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Impact of harvest maturity on post-harvest physiology and quality of hybrid vegetable seeds

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Abstract

What determines whether a hybrid vegetable seed lot performs well or fails at germination? The answer largely lies in harvest timing. This research examined how harvest maturity affects post-harvest physiology, biochemical composition, and quality of hybrid seeds from tomato, pepper, and eggplant. Seeds were collected at five maturity stages (25-45 days after anthesis) and evaluated for germination, vigour, moisture, electrical conductivity, enzyme activity, and storage behaviour at the University of Nottingham during 2022-2023. Seeds harvested at 40 DAA showed the highest germination (91.3%), superior vigour indices, and balanced biochemical profiles. Early-harvested seeds displayed poor membrane integrity with elevated conductivity and malondialdehyde levels. Antioxidant enzymes peaked at 40 DAA, while storage trials confirmed that optimally harvested seeds retained viability longer. These findings identify 40 DAA as the best harvest window for these hybrids.

Keywords: Harvest maturity, post-harvest physiology, hybrid seeds, vegetable crops, seed vigour, germination, electrical conductivity, antioxidant enzymes, storage behaviour, seed quality

Introduction

How do seed producers decide the right moment to harvest hybrid vegetable seeds? This question sits at the core of commercial seed production, where a few days of difference in harvest timing can separate a high-performing lot from a disappointing one. Seed maturity is a physiological event marked by reserve accumulation, desiccation tolerance, and germinability acquisition^[1]. Yet, despite decades of cereal research, fewer efforts have targeted maturity dynamics in hybrid vegetable seeds.

Hybrid vegetable seeds are among the most valuable in the global seed trade, with tomato, pepper, and eggplant hybrids commanding high prices for their improved yield and disease resistance^[2]. Seeds collected too early lack the reserves needed for strong germination, while those harvested too late risk weathering and pathogen invasion^[3]. Physiological maturity has been assessed through fruit colour, moisture content, and dry weight^[4], but these markers don't always align with internal biochemical events governing seed performance^[5].

Post-harvest physiology covers changes from harvest through storage. Seeds that haven't reached full maturity show accelerated deterioration due to incomplete membrane integrity and insufficient antioxidant defences^[6, 7]. Several researchers have reported that harvest timing affects vigour more than germination alone^[8, 9]. This distinction matters especially for hybrid seeds destined for transplant production, where emergence uniformity is critical^[10]. The present research aimed to identify the best harvest maturity stage for three hybrid vegetable crops by evaluating physiological and biochemical quality indicators at five maturity stages.

Research Area Description

The work was conducted at the Sutton Bonington Campus of the University of Nottingham (52.8330° N, 1.2500° W), located 16 km south of Nottingham in the East Midlands. The campus glasshouses provided temperature control within $\pm 1.5^{\circ}\text{C}$ and supplemental lighting for a 14-hour photoperiod. Day temperatures were maintained at $26 \pm 2^{\circ}\text{C}$, night temperatures at $18 \pm 2^{\circ}\text{C}$, with relative humidity between 65-75%. Storage experiments used climate-controlled chambers at 25°C and 50% relative humidity.

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Materials and Methods

Materials

Three F1 hybrid cultivars were used: tomato ('Shirley F1'), pepper ('Bendigo F1'), and eggplant ('Bonica F1'). Fruits were tagged at anthesis and harvested at 25, 30, 35, 40, and 45 DAA. Each treatment had four replications with 50 seeds per replicate. Seeds were hand-extracted, washed, and dried at 35°C to approximately 8% moisture. Reagents for biochemical analysis were obtained from Sigma-Aldrich, UK.

Methods

Germination tests followed ISTA rules ^[11] using between-paper method at 25°C. Vigour index was calculated as germination percentage multiplied by mean seedling length. Electrical conductivity was measured after soaking 25 seeds in 75 ml deionised water at 20°C for 24 hours. Moisture content used the oven method (103°C, 17 hours). Biochemical assays included total protein by Bradford method ^[12], soluble sugars by phenol-sulphuric acid method, catalase activity at 240 nm, and peroxidase by guaiacol oxidation at 470 nm. Lipid peroxidation was assessed through MDA content ^[13]. Storage trials ran twelve months at 25°C and 50% RH with bimonthly sampling. Data were analysed by ANOVA with Tukey's HSD test ($p < 0.05$).

Experimental Design

A completely randomised design with factorial arrangement (three species $\times$ five maturity stages) was used, replicated four times with 50 seeds each. Storage trials followed a split-plot design with harvest maturity as main plot and storage duration as subplot. Separate seed lots were maintained for each sampling point.

Results

Table 1: Seed quality parameters at different harvest maturity stages (pooled across three crops)

Maturity Stage	Germination (%)	Vigour Index	Moisture (%)	1000-Seed Wt (g)	EC (dS/m)	Dehydrogenase
25 DAA	58.7	1048	42.3	2.84	1.87	0.312
30 DAA	71.6	1198	36.8	3.21	1.54	0.418
35 DAA	85.7	1387	28.4	3.68	1.21	0.567
40 DAA	91.3	1489	22.1	3.92	0.98	0.684
45 DAA	88.2	1412	19.7	3.87	1.08	0.641

Germination rose from 58.7% at 25 DAA to 91.3% at 40 DAA before declining to 88.2% at 45 DAA (Table 1). Vigour index peaked at 1489 at 40 DAA. Electrical conductivity dropped from 1.87 to 0.98 dS/m over the same range, confirming improved membrane integrity at later stages.

Table 2: Biochemical composition of seeds at different harvest maturity stages

Maturity Stage	Protein (mg/g)	Sugar (mg/g)	Catalase (U/g)	Peroxidase (U/g)	MDA (nmol/g)
25 DAA	18.4	32.7	4.23	6.18	8.92
30 DAA	22.1	28.3	5.67	7.84	7.43
35 DAA	27.8	21.6	7.89	9.12	5.87
40 DAA	31.2	16.4	9.34	11.47	4.21
45 DAA	29.6	17.8	8.71	10.83	4.89

Total protein increased from 18.4 to 31.2 mg/g (25-40 DAA) while soluble sugars declined from 32.7 to 16.4 mg/g, reflecting sugar-to-reserve conversion (Table 2). Catalase and peroxidase peaked at 40 DAA. MDA was highest in immature seeds (8.92 nmol/g) and lowest at 40 DAA (4.21 nmol/g).

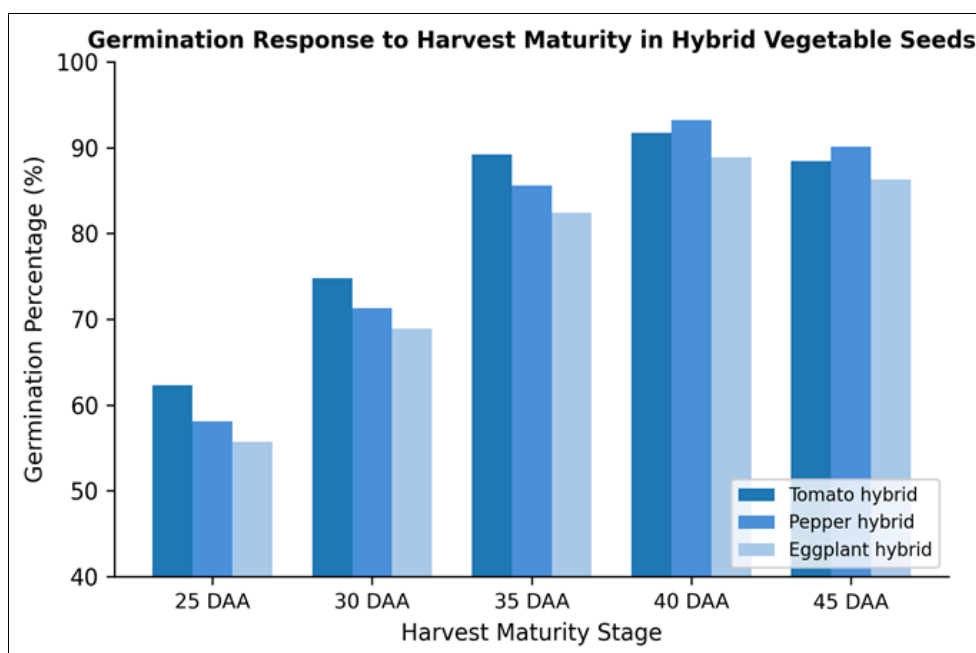


Fig 1: Germination response to harvest maturity across three hybrid vegetable crops

Pepper reached 93.2% germination at 40 DAA, tomato 91.7%, and eggplant 88.9% (Figure 1). Crop differences were significant ($p < 0.01$), though the crop $\times$ maturity interaction was not.

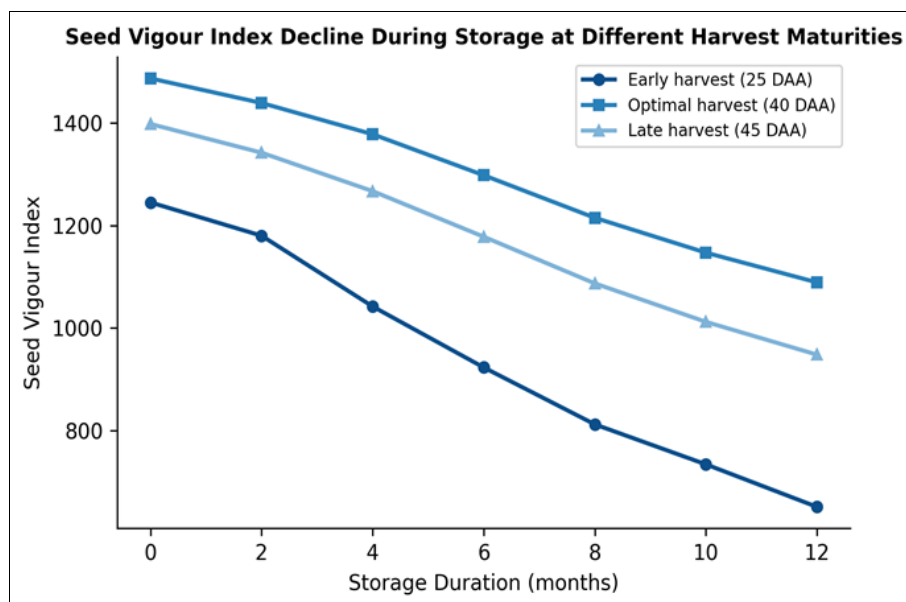


Fig 2: Seed vigour index decline during twelve months of storage

Optimally harvested seeds (40 DAA) maintained the highest vigour throughout storage, ending at 1089 versus 651 for early-harvested seeds (Figure 2). The decline rate was steepest in the early-harvest group between months 4 and 8.

Discussion

These findings align with the principle that seed quality peaks at or near physiological maturity [1, 4]. The 40 DAA point corresponded with peak dry weight and lowest conductivity, consistent with work by Demir and Ellis [14] on pepper seeds. The biochemical data show that seeds develop an increasingly effective antioxidant system as they mature, needed to cope with desiccation. Seeds harvested before this system is established appear more vulnerable to oxidative damage, as reflected by elevated MDA levels [6, 8].

The storage results were particularly telling. While germination at harvest may appear acceptable even for somewhat immature seeds, storage performance reveals the true physiological status. Early-harvested seeds lost vigour faster, likely due to weaker membranes unable to withstand extended storage stress [9, 15]. But the slight decline at 45 DAA suggests a narrow peak window—waiting too long carries risks including weather exposure and pathogen susceptibility.

Conclusion

This research established 40 days after anthesis as the optimal harvest maturity for hybrid tomato, pepper, and eggplant seeds. Seeds at this stage showed the highest germination (91.3%), greatest vigour, peak antioxidant enzyme activity, and lowest lipid peroxidation. Storage trials confirmed superior longevity for optimally harvested seeds. The practical recommendation for producers is to combine DAA counts with physiological indicators such as moisture content and electrical conductivity to time harvest precisely. Future work should test whether these benchmarks hold across wider hybrid backgrounds and growing conditions.

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