH	H	M	L
1. Begomovirus resistance	3	9	0.88	0.13	-	0.13
2. High yield	3	5	0.63	0.31	0.06	0.06
3. Powdery mildew resistance	4	9	0.50	0.38	0.19	0.06
4. Gy line development	1	4	0.50	0.19	0.13	0.06
5. Keeping quality (shelf-life)	4	7	0.44	0.38	0.13	0.13
6. High female: male flower ratio	3	4	0.44	0.31	0.13	0.13
7. Early fruit maturity	2	4	0.25	0.31	0.25	0.19
8. Color	2	7	0.19	0.56	0.06	0.19
9. Plant vigor	2	5	0.19	0.44	0.06	0.31
10. Fruit size	3	6	-	0.44	0.38	0.19
11. Skin pattern	3	6	-	0.38	0.38	0.25
12. Fruit bitterness	1	3	-	0.13	0.38	0.50

Notes: VH=Very high priority; H=High priority; M=Medium priority; L=Low or very low priority.

B. Pepper	Used in varieties	Used in breeding program	Level of priority (proportion of 16 companies)			
			VH	H	M	L
1. Anthracnose resistance (<i>Colletotrichum</i> spp.)	0	3	0.63	0.31	-	0.06
2. High yield	2	7	0.63	0.13	0.06	0.13
3. Bacterial wilt resistance (<i>Ralstonia solanacearum</i>)	1	2	0.44	0.31	-	0.19
4. Heat tolerance	1	6	0.44	0.25	0.19	0.06
5. Phytophthora blight resistance (<i>Phytophthora capsici</i>)	2	4	0.38	0.31	0.19	0.06
6. Cytoplasmic male sterility (CMS)	2	5	0.25	0.38	0.13	0.19
7. Cucumber mosaic virus (CMV) resistance	2	3	0.25	0.31	0.13	0.25
8. Chilli veinal mottle virus (ChiVMV) Resistance	1	3	0.25	0.25	0.19	0.31
9. Tobacco mosaic virus (TMV) resistance	1	3	0.19	0.31	0.25	0.25
10. Bacterial spot resistance	0	1	0.13	0.25	0.13	0.38
11. Potato virus Y resistance	1	2	0.13	0.19	0.19	0.38
12. Color or size	0	3	0.13	0.19	0.19	0.38
13. Aphid Resistance	0	0	0.06	0.19	0.19	0.44
14. Taste	0	2	0.06	0.13	0.19	0.50
15. Keeping quality (shelf-life)	0	2	-	0.44	0.19	0.25
16. Short duration	0	1	-	0.25	0.31	0.31

Notes: VH=Very high priority; H=High priority; M=Medium priority; L=Low or very low priority.

C. Pumpkin	Used in varieties	Used in breeding program	Level of priority (proportion of 14 companies)			
			VH	H	M	L
1. Begomovirus resistance	1	1	0.57	0.36	-	-
2. Early maturity	2	4	0.50	0.21	0.14	0.14
3. High yield	1	2	0.50	0.21	0.14	0.07
4. Powdery mildew resistance	1	2	0.43	0.14	0.36	0.07
5. Fruit flesh color	1	3	0.36	0.21	0.07	0.36
6. Cucumber mosaic virus resistance	0	0	0.29	0.29	0.14	-
7. Fruit size or shape	1	2	0.29	0.21	0.29	0.21
8. Zucchini yellow mosaic virus resistance	0	0	0.29	0.21	0.14	-
9. Papaya ringspot virus resistance	0	0	0.21	0.21	0.21	-
10. Taste	2	3	0.14	0.36	0.29	0.14
11. Fruit skin color	1	2	0.14	0.29	0.14	0.43
12. Keeping quality (shelf-life)	1	2	-	0.64	0.14	0.14

Notes: VH=Very high priority; H=High priority; M=Medium priority; L=Low or very low priority.

D. Tomato	Used in varieties	Used in breeding program	Level of priority for WorldVeg (18 companies)			
			VH	H	M	L
1. Tomato yellow leaf curl virus (TYLCV) resistance	8	13	0.94	0.06	-	-
2. Heat tolerance	1	8	0.83	0.11	0.06	-
3. High yield	1	6	0.72	0.17	0.06	-
4. Bacterial wilt resistance (<i>Ralstonia solanacearum</i>)	6	11	0.61	0.22	0.17	-
5. Late blight resistance (<i>Phytophthora infestans</i>)	3	9	0.56	0.28	0.11	-
6. Early blight resistance (<i>Alternaria solani</i>)	0	4	0.50	0.33	0.11	0.06
7. Keeping quality (shelf-life)	0	5	0.50	0.28	0.22	-
8. Peanut bud necrosis	0	1	0.39	0.17	0.11	0.17
9. Tomato mosaic virus (TMV) resistance	4	6	0.39	0.17	0.17	0.22
10. Taste	0	1	0.33	0.17	0.22	0.22
11. Color or size	1	5	0.28	0.39	0.17	0.11
12. Root-knot nematode resistance	1	5	0.28	0.17	0.33	0.17
13. Short duration	0	4	0.22	0.22	0.22	0.28
14. Insect pest resistance	0	2	0.22	0.22	0.33	0.22
15. Stem Canker (<i>Alternaria alternata</i>)	0	0	0.22	0.06	0.28	0.28
16. Powdery mildew	0	0	0.17	0.28	0.17	0.22
17. Gray leaf spot resistance (<i>Stemphylium solani</i>)	1	1	0.17	0.06	0.33	0.39
18. Bacterial spot (<i>Xanthomonas</i>)	0	1	0.11	0.33	0.28	0.11
19. Fusarium wilt resistance (<i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i>)	1	2	0.11	0.17	0.28	0.39
20. High lycopene content	0	3	0.06	0.33	0.39	0.17
21. High beta carotene content	0	0	0.06	0.17	0.44	0.28

Notes: VH=Very high priority; H=High priority; M=Medium priority; L=Low or very low priority.

7 Summary of key findings

1. Consortium membership increased from 43 members in 2019 to 44 members in 2020. The share of small companies (<100 employees) has increased every year since 2017 and was 48% in 2020. Half of the consortium members are based in India.

2. This study collected data on key performance indicators for 23 seed companies in 2021, which is substantially better than in previous years showing that the revised data collection method worked. A total of 34 seed companies have provided data at any time since 2017.
3. These data show that WorldVeg-developed germplasm was found in 25 tons of tomato, pepper, bitter melon and pumpkin seed sold in Asia by 19 different seed companies. This seed is potentially enough to plant 171,000 hectares under these vegetable crops and benefit 490,000 small-scale farm families.
4. These estimates are substantially higher (+48%) than the previous study we did in 2019, which showed that WorldVeg genetic material was used by 7 seed companies and reached 112,200 hectares under these vegetable crops and benefited 330,300 small-scale farm families. This increase can partly be attributed to a larger sample of seed companies in this study as compared to the previous study.
5. Our data showed that WorldVeg bitter melon lines and hybrids were sold by 7 companies in 2020 with total seed sales of about 2.6 tons. This is the first evidence for impact of the WorldVeg bitter melon program as our 2019 study showed zero sales. Thirteen companies are currently using WorldVeg bitter melon material in their breeding program.

8 Recommendations

1. The current data collection method, which relies on pre-filled data entry sheets and individualized communications sent out in mid-January, can be continued as it appears effective.
2. There is a high turnover rate of consortium members with 14 seed companies joining the consortium in 2020 and 13 companies exiting in the same year. It is recommended to do a follow-up study among companies that left the consortium in 2020 to understand the reasons for their discontinuation.
3. The strategy to require companies participating in special projects to join the consortium is likely to have increased membership. Developing new attractive projects every year will be important to maintain and expand membership.
4. Of particular concern is the discontinuation of three large seed companies that account for a large share of the overall impact: VNR Seeds, JK Agri Genetics, and PT BISI International. Jointly, these companies account for 35% of the impact of WorldVeg breeding programs. A new bitter melon project to be launched in 2021 or 2022 may entice some of these companies to join the consortium again.
5. It is important to promote the consortium in countries outside India to maintain a balance of geographies as India-based companies currently account for half the members. Participation in national seed fairs and the Asian Seed Congress can help to promote the consortium.

Annex 1: Membership data

Table A1. Members of the APSA-WorldVeg Consortium in 2020, including membership history

Nr.	Company name	Location	2020	2019	2018	2017
1	Acsen HyVeg Pvt. Ltd.	India	1	1	0	0
2	Advanta Seed (United Phosphorus Limited Group)	India	1	1	1	0
3	BHN Seed	USA	1	0	0	0
4	Certus Seeds	Pakistan	1	0	0	0
5	Ch. Khair Din & Sons (CKD Seeds & Fertilizer)	Pakistan	1	1	0	0
6	Chakra Seeds, Bharat Nursery Pvt. Ltd.	India	1	0	0	0
7	Chia Tai Co., Ltd.	Thailand	1	1	0	0
8	Chung Kuan Seed Co., Ltd.	Thailand	1	0	0	0
9	Clover Seed Co., Ltd.	Hong Kong, China	1	1	1	1
10	Comienzo Agri Science Limited (formerly known as Sattva Seeds Pvt. Ltd. and Vachan Seeds)	India	1	1	1	0
11	East-West Seed International Limited	Thailand	1	1	1	1
12	Flotech Seeds Co., Ltd.	Thailand	1	0	0	0
13	HM.Clause (Thailand) Co., Ltd.	Thailand	1	1	1	1
14	I & B Seeds Private Limited	India	1	1	1	1
15	Indo-American Hybrid Seeds (India) Pvt. Ltd.	India	1	1	0	0
16	Kalash Seeds Private Limited	India	1	0	1	0
17	Kaneko Seeds Co., Ltd.	Japan	1	0	0	0
18	Kaveri Seed Company Limited	India	1	0	1	0
19	Known-You Seed Co., Ltd.	Taiwan	1	1	0	0
20	Landmark Agro Seeds (Private) Limited	Sri Lanka	1	0	0	0
21	Laxmi Inputs	India	1	0	0	0
22	Loc Troi Joint Stock Company	Viet Nam	1	0	0	0
23	Mahyco Private Limited / Sungro Seeds Pvt. Ltd.	India	1	1	1	0
24	Monsanto Holdings Pvt. Ltd.	India	1	1	0	0
25	Namdhari Seeds Pvt. Ltd.	India	1	1	1	0
26	Nath Bio Genes (India) Ltd.	India	1	1	0	0
27	Nongwoo Seed India Pvt. Ltd.	India	1	1	1	1
28	Nu Genes Pvt. Ltd.	India	1	0	0	0
29	Nunhems Bv (BASF/Monsanto)	Netherlands/India	1	1	1	1
30	Nuziveedu Seeds Ltd.	India	1	0	0	0
31	Onesh Agri Pvt. Ltd.	Sri Lanka	1	1	0	0
32	PT. East West Seed Indonesia (EWINDO)	Indonesia	1	1	1	1
33	Rallis India Limited (Metahelix Life Sciences Pvt. Ltd.)	India	1	1	1	0
34	Rijk Zwaan	Netherlands	1	1	1	1
35	Sakata Seed Corporation	Japan	1	1	1	0
36	Seedworks International Pvt. Ltd.	India	1	1	1	1

Nr.	Company name	Location	2020	2019	2018	2017
37	Semillas Fito India Pvt. Ltd.	India	1	0	0	0
38	Shriram Bioseed Genetics (A Division of DSCL)	India	1	1	0	1
39	Sing-Flow Seed Co., Ltd.	Taiwan	1	1	1	0
40	Syngenta India Limited	India	1	1	1	1
41	Takii & Company, Ltd.	Japan	1	1	1	1
42	Tokita Seed India Private Limited	India	1	1	1	0
43	Welcome Crop Science Pvt., Ltd.	India	1	1	0	1
44	Your Chain Seed Co., Ltd.	Taiwan	1	1	0	0

Table A2. Former members of the APSA-WorldVeg Consortium, including membership history

Nr.	Company name	Location	2020	2019	2018	2017
45	Ankur seeds Pvt. Ltd.	India	0	0	1	0
46	Beijing Bannerseeds Oriental Agriculture Development Co. Ltd.	China	0	1	0	0
47	Degao Vegetable Seed and Seedling Research Institute	China	0	1	0	0
48	Enza Zaden Asia Sdn Bhd	Malaysia	0	1	1	1
49	Feltrin Sementes Ltda	Brazil	0	1	0	0
50	JK Agri Genetics Ltd.	India	0	1	1	1
51	Kumar Bioseeds and Agro Products Pvt. Ltd. (formerly known as KF Bioplant Pvt. Ltd.)	India	0	0	1	1
52	Kagome Co., Ltd.	Japan	0	1	1	0
53	Mahindra Agri Solutions Ltd.	India	0	1	1	1
54	Mehr Muhammad Din and Sons	Pakistan	0	1	0	0
55	Musashino Seed Co., Ltd.	Japan	0	0	1	0
56	Nethra Enterprises Pvt. Ltd.	India	0	0	1	0
57	Noble Seeds	India	0	0	1	1
58	PT. BISI International Tbk	Indonesia	0	1	1	1
59	Ruchi Hi-rich Seeds Pvt. Ltd.	India	0	1	0	0
60	Shouguang Yinong Horticulture Co., Ltd.	China	0	1	0	0
61	Tierra Seed Science Pvt. Ltd.	India	0	1	0	0
62	United Genetics India Pvt.Ltd.	India	0	1	1	0
63	VNR Seeds Pvt. Ltd.	India	0	0	1	0