Producing High-quality Seeds of an Heirloom Cabbage in Different Crop Management Systems

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Abstract. Small- to midsized farmers in the southeastern United States have expressed interest in regaining on-farm seed production of regionally adapted high-value vegetable crops. However, a considerable knowledge gap exists related to how locally produced seeds perform in the region. We investigated how the first generation of local, farm-produced seeds compared with the original, nonlocal, certified commercial seed stock in terms of initial germination, seedling vigor, and subsequent vegetative traits of ‘Yukina Savoy’ (Brassica rapa L.), an heirloom Chinese cabbage. Locally produced seeds consistently outperformed seeds of the commercial lot. Germination for local and nonlocal seeds reached 99% and 94%, respectively. However, locally produced seeds germinated 1.5-fold more rapidly than nonlocal seeds, and germination was more uniform in local seeds. Seedlings produced from local seeds appeared more vigorous and displayed a significant height advantage compared with nonlocal seeds when grown in the greenhouse. Likewise, transplants from local seeds maintained an advantage over transplants from nonlocal seeds for plant vigor, growth traits, and harvestable yield during the 4-week field cultivation period. We conclude that production of high-quality ‘Yukina Savoy’ seeds is possible in the southeastern region despite challenging environmental conditions and varied farming practices of our partners during the seed production cycle.

On-farm seed production is the practice of farmers producing, saving, and disseminating seeds directly from their own crops. On-farm seed production of open-pollinated crops was standard practice throughout most of our agricultural history. This method endured across much of the early 20th century in countries such as the United States and continues to some extent as part of informal seed systems throughout the world (Thomas et al. 2012). On-farm seed production is rare, especially in areas with robust formal seed systems. Factors such as the advent of hybrid varieties, intellectual property protections, and extensive consolidation within a once-diverse global seed industry have contributed to the substantial decrease in on-farm seed production (Howard 2015; Peschard and Randera 2020). Resultant erosion of technical knowledge related to seed production and storage practices, particularly in farming locales outside of traditional seed production areas, may have also contributed to the precipitous decline of this practice.

Nonetheless, on-farm seed production presents opportunities and challenges that may have large impacts on smallholder farmers (i.e., farmers who manage 1 to 10 hectares; Khalil et al. 2017). Seed production combined with seed-saving practices ensures the continuation of landrace (e.g., a locally adapted crop originating and grown in a specific region) and heirloom (e.g., a generationally preserved crop not bound to a specific locality) crop varieties. Heirloom varieties have been recognized as essential genetic resources by scientists since the early 19th century. There are more than 1750 gene banks globally that preserve the genetic material of crop wild relatives for future plant breeding efforts (Khoury et al. 2022). However, on-farm production and continued stewardship are important keys to replenishing these genetic resources. Producing then planting regionally harvested seeds supports the maintenance of genetically diverse crop lines. Furthermore, these practices bolster crop adaptive capacity and resilience against catastrophic crop disease (Khoury et al. 2022). The benefits of local seed production reach far beyond the field. Many landrace varieties have long-standing cultural and ethnoecological significance to the region that is maintained by smallholder farmers (Zeven 1998).

There are many challenges to on-farm seed production. Farmers may lack seed production experience or accessibility to information on these practices. Other barriers may be inadequate labor supply, time, and resources necessary to cultivate, manage, harvest, process, and store high-quality seed crops. Simultaneously, regional environmental conditions, such as high humidity and temperature, may hinder successful seed production. Farmers may then question whether seed production is profitable given the previous challenges. Additionally, the initial source of seeds can influence subsequent crop quality by impacting the ability to adapt to local environmental conditions and disease pressure. Seed quality is a critical factor for producing plants with normal and uniform seedling establishment, high-yielding capacity, and tolerance to stressful field conditions.

Florida is a major global agricultural epicenter with vegetable production accounting for a large proportion of exports (Florida Department of Agriculture and Consumer Services 2022). Domestically, Florida is the second highest-yielding state in terms of revenue generated from the sale of fresh vegetables (US Department of Agriculture, National Agriculture Statistics Service 2017). Almost all the vegetable crops grown in Florida are propagated by seeds. However, despite the abundance of vegetable production within the state, most vegetable seed production occurs outside the southeastern region of the United States. Persistently high levels of relative humidity and temperature, along with nutrient-poor, rapidly draining soils are often mentioned as reasons for the lack of seed production in Florida. This production gap leaves farmers with limited options for sourcing seeds. Many must opt for seeds of commercial varieties that have widespread adaptability but require substantial inputs for crop management.

In response, some southeastern farmers are expressing interest in the nearly lost practice of producing farm-grown seeds from open-pollinated crops, particularly for species that may demonstrate appropriate market demand and regional adaptability. ‘Yukina Savoy’ (Brassica rapa L.) is an heirloom, cool weather, annual vegetable crop that meets these criteria. It produces a basal rosette and is harvested for its leaves, much like tatsoi (Brassica rapa ssp. narinos L.). ‘Yukina Savoy’ typically reaches market maturity in 28 d. It is currently produced in the north-central Florida region and farmers have expressed an interest in it as a crop for seed production. There is a lack of documented agronomic studies on this crop, despite the popularity and prevalence of studies on close Brassica relatives.

Our long-term goal is to understand the impacts of local seed production on crop yield. In this study, we evaluate how plants grown from the first generation of locally saved seeds compare with plants grown from parent, commercially available seeds grown outside the region. We evaluate how seed source impacts seedling height at transplant and traits including plant height, crown width, biomass production, and plant vigor.
Materials and Methods

Seed sources. We initially purchased ‘Yukina Savoy’ seeds from a commercial supplier (Kitazawa Seed Company, Salt Lake City, UT, USA) and received seeds in the laboratory on 29 Oct 2019 (label germination: 85%, test date: Sep 2019). The seeds originated from open-pollinated plants grown in Italy. More detailed information on seed origin was unavailable. We then distributed seeds from our initial purchase to three local (Gainesville, FL, USA) farmer partners for late fall planting. Farm 1 sowed seeds on 31 Oct 2019, and Farms 2 and 3 sowed seeds on 11 Nov 2019. Our partners cultivated ‘Yukina Savoy’ plants according to their farm-specific production plans. Farm 1 directly sowed seeds into their production fields, whereas Farms 2 and 3 propagated seeds in plastic cell trays then transplanted seedlings into the field. Farm 1 preamended the bed with heat-treated chicken manure (0.224 kg/m²). After direct seeding, they thinned the plants to 0.305-m spacing.
Farm 1 irrigated twice weekly with an overhead irrigation reel. They applied three rounds of fertilizer during the growth cycle. The mixture included fish emulsion (Indian River Organics, Maitland, FL, USA), seaweed powder, and diatomaceous earth. Their pest management consisted of two to three rotations of chrysanthemum extract (PyGanic, McLaughlin Gormley King Company, Minneapolis, MN, USA), Spinosad (Entrust SC, Dow AgroSciences, Indianapolis, IN, USA), and Bacillus thuringiensis (DiPel DF, Valent BioSciences, Libertyville, IL, USA) throughout the cultivation period. They managed weeds with a weed torch as necessary.

Farm 2 preamended the bed with 10N–2P–8K fertilizer (Nature Safe, Irving, TX, USA) at a rate of 0.017 kg m⁻², which was the only fertility treatment that the bed received during the production period. They transplanted seedlings to 0.305-m spacing. Farm 2 irrigated by dripline at 0.153-m spacing and ran four times per day for 4 min during the seedling stage. Once the plants were mature, drip irrigation ran three times a day for 4 min. The garden bed was maintained by hand weeding as necessary.

Farm 3 preamended the bed with on-farm compost consisting of mulch and chicken manure, as well as 10N–2P–8K fertilizer (Nature Safe, Irving, TX, USA) at a rate of 0.073 kg m⁻². They transplanted onto plastic mulch with 0.457-m spacing. They irrigated twice a day for 20 min by dripline irrigation. Pest management included biweekly rotating applications of Entrust and PyGanic. Beds were weeded by hand, and aisleways were cultivated by a tractor as necessary. Farmers did not have other Brassica sp. in flower during the ‘Yukina Savoy’ seed production trial. We allowed ‘Yukina Savoy’ plants to cross-pollinate then harvested dry, mature siliques at the dehiscence stage in Apr 2020. We removed seeds from fruits in the laboratory then stored seeds (ca. 10% moisture content, 4 °C) in a refrigerator until commencement of trials in Nov 2021.

Laboratory germination testing. We performed an initial germination test on all four seed lots before the field experiment. We placed four samples of 25 seeds each per seed lot on one sheet of moist blotter paper (Blue Steel, Anchor Paper, St. Paul, MN, USA) in polystyrene germination boxes (156C, Hoffman Manufacturing, Inc., Corvallis, OR, USA). We then transferred boxes into growth chambers (130VL, Percival Scientific Inc., Perry, IA, USA) programmed to 25 °C and a 12-h photoperiod. We irrigated blotters with 0.2% solution of Plant Preservative Mixture (PPM; Plant Cell Technologies, Washington, DC, USA) as necessary and made observations daily for 28 d. We defined

<table>
<thead>
<tr>
<th>Seed source</th>
<th>t₀ [95% CI]</th>
<th>t₀ [95% CI]</th>
<th>μ₁ [t₀]</th>
<th>μ₂ [t₀]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm 1</td>
<td>2 [−−]</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Farm 2</td>
<td>2 [−−]</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Farm 3</td>
<td>3 [−−]</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Commercial</td>
<td>3 [3,4]</td>
<td>0.33</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* 95% confidence interval.
  a 0 refers to 10% and 90% of the seed population germinating on the same day.

![Graph A](image)

Fig. 3. Average (+ SE) length (cm) of Brassica rapa seedlings four weeks after sowing. Lowercase letters indicate a significant difference between treatments (P < 0.05). Eta-squared (η²) value denotes effect size of seed source on seedling height.

![Graph B](image)

Fig. 4. Average plant height (centimeters) and crown diameter (centimeters) of Brassica rapa across a 4-week growth period. Lowercase letters indicate a significant difference between treatments (P < 0.05).
Evaluation of crop traits from plants of different seed sources. We produced ‘Yukina Savoy’ transplants from all seed sources by sowing seeds (15 Oct 2021) in 128-cell trays filled with a soilless germination media (Proline C/GP, Jolly Gardener Inc., Poland Spring, ME, USA). We randomly assigned trays to a bench within a non–climate-controlled greenhouse, provided irrigation daily by misting overhead for 1 to 2 min, and grew seedlings for 14 d. We established a field plot (21.9 \times 0.9 \text{ m}) with a north–south orientation at the University of Florida’s sustainable agriculture farm in Gainesville, FL, USA (lat. 29.6445\textdegree N, long. 82.3625\textdegree W, elevation 20.12 m) during the seedling production period. Our field experiment consisted of transplanting seedlings (29 Oct 2021) from the four seed sources in a randomized complete block design replicated four times (Fig. 1). We blocked across a slight north to south elevational gradient. We created four planting rows, spaced 0.203 m apart, across the blocks and spaced transplants 0.305 m apart within rows. We randomly assigned seed lots to planting rows within each block after the seedling production period then transplanted 16 seedlings from each of the four seed lots into the appropriate treatment within all four blocks \( (n = 64 \text{ seedlings per treatment}) \). We irrigated plants by drip line for 6 min twice daily when rainfall was absent. We applied fertilizer \((10\text{N–}2\text{P–}8\text{K, rate } = 0.020 \text{ kg m}^{-2})\) to the field plot 10 d before transplanting.

We measured seedling length before transplanting them into the field. Seedling length was measured from the base of the hypocotyl to the shoot tip. We then measured plant height, crown width, and vigor on a weekly basis for 4 weeks for all plants in the experiment. We calculated plant height from the base of the rosette to the tip of the tallest leaf. We summed two perpendicular width measurements then took the average for crown diameter measurements. We used an index \((1 = \text{poor}, 2 = \text{stunted}, 3 = \text{fair}, 4 = \text{good}, 5 = \text{excellent})\) to assess plant vigor. Vigor was assessed by considering rosette fullness, leaf number and size, and the presence of pest damage. The same researcher measured vigor weekly.

‘Yukina Savoy’ plants reached harvest maturity after 28 d. Subsequently, we randomly selected four plants per seed lot within each block \( (n = 16 \text{ plants per treatment}) \) then measured the fresh weight of leaves and roots. We rinsed soil from roots in the field, gently shook excess water from roots, and allowed roots to air dry for 3 min before measurements. We then placed leaves and roots in brown paper bags, transferred these into a drying oven set to 70 \textdegree C, and dried the biomass for 96 h after which time we recorded dry mass.

Statistical analysis. We used nonparametric time-to-event analyses to assess temporal patterns of germination and calculate germination parameters. We generated quartile estimates of germination from the product-limit survival estimates. Quartile estimates correspond

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Fig. 5. Vigor indices (1–5) of Brassica rapa from four seed sources across a 4-week growth period. Vigor is ranked from 1 to 5 (1 = poor, 2 = stunted, 3 = fair, 4 = good, 5 = excellent) and indicated by red, pink, grey, purple, and blue, respectively.
to the smallest event times such that the probability of germination earlier is greater than 0.25, 0.50, or 0.75. We calculated germination rate as the inverse of median germination time ($1 \cdot T_{50}$). Germination uniformity ($U$) was calculated as $U = \frac{T_{90} - T_{10}}{10}$, where $T_{90}$ and $T_{10}$ represent the number of days for the seed samples to reach germination probabilities >0.90 and 0.10. We generated Kaplan-Meier estimates of survivor functions for all germination data and stratified survivor functions by seed source. We then used the log-rank statistic to test the null hypothesis that temporal patterns of germination were the same between seed sources. We assessed significant differences in temporal germination patterns by multiple pairwise comparisons with Bonferroni correction ($z = 0.05$) where appropriate. We used the chi-square goodness of fit test to evaluate the number of germinated seeds from each seed lot.

We used analysis of variance (ANOVA; i.e., PROC GLM) to evaluate seedling lengths after the 14-d greenhouse production period and compared means with the Bonferroni-adjusted least square means approach ($\alpha = 0.05$).

Next, we evaluated changes in plant height and crown width using generalized linear mixed model ANOVA (i.e., PROC GLMMIX) with weeks as the random variable, the effects of block and farm held as fixed variables, and repeated measures taken on plants within each seed source. We applied the Kenward Roger correction, modeled covariance structure based on Akaike’s and Bayesian information criteria, and specified a first-order autoregressive covariance structure for height and a heterogeneous Toeplitz covariance structure for crown diameter in these analyses (Kenward and Roger 2009; Stroup et al. 2018). We also used the least squares means procedure to evaluate planned comparisons.

Alternatively, we applied the generalized estimating equation (GEE) approach to assess repeated measures (i.e., PROC GENMOD) associated with weekly changes in plant vigor given the categorical nature of this data (Stokes et al. 2012). We specified the cumulative logit as the link function, a multinomial distribution, and an independent correlation structure. We extended the GEE method to analyze planned comparisons by constructing single degree of freedom (df) orthogonal contrasts for differences in vigor within seed sources and time after transplanting ($\alpha = 0.05$). Finally, we employed multivariate ANOVA (i.e., PROC GLM) to examine differences in above- and below-ground biomass production among the four seed sources and examine correlations among the dependent variables. We then created orthogonal contrasts to test the hypothesis ($\alpha = 0.05$) that biomass measurements of plants produced from seeds of the original commercial source differ from that of other sources. We assessed effect sizes by calculating Cohen’s $d$, $r$, and partial eta-squared ($\eta^2$) where appropriate and used the standardized parameter methods to calculate effect sizes for mixed model and GEE approaches (Ben-Shachar et al. 2020). We performed all analyses in statistical software (SAS ver. 9.4; SAS Institute Inc., Cary, NC, USA).

### Results

#### Seed germination

Final germination at 28 d reached 99% across the locally produced seeds but decreased to 94% for seeds from the commercial lot. The chi-square goodness-of-fit test did not detect a significant difference in germination proportion ($\chi^2 = 0.19$, $P < 0.05$). However, temporal patterns indicated that germination was 1.5-fold faster and twice as uniform in seeds grown from Florida sources compared with their commercial counterpart (Fig. 2, Table 1). The null hypothesis that temporal germination patterns were the same across seed lots was rejected (log-rank $\chi^2 = 337.0, P < 0.0001$). Multiple comparisons indicated that germination patterns were similar ($\chi^2 = 0.00, P = 1.00$) across Florida seed sources, but significantly different ($\chi^2 = 229.0, P = 0.0001$) when comparing Florida seed sources to the commercial seed source (Fig. 2).

#### Crop quality characteristics

Transplants produced from locally and commercially sourced seeds grew to ~1.4 and 1.1 cm in length, respectively, during the 14-d greenhouse production cycle. Analysis of variance detected a significant ($F_{3, 245} = 10.46, P < 0.0001$) seed source effect on seedling length. Multiple comparisons revealed that lengths of seedlings derived from locally produced seeds differed significantly from seedling lengths of transplants from the commercial source but not each other (Fig. 3). ‘Yukina Savoy’ plants from all seed sources grew considerably after transplanting (Figs. 3, 4A, and 4B). However, plants produced from seeds of the commercial source always underperformed in terms of vegetative growth compared with plants from local seed sources.

For example, 1 week after transplant, the heights of plants from the local seed sources were ~23% to 30% greater than that of plants from the commercial source. These differences persisted until harvest at week 4. At this stage, plants from local seeds remained ~8% to 12% taller than plants from commercial seeds (Fig. 4A). Plant diameters 1 week after transplant were ~35% to 38% greater for plants from local seeds than commercial seeds. However, differences in diameter throughout the field growing period were larger (~20%) than differences in heights (8% to 12%). Plant diameters were roughly 21% to 25% larger for plants grown from local seeds compared with those of the commercial source at harvest (Fig. 4B). The mixed model repeated-measures ANOVA revealed a statistically significant interaction between seed source and weeks since transplanting on plant height ($F_{5, 591} = 7.39$, $P = 0.0032$) and diameter ($F_{5, 540} = 4.57$, $P < 0.0001$) suggesting that the effect of seed source on the selected vegetative traits differed as plants grew during the 4-week production cycle. We examined these interactions in greater detail by comparing plant heights and diameters across the four seed sources at each time point.

Interactive effects only appeared for the heights of plants grown from locally sourced seeds, and these were more noticeable during the second through fourth weeks of production. For example, plants grown from Farm 1 seeds were somewhat taller than plants grown from Farms 1 or 2 seeds during weeks 1 and 2. However, plants from Farm 3 seeds were somewhat shorter than plants from Farms 1 or 2 seeds after 3 and 4 weeks of growth.
production. Nonetheless, the only difference in height among locally sourced seeds occurred during week 2. Alternatively, plants from the commercial seed source always displayed significantly shorter plants (Fig. 4A).

Likewise, plants from the commercial seed source displayed significantly smaller crown diameter compared with plants from all local seed sources (Fig. 4B). Negligible and nonsignificant differences in diameter were evident between plants sourced from local seeds during weeks 1, 2, and 4. However, at week 3, Farm 2 had larger average crown diameter than Farms 1 and 3 (Fig. 4B). The partial $\eta^2$ value ($\eta^2 = 0.13$) indicated a medium effect size of the farms on height. However, the farm effect size on crown diameter was large ($\eta^2 = 0.35$).

Plant vigor was mostly moderate (i.e., vigor index value = 3) 1 week after transplanting but increased as the time since transplanting increased (Fig. 5). The increase in vigor index was most evident for plants grown from local seed sources rather than the commercial source. For instance, most plants from the commercial seed source displayed a vigor index of 3 throughout the 4-week production time. However, the proportion of plants grown from locally sourced seeds displaying vigor index values $\geq$ 4 increased considerably from the second through fourth weeks of production (Fig. 5). The generalized estimating equation approach detected a significant seed source × week interaction ($\chi^2 = 35.1$, $P < 0.0001$) but no block effects ($\chi^2 = 0.75$, $P = 0.81$), suggesting that the effect of seed source on plant vigor depended on time since transplanting. However, the interactive effect was small (Cohen’s $w = 0.19$). Single df contrasts from the GEE analysis revealed that plant vigor differed significantly between plants from locally sourced seeds and those produced from the commercial lot, but vigor was not different among plants from the locally sourced seeds (Table 2). Vigor differed significantly between the first through fourth and second through fourth weeks after transplanting but not between the third and fourth weeks of field production. The strongest effects occurred for differences between the first week and any subsequent week of production (Table 3).

Plants grown from commercial seeds also underperformed in terms of biomass produced at harvest compared with plants grown from locally produced seeds. Plants derived from the commercial seed lot displayed a 46% to 55% reduction in leaf fresh and dry mass (Fig. 6A and B) and a 46% to 66% reduction in root fresh and dry mass (Fig. 6C and D) compared with plants from the local seeds. The largest differences occurred for root dry mass.

The moderate to strong correlations between dependent variables (Table 4) further justified use of multivariate ANOVA. This method detected highly significant seed source (Wilks’s $\lambda = 0.54$, $F_{12, 143.2} = 3.16$, $P = 0.0005$) and block effects (Wilks’s $\lambda = 0.49$, $F_{12, 143.2} = 3.61$, $P = 0.0001$) on the biomass variables. Furthermore, partial $\eta^2$ values indicated large effects of seed source on biomass variables (Fig. 6A–D). Ensuing single df contrasts from the GEE analysis revealed that plant vigor differed significantly between the first through fourth and second through fourth weeks after transplanting but not between the third and fourth weeks of field production. The strongest effects occurred for differences between the first week and any subsequent week of production (Table 3).

Fig. 6. Aerial and root fresh and dry mass yield of *Brassica rapa* at the end of the 4-week growth period. Lowercase letters indicate a significant difference between treatments ($P < 0.05$). Eta-squared ($\eta^2$) value denotes effect size of seed source on harvest mass.
conomic consequences include the cost of addi-
compensate for emergence failure. The eco-
for direct seeding may have to overseed to
thus leading to a missing production unit,
Seeds with poor vigor may fail to emerge,
impact total yield and produce nonuniform
mity in seedling emergence can signi-
production period. Delayed or poor unifor-
mained high quality, despite the local
farm-saved seeds and may have some level of ac-
differences. First, the commercial seed lot is in-
herently older than the first generation of local,
farm-saved seeds and may have some level of ac-
culated aging-induced damage. For example, the
seed supplier could not provide the exact age of
the seeds due to the unknown period from har-
vest by the commercial source until our purchase
in Oct 2019. Likewise, the supplier could not pro-
vide information regarding postharvest storage
and handling conditions. Extended periods of sub-
opimal postharvest conditions such as improper
storage temperatures and seed moisture levels
along with mechanical damage associated with
harvesting, processing, packaging, and transporta-
tion can lead to seed quality deterioration. Un-
regulated climatic factors deteriorate quality by
inducing oxidative stress, leading to aging and
ultimate loss of viability (Zhang et al. 2021). Fur-
thermore, high humidity and temperature condi-
tions enable the growth of seed-borne pathogenic
d fungi and bacteria, thus also leading to deteriora-
tion of quality (Martin et al. 2022).

Next, germination assays conducted in the
laboratory under benign conditions are not
able of reflecting the comprehensive quality of
the seed lot nor the ability of a seed lot to
withstand unfavorable or stressful environ-
mental conditions. Seeds first lose vigor dur-
ing the process of deterioration. Vigor loss is
then followed by viability loss (Delouche and
Caldwell 1962). Thus, a seed lot may maintain
a high germination percentage while having
decreased vigor. It appears that the commer-
cial seed lot reflects these principles compared
with the seeds produced from Florida-grown
plants given the slower and less uniform ger-
mination in laboratory tests combined with
slower, more erratic emergence that culmi-
nated in smaller greenhouse-grown seedlings
(Figs. 2, 3, and 7). Seed viability and vigor are
therefore vital characteristics that impact crop
establishment, marketable yield, and long-term
production success (Finch-Savage and Bassel
2016).

In addition to having more robust seedlings,
plants from Florida sourced seeds produced
larger plants across all 4 weeks of growth. Alter-
natively, plants from seeds of the commercial
source significantly underperformed in terms
of plant vigor. At the end of the growth period,
Florida-sourced seed plants produced 46% higher
marketable harvest yield compared with the
plants grown from commercial seeds. ‘Yu-
kina Savoy’ plants from Florida-sourced seeds
could have displayed higher plant vigor due to
improved adaptability to withstand stressors in
the local environment. This type of improvement
has been attributed to transgenerational stress
memory. The transgenerational stress memory
hypothesis refers to the ability of a plant to re-
spond to a reoccurring environmental signal
with an adaptive epigenetic modification

These epigenetic changes have been ob-
served as DNA methylation, histone modifi-
cation, and changes in the positioning of the
nucleosome which help plants overcome in-
tergenerational environmental challenges by
conferring greater phenotypic plasticity and
resilience to biotic and abiotic stressors (Bej
and Basak 2017; Holeski et al. 2012; Lamke
and Baule 2017). For instance, Hatzig et al.
(2018) and Racette et al. (2020) demonstrated
that parental crops exposed to drought condi-
tions produce offspring with higher seedling
vigor and emergence. Although the underly-
ing mechanisms behind the vigor differences
in the commercially and locally sourced seeds
are yet to be fully elucidated, the results of
the study illustrate that ‘Yukina Savoy’ is a
good candidate for seed production in the re-
region. Farm-produced seeds across all three
local farms maintained high quality, despite
varying farming management practices dur-
ing the seed production period.

Discussion

Seed quality plays an important role in
seedling emergence and stand establishment,
which subsequently impacts crop success.
This is especially relevant for vegetable crops
such as ‘Yukina Savoy’ where one seed pro-
duces one harvestable head at the end of the
production period. Delayed or poor unifor-
mity in seedling emergence can significantly
total yield and produce nonuniform crop stands that may complicate harvest.
Seeds with poor vigor may fail to emerge,
thus leading to a missing production unit,
which a farmer may have to back plant
(Bradford and Bello 2022). Farmers who opt
for direct seeding may have to oversee to
compensate for emergence failure. The eco-
nomic consequences include the cost of ad-
ditional seeds and the labor necessary to thin
the field. Furthermore, overseeding may cre-
ate competition for space and resources in the
seedling rhizosphere. Seed vigor also has a
direct relationship to vegetative growth, so
high-quality seeds are crucial for crops such as
‘Yukina Savoy’ that are harvested for their
vegetative mass (TeKrony and Egli 1991).

‘Yukina Savoy’ seeds produced on the three
Florida farms displayed a slight advantage in
total germination (viz. 99%) during laboratory
tests compared with seeds from the com-
cmercial, parental seed lot (94%). However, the lo-
cally saved seed lots displayed faster and more
uniform germination than seeds from the
commercial seed lot (Fig. 2, Table 1). We ob-
served similar patterns of emergence when eval-
uating seedlings produced in the non-
climate-controlled greenhouse (Fig. 7). More-
over, seedlings from locally sourced seeds were
on average 1.25-fold larger than seedlings from
commercially sourced seeds. Collectively,
this variation suggests potential vigor differ-
ces between the local and commercial seed
lots.

Various explanations exist for these seed vigor
differences. First, the commercial seed lot is in-
herently older than the first generation of local,
farm-saved seeds and may have some level of ac-
culated aging-induced damage. For example, the
seed supplier could not provide the exact age of
the seeds due to the unknown period from har-
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then followed by viability loss (Delouche and
Caldwell 1962). Thus, a seed lot may maintain
a high germination percentage while having
decreased vigor. It appears that the commer-
cial seed lot reflects these principles compared

Conclusion

We demonstrate that the production of high-quality vegetable seeds in north-central
Florida is achievable despite the climatic challenges that plague this region and differ-
cultivation practices employed by farm-
ers. Furthermore, this study emphasizes the
importance of seed vigor, in addition to seed
viability, as an important component of seed
quality that should be investigated for other
crops that farmers may target for seed pro-
duction. For example, direct seeding is bene-
ficial and often preferred by farmers because
of the additional costs associated with produ-
ducing and installing transplants. However,
direct seeding may be a riskier option when
sowing seeds with compromised vigor due to
a reduced ability to tolerate stressful field

Fig. 7. A sample of ‘Yukina Savoy’ seedlings before transplanting. Seedlings in the upper left are from 
commercially sourced seeds. All other seedlings are from Florida farm produced seeds.
conditions during seedling establishment. Ultimately, ‘Yukina Savoy’ represents a good candidate for continued seed production in the southeastern region, and results from this study may spark further enthusiasm among southeastern farmers to consider on-farm seed production.

References Cited


