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Organic Plant Breeding: A Key to Improved Vegetable Yield and Safe Food

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Abstract: Most often, organic farming focuses on the improvement of management practices such as nutrient application and pest control, and very seldom deals with variety improvement or breeding. Because it has been dependent on commercially-available varieties developed under conventional high-input methods, traits are expressed resulting in low yields that are commonly attributed to organic farming practices rather than to the adaptability of the cultivar to the system. A research program in the Philippines involving several regions and institutions has pioneered in the evaluation and improvement of varieties through breeding under low-input organic conditions. After making several crosses, pedigree selection, replicated yield and on-farm trials, promising and potential varieties were developed and identified in squash, cucumber, lettuce and yardlong bean. The most promising yield advantages over the respective check varieties ranged up to 47% in squash, 31% in yardlong bean, 42% in lettuce, and 43% in cucumber. Pest and disease resistance were also considered during the selection process, and top performers were moderately to highly resistant. General acceptability in appearance, taste and marketability provided additional selection criteria for considering the top performers and potential varieties. Commercial varieties developed and performing well under conventional high-input methods were mostly not suitable under organic low-input conditions. Hence, breeding under organic low-input conditions is a must to achieve high yield in organic farming systems.

Keywords: low input; squash; cucumber; lettuce; yardlong bean; Philippines

1. Introduction

In the last 14 years, the total organic agricultural land in the world has increased by almost 300%. India has the largest number of organic producers (650,000), Australia has the largest area (17.2 million hectares), the USA has the largest market (24,347 million Euros), and Switzerland has the highest per capita consumption as reported by the International Federation of Organic Agriculture Movements (IFOAM) [1]. It is common practice to approach organic production by replacing application of synthetic chemicals with biologically- or naturally-derived alternatives. Numerous products and methods of cultivation, soil inputs, weed control, nutrient recycling and application, and non-chemical pest control have been developed. Recently, especially in the Asia and Pacific region, efforts have been initiated in breeding varieties for organic production systems. This is an approach not yet been widely exploited by researchers.

Organic varieties or seeds are required in organic production. However, limitations in the availability of organic varieties triggered policy makers to adjust and consider this gap. Conventional F1 varieties from private seed companies are allowed in organic production provided that seeds are produced for at least one generation under an organic system [2,3]. However, previous variety trials show that conventional varieties do not always perform well under organic conditions. This may be because conventional varieties are intentionally developed under optimum conditions but are not adaptable to low input conditions and an organic environment.

Basically, the concept of organic breeding is the same as conventional breeding, with Phenotype (P) = Genotype (G) + Environment (E) + Genotype × Environment (GE), wherein the performance of the variety (P) is dependent on the genetic trait (G), effect(s) of the environment (E), and the interaction between the variety and the environment (GE). However, varieties from conventional breeding may have traits that may be unsuitable for organic production systems, and some important traits for organic farming systems may not be found in the conventional varieties [4]. Breeding under organic conditions may result in improved levels of stress tolerance and disease resistance in the resulting varieties. Hence, the evaluation and improvement of varieties through breeding under organic conditions at minimum levels of input application are essential for the development of the organic sector and for the quality of organic products.

As IFOAM [5] mentioned in a position paper, "organic plant breeding is inevitable." Thus, this research has the objectives of selecting, recommending or developing organic vegetable cultivars such as yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*), squash (*Cucurbita moschata*), lettuce (*Lactuca sativa*) and cucumber (*Cucumis sativus*) for organic production and consequently to increase vegetable production in organic systems.

2. Experimental Section

2.1. Variety Development

From 1992 to 2002, selected open-pollinated lines and segregating populations of yardlong bean, squash, lettuce and cucumber were subjected to primary evaluation under the DA-BAR funded project "Varietal Evaluation of Selected Vegetables under Organic Conditions" [6]. From these lines and populations, entries with good quality and performance under organic conditions were selected and crosses were made among the selections. The crosses made were evaluated in two sites at the University of the Philippines Los Baños (UPLB), one at the Institute of Plant Breeding (IPB) main compound and another at the PAMANA station along Pili Drive. Pedigree selection was employed under low-input organic conditions.

At the experimental sites, raised beds with dimensions of 1 m × 5 m were prepared for the evaluation of the lines and crosses. Each raised bed was lined with two rows having 20 hills per row and a distance of 50 cm between hills. The evaluation sites were calibrated to be able to select for genotypes with tolerance to weed populations, resistance or tolerance to pests and diseases, and efficiency in nutrient utilization and related stress(es), following Philippine National Standards (PNS) for Organic Agriculture. Organic fertilizers (vermicompost and other compost materials) were applied at a minimal level of about 50%–75% of the nutrition required by the plant, specifically at 2–3 $t \cdot ha^{-1}$. Fermented plant juice and fermented fruit juice were also applied at specific stages of the plants. Minimal weeding and pest control measures were also practiced. Plastic mulch was used to control weeds, while aromatic pest-repellent plants such as lemon grass and marigold were planted as a means of pest control. Furthermore, flowering plants such as Mexican sunflower and Zinnia were planted to attract pollinators and other beneficial insects, while barrier plants were established around the experimental areas to prevent contamination from neighboring farms. These farm practices were employed for every season of evaluation of the selected lines.

For every generation, individual plants were selected based on general vigor, fruit characteristics, resistance to pests and diseases, and tolerance to environmental stress. Selfing was performed for each individual plant selection, and the selfed seeds obtained were used for the following generation. At the F6 generation, the selected lines were evaluated in an observational trial to determine the top lines to be included in the yield trials. The observational trials were conducted at IPB-UPLB, Palawan Agricultural Center (PAC), DA-Palawan Agricultural Experiment Station (DA-PAES), and the Bureau of Plant Industry—Los Baños National Crop Research and Development Center (Los Baños, Laguna, Philippines).

2.2. Replicated Yield Trials

Replicated yield trials were conducted at PAMANA, Pili Drive, UPLB and DA-PAES. The entries included for each yield trial were the top selected lines and a commercial check variety for each crop. Each trial was carried out using a Randomized Complete Block Design (RCBD) with three replications. The replicated yield trials also followed the aforementioned farm practices employed during the preliminary evaluation of the lines. Data on horticultural and fruit characteristics were gathered from five plant samples per replication. Total yield was obtained and fruits were graded as marketable and non-marketable.

2.3. On-Farm Trials (OFT)

The top performing lines for each crop were further evaluated through on-farm trials in order to assess their acceptability and performance in different locations. The OFT sites were located in some Philippine provinces of Region 4, namely, Laguna, Quezon, Cavite, and Palawan and were all under organic farming conditions. All entries were planted in plots of commercial sizes with at least 20 m^2 per entry. A commercial hybrid variety which served as the check was also included for each trial. Cultural management followed the practices of the farmer cooperators. At the end of each trial, the cooperators were asked to rank the lines based on their preferences and to identify the lines they preferred the most, as well as the basis of their selection. Notes on the performance of the entries on-farm were taken. Seed production was also performed by the cooperators in order to use their selected lines in the next season.

2.4. Breeder Seed Production

Breeder's seeds of the potential varieties were produced on-station at PAMANA to ensure purity of supply for the following trials and also for variety registration. All top-performing entries across crops were produced following the cultural management practices for organic production. Fruits were allowed to mature prior to extraction of seeds, after which seeds were air dried for 2–3 days and then dried under the sun for another 2–3 days. Completely dried seeds were kept in tightly sealed containers.

2.5. Data Analysis

All data were analyzed by ANOVA using the Statistical Analysis System (SAS) Software (SAS Institute Inc., Cary, NC, USA). Means were compared using Fisher's Least Significant Difference (LSD) test at $p = 0.05$.

3. Results and Discussion

The study resulted in the recommendation of four selections per crop that were vigorous, prolific, early, high yielding and highly acceptable to farmers and the market (Table 1).

3.1. Yardlong Bean

In the development of varieties of yardlong bean, average yields of 22.29 $t \cdot ha^{-1}$ (selection 0801-5-1-1-0), 22.13 $t \cdot ha^{-1}$ (selection 1096-1-1-0-0), 20.29 t/ha (selection 10116-1-1-0-0) and 21.25 $t \cdot ha^{-1}$ (selection 10421-0-0) were achieved. These selections had average yield advantages of 31%, 30%, 25% and 19%, respectively, over the check variety. The selections were highly acceptable in the market due to their medium to long pods. Green podded 1096-1-1-0-0 had an average pod length range of 58cm, light green podded 10421-0-0 was 57 cm, dark green podded 10116-1-1-0-0 was 54 cm, and green podded 0801-5-1-1-0 was 52 cm (Figure 1). Selection 1096-1-1-0-0 had the heaviest pod weight ranging of 22.9–32.7 g, 0801-5-1-1-0-0 ranged from 23–24.4 g, 10116-1-1-0-0 ranged from 23.3–25.7 g, and 10421-0-0 ranged from 23.9–26.3 g.

Table 1. Yield and percent yield advantage above the check yield of potential varieties developed for organic low-input conditions.

Crop/Entry	Yield (t/ha)	Yield Advantage (%)
Yardlong bean		
0801-5-1-1-0	22.29	31.0
1096-1-1-0-0	22.13	30.1
10421-0-0	21.25	24.9
10116-1-1-0-0	20.29	19.3
Check	17.01	
Cucumber		
11622	26.03	43.0
11621	18.87	3.7
11617	18.54	1.8
11624	17.97	−1.3
Check	18.21	
Lettuce		
Le 1103(Looseleaf)	10.96	44.0
Le 0701 (Looseleaf)	6.38	−16.1
Check (Looseleaf)	7.61	
Le 0702 (Cos)	7.74	0.9
Le 1104 (Cos)	6.93	−9.7
Check (Cos)	7.67	
Squash		
10128-1-1	61.03	47.5
1058-1-1	48.03	16.1
1056-1-1	42.83	3.5
10127-1-2	49.67	20.1
Check	41.37	

Figure 1. Yardlong bean top yielders: (**A**) 0801-5-1-1-0; (**B**) 10116-1-1-0-0; (**C**) 10421-0-0 and (**D**) 1096-1-1-0-0.

In Alfonso, Cavite, green-podded yardlong bean, 0801-5-1-1-0 and 10116-1-1-0-0 were sold in the local market. Selection 0801-5-1-1-0 was also chosen for its resistance to bean rust. In Majayjay, Laguna, 10116-1-1-0-0, 10421-0-0 and 0801-5-1-1-0 were preferred for their characteristics, while 1096-1-1-0-0 was not chosen because it did not survive the intermittent rains and waterlogging in the area. The Majayjay cooperator preferred 0801-5-1-1-0 because of its high yield capacity, for good pod qualities such as wider, longer pods, and for its dark green color. In Quezon, the light-green pods of 10421-0-0 were highly preferred. Generally, all cooperators chose all entries because of their moderate to high resistance to common bean diseases and pests, long pods that were stringless and snappy, high yield, and market acceptability.

3.2. Cucumber

For cucumber variety selections, average yields observed were 11622 with 26.03 t·ha^{-1}, 11,621 with 18.87 t·ha^{-1}, 11,617 with 18.54 t·ha^{-1} and 11,624 with 17.97 t·ha^{-1}. Entry 11622 had an average yield advantage over the check variety of 43%, 11621 was 4% more, and aa617 was 1.8% more. Cucumber selection 11,617, which has a light green or bicolor (green with white streaks) fruit skin, had an average fruit weight of 241.6 g and an average length of 14.7 cm; bicolor fruit skin 11621 had a 277.7 g average fruit weight and 16.6 cm average length; light green or bicolor skin 11622 had a 234.4 g average weight and 13.5 cm average length; and, 11,624, which is a bicolored, had a 202.8 g average fruit weight and 11.4 cm average length (Figure 2). All selections flowered on the 26th day after planting. All were thin skinned and sweet.

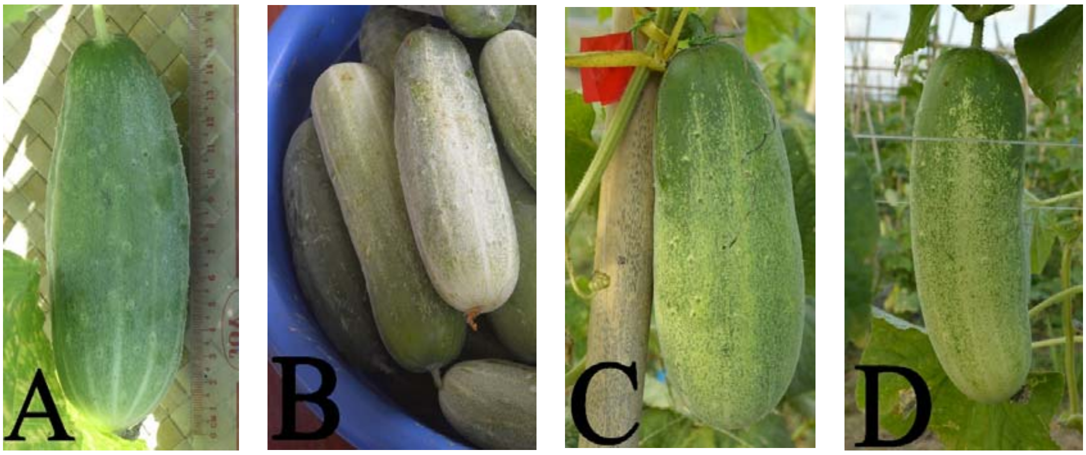

Figure 2. Cucumber lines selected for their high yield and acceptability: (**A**) 11622; (**B**) 11621; (**C**) 11617 and (**D**) 11624.

Lines 11,621 and 11,624 were the top selections of the farmer-cooperator in Alfonso for their juicy flesh, green and thin skin, and high yield capacity. In its preliminary OFT, line 11,621 was also selected for its vigor and earliness. These cucumber selections were highly accepted by the market around Alfonso and nearby municipalities. In Lucban, Quezon, the cooperator selected 11,621 for its prolific fruiting, thin skin and juicy flesh.

3.3. Lettuce

There are two types of lettuce recommended from the study, the loose-leaf and the Cos or Romaine type (Figure 3). Two selections were identified per lettuce type. Loose-leaf type Le 1103 had the highest average yield of 10.96 t·ha^{-1} with average yield advantage over the check of 44%, and Le 0701 yielded 6.38 t·ha^{-1}. While Le 0701 had a lower average yield, it was highly acceptable. Le 0702, on the other hand, was the top yielder of the Cos type with a 7.74 t·ha^{-1} and a yield advantage of 0.9%. Loose-leaf Le 1103 has light green color with a purple tinge, is curly and spreading, while Le 0701 is light green, curly and also has spreading leaves. The Cos-type Le 0702 has green, closed-heads with slightly curly leaf blades, and is upright, while Le 1103 is green, has a flat-head and is semi-upright. These selections were also late bolting, highly uniform and vigorous.

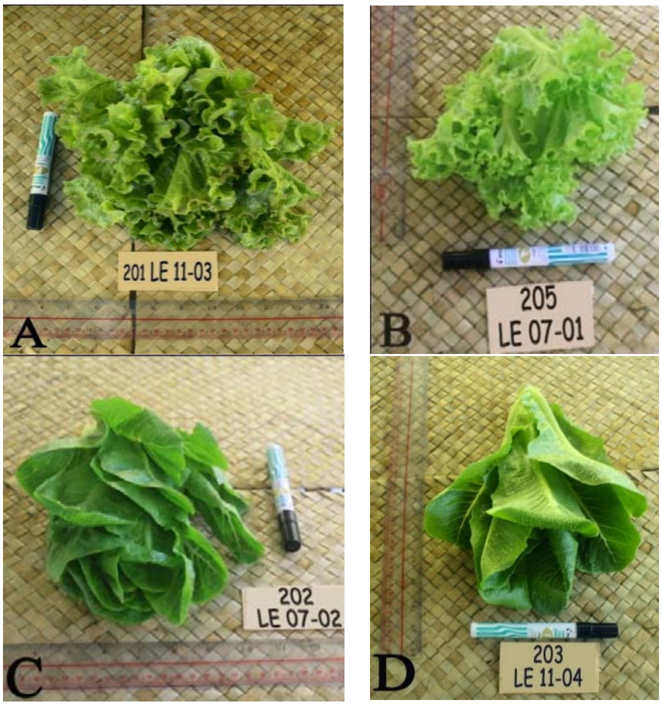

Figure 3. Loose-leaf (**A**,**B**) and cos-type lettuce selections (**C**,**D**).

Consumers in the markets in Alfonso, and Tagaytay, Cavite, preferred loose-leaf types—Le 07-01 and Le 11-03 and Cos-type Le 07-02. The cooperator-farmers chose these selections because of their late-bolting trait, too. In Lucban, Quezon, Le 0701, a loose-leaf type, was selected for its late-bolting, high yield, and vigor, while Le 1104 was preferred for its resistance or tolerance to stem rot that was observed in the area. Le 1104 was also high yielding and late bolting. The cooperator in Silang, Cavite, chose Le 0701 for loose-leaf and Le 0702 for a Cos-type for their high yield. In Majayjay, Laguna, the cooperator chose loose-leaf Le 0701 and Cos type Le 0702 due to their high yield, acceptability based on their taste and appearance, and their high marketability. They were also late bolters and vigorous when grown on regular plots or in vertical gardens.

3.4. Squash

Squash selection 10128-1-1 was the top yielder from two preliminary yield trials in DA-PAES. Average total yield of this selection was 61.03 t·ha^{-1} with a yield advantage of 47.5% above the check variety, followed by line 1058-1-1 with 48.03 t·ha^{-1} (a 16% yield advantage) and line 1056-1-1 with 42.83 t·ha^{-1} (a 3.5% yield advantage). These three top yielders are the round types with varying sizes. The last squash selection was 10127-1-2 which is a long-necked or cacao-type squash that yielded an average 49.67 t·ha^{-1} (a yield advantage of 20%). Line 10128-1-1 has yellow orange flesh with average length and diameter of 14 cm and 15 cm, respectively, while 1058-1-1 has yellow flesh with an average fruit length and diameter of 10 cm and 13 cm, respectively, and 1056-1-1 also has yellow orange flesh with average length of 9.5 cm and average fruit diameter of 13 cm. Lastly, cacao type 10127-1-2 has a 33.5 cm average fruit length and a 10 cm average diameter. The flesh color is also yellow orange (Figure 4).

Figure 4. Round-type squash (**A**) 10128-1-1; (**B**) 1058-1-1; (**D**) 1056-1-1; and cacao-type squash (**C**) 10127-1-2 selections.

In Alfonso, Cavite, the farmer-cooperator selected the solo type 10128-1-1 for its size, shape and fruit yield capacity. Organic market-goers in Lucban, Quezon, preferred line 10128-1-1 because of its size which is suitable for a one-serving dish. It was also selected by the cooperator-producer because of its heart-shaped fruits and its low number of seeds. In Tayabas, Quezon, lines 10127-1-2 and 1056-1-1 were preferred for their prolific yield. Another cooperator located in Brgy. Isugod, Quezon, Palawan, selected line 10128-1-1 for its highly acceptable fruit.

4. Conclusions

Commercial varieties from conventional production systems do not always perform best under organic systems. Therefore, it is inevitable that breeding vegetable varieties adaptable for organic low-input conditions will be needed to achieve a high yield in organic farming. From the present studies, varieties developed under organic conditions were observed to be at par or yield more than commercial varieties commonly grown for the market. These lines have also shown resilience under adverse conditions such as high disease incidence and environmental aberrations along with high consumer acceptability. Thus, these varieties developed under organic agricultural systems show promise for answering the need for diversity, sustainability and efficiency in crop production.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. IFOAM. *Consolidated Annual Report of IFOAM—Organics International*; IFOAM-Organics International Head Office: Bonn, Germany, 2015.
2. Ratanawaraha, C.; Ellis, W.; Panyakul, V. *Organic Agri-Business: A Status Quo Report for Thailand 2007*; Thai-German Programme for Enterprise Competitiveness, Sustainable Agriculture Foundation and GreenNet Foundation: Bangkok, Thailand, 2007.
3. Lammerts van Bueren, E.T. Organic Plant Breeding and Propagation: Concepts and Strategies. Ph.D. Thesis, Wageningen University, Wageningen, The Netherlands, 2002.
4. Legzina, L.; Skrabule, I. *Plant Breeding for Organic Farming: Current Status and Problems in Europe*; Compendium ENVIRFOOD: Talsi, Latvia, 2005.
5. IFOAM. *IFOAM Position on the Use of Organic Seed and Plant Propagation Material in Organic Agriculture*; IFOAM Head Office: Bonn, Germany, 2011.
6. Maghirang, R.G.; Rodulfo, G.S.; Enicola, E.E.; Candelaria, R. Organic Breeding and Seed Production in Selected Vegetables. In Proceedings of the Organic Seed Preconference of the 17th IFOAM Organic World Congress, Namyangju, Korea, 26–27 September 2011.