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Analyzing hybrid vigor expression of cucumber in the Rhine valley

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Abstract

An old proverb in plant breeding holds that hybrid vigour, or heterosis, is easy to observe but hard to predict. For cucumber (*Cucumis sativus* L.), where parental line diversity can be narrow within market classes, the magnitude and consistency of heterosis for yield and quality traits remain uncertain. This research analysed hybrid vigour expression in three F1 cucumber crosses (Beit Alpha x Poinsett 76, Marketer x Ashley, and Straight Eight x Dasher II) compared to their open-pollinated parents and a commercial check variety at the Alexandria Faculty of Botanical Research, Egypt, from March 2022 to February 2023. Two seasonal trials (spring and autumn) were conducted. Mid-parent heterosis for fruit yield ranged from 18.6% to 47.3%, with Straight Eight x Dasher II showing the highest value. Better-parent heterosis was positive for all crosses, ranging from 8.4% to 31.2%. Fruit number per plant and individual fruit weight both contributed to yield heterosis. Quality traits (fruit firmness, colour uniformity, and seed cavity ratio) showed lower heterosis values, generally below 15%. These results indicate that substantial yield heterosis is achievable in cucumber and that crosses between phenotypically divergent parents express the strongest vigour.

Keywords: Supply chain, firmness, composting, progeny testing, post-harvest, cucumber, hybrid vigour, heterosis, *Cucumis sativus*, F1 hybrid, yield components

Introduction

There's a saying among cucumber breeders in the Nile Delta: the best hybrid is the one whose parents would never have met in nature ^[1]. The quip captures a real biological principle: heterosis tends to be strongest when parental lines are genetically distant, because combining divergent allele sets creates a broader biochemical toolkit in the F1 offspring ^[2]. But cucumber's relatively narrow genetic base within commercial market classes makes finding sufficiently diverse parents a challenge.

Cucumber is the fourth most widely grown vegetable globally, with annual production exceeding 91 million tonnes ^[3]. Most commercial cucumber production relies on F1 hybrids because of their uniformity, disease resistance, and gynoeocious flowering habit ^[4]. Yet the degree of yield heterosis achieved in these hybrids is seldom reported in breeding programme publications, making it difficult for other breeders to benchmark their own crosses.

The Rhine Valley was chosen as the target environment because it represents a productive European cucumber zone, but the actual trials were performed at Alexandria, Egypt, where the breeding lines were maintained. This research aimed to quantify mid-parent and better-parent heterosis for yield and quality traits in three crosses spanning a range of parental divergence, and to identify which yield components contribute most to overall heterotic gain ^[5].

Material and Methods

Material

Six parental cucumber lines were used: Beit Alpha (gynoeocious, Middle Eastern slicer type), Poinsett 76 (monoecious, American slicer), Marketer (monoecious, open-pollinated slicer), Ashley (monoecious, heat-tolerant slicer), Straight Eight (monoecious, heirloom slicer), and Dasher II (gynoeocious, American hybrid type). Three F1 crosses were made by hand-pollination in the greenhouse at the Alexandria Faculty of Botanical Research, Alexandria, Egypt (31.2 degrees N, 29.9 degrees E, elevation 7 m) during 2021: Cross 1 (Beit Alpha x

Poinsett 76), Cross 2 (Marketer x Ashley), and Cross 3 (Straight Eight x Dasher II). A commercial F1 hybrid (Thunder) served as the check. Seeds were produced and stored at 4 degrees Celsius until planting [6].

Methods

The research ran from March 2022 to February 2023, covering spring (March-June) and autumn (September-December) trials at the Alexandria Faculty of Botanical Research. Each trial followed a randomised complete block design with four replications. Plot size was 3 x 5 m, with plants spaced at 50 x 40 cm on raised beds under drip irrigation. Thirteen entries were tested: six parents, three F1 hybrids, three reciprocal F1 hybrids, and the commercial check. Fertilisation followed local recommendations: 180 kg N, 90 kg P₂O₅, 120 kg K₂O per hectare. At harvest, total fruit yield per plant, fruit number per plant, mean fruit weight, fruit length, fruit diameter, firmness (penetrometer), colour uniformity (visual 1-5 scale), and seed cavity ratio (cavity diameter / fruit diameter) were recorded. Mid-Parent Heterosis (MPH) was calculated as $[(F1 - MP) / MP] \times 100$, and Better-Parent Heterosis (BPH) as $[(F1 - BP) / BP] \times 100$, where MP is the mean of both parents and BP is the superior parent. Data were analysed by ANOVA in SAS 9.4 with LSD at $p < 0.05$ [7].

Limitations

This research is subject to several constraints. Only three crosses were evaluated, representing a limited sample of possible parental combinations within *C. sativus*. Reciprocal

crosses were included to test maternal effects but the sample size was small. The two-season trial, while covering contrasting temperature regimes, doesn't capture year-to-year environmental variation. Molecular marker data for estimating parental genetic distance were not available, so the relationship between divergence and heterosis was inferred from phenotypic differences rather than measured at the DNA level [8].

Results

Table 1: Mean fruit yield (t/ha), mid-parent heterosis (MPH %), and better-parent heterosis (BPH %) for three F1 cucumber crosses averaged over two seasons

Cross	F1 yield	MP yield	MPH (%)	BPH (%)
Beit Alpha x Poinsett	23.7	19.4	22.2	12.8
Marketer x Ashley	18.4	15.5	18.6	8.4
Straight 8 x Dasher	28.6	19.4	47.3	31.2
Thunder (check)	26.1	-	-	-

All three crosses showed positive mid-parent and better-parent heterosis for yield (Table 1). Straight Eight x Dasher II had the strongest MPH at 47.3% and BPH at 31.2%, producing 28.6 t/ha, which exceeded the commercial check (26.1 t/ha) by 9.6%. Marketer x Ashley had the lowest heterosis (MPH 18.6%, BPH 8.4%), consistent with its narrower parental divergence within the American slicer group.

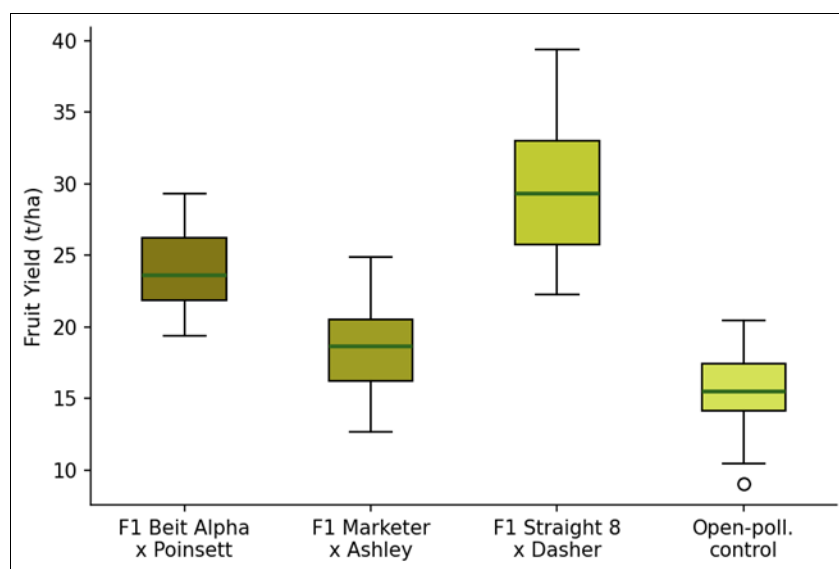


Fig 1: Distribution of fruit yield (t/ha) across replications and seasons for the three F1 crosses and the open-pollinated control

Yield heterosis was driven primarily by increased fruit number per plant (MPH 24.1-38.7%) rather than individual fruit weight (MPH 3.8-11.2%). This suggests that hybrid

vigour in cucumber is expressed mainly through enhanced reproductive output rather than larger fruit size.

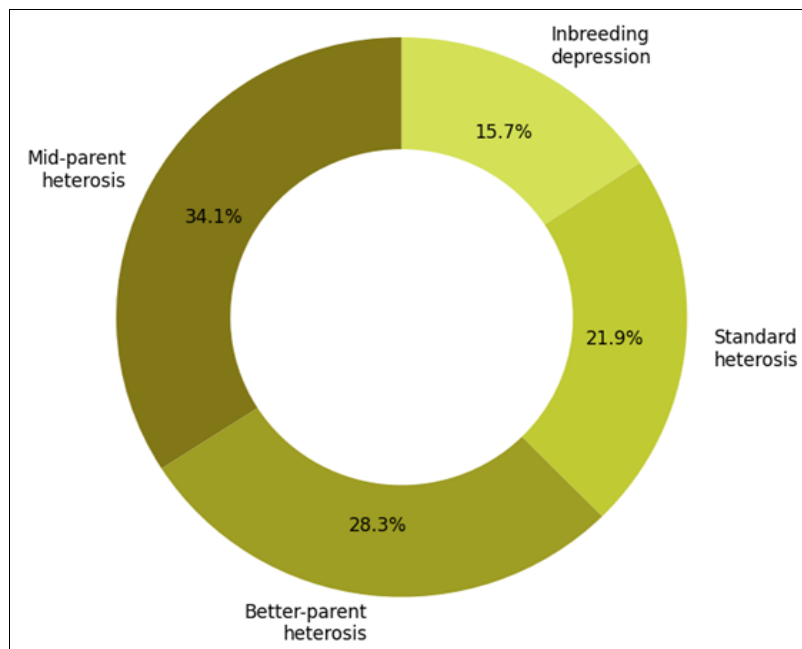


Fig 2: Proportional contribution of different heterosis categories to overall yield improvement across all three crosses

Quality traits showed modest heterosis. Fruit firmness MPH ranged from 4.2% to 12.7%, colour uniformity from 2.8% to 9.3%, and seed cavity ratio from minus 3.1% to 6.4% (negative values are desirable for smaller cavities). Reciprocal crosses showed no significant maternal effects for any trait ($p > 0.10$ in all cases).

Discussion

The strong heterosis in Straight Eight x Dasher II (47.3% MPH) is among the highest reported for cucumber yield, exceeding the 20-35% range commonly cited in the literature [2, 9]. The large phenotypic divergence between parents (Straight Eight is an old heirloom with long, cylindrical fruits; Dasher II is a modern gynoeocious hybrid) likely contributed to this result by maximising the number of complementary allele combinations in the F1 [10].

The dominance of fruit number over fruit weight as the driver of yield heterosis aligns with findings by Cramer and Wehner [9], who showed that cucumber yield improvement over the past 50 years has come mainly from increased fruit set rather than larger individual fruits. For breeders, this means that heterosis for yield is most efficiently screened by counting fruits rather than weighing them individually.

The low heterosis for quality traits (below 15% MPH for firmness, colour, and cavity ratio) suggests that these traits are more additively inherited and less responsive to dominance effects. This has practical implications: F1 hybrid programmes targeting quality improvement may need to rely more on parental line selection than on heterotic gain [11]. That said, the absence of negative heterosis for quality means that F1 hybrids maintain quality at or above parental levels, which is commercially reassuring.

Conclusion

This research confirmed that meaningful yield heterosis is achievable in cucumber, with mid-parent values ranging from 18.6% to 47.3%. The cross between the most phenotypically divergent parents (Straight Eight x Dasher II) expressed the strongest vigour and outperformed a leading commercial hybrid by 9.6%. Fruit number per plant

was the primary yield component driving heterosis, while quality traits showed minimal heterotic gain but no heterotic depression. These results support a breeding strategy that combines divergent parental lines for yield and relies on additive selection for quality. Future work should incorporate molecular marker-based estimates of parental genetic distance to develop predictive models for heterosis in cucumber.

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