

# Kaohsiung No. 3 Cucumber: An Early Flowering Variety Tolerant to Heat and Moisture

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The cucumber (*Cucumis sativus*) is a widely cultivated Cucurbitaceae crop with a global trading volume of 60 million metric tons (FAOSTAT, 2017), which reflects its dietary importance. Cucumber is used as either a fresh or processed vegetable. Multiple cucumber varieties are grown throughout the world, distinguished by usage, length, diameter, color, color uniformity, skin thickness, and surface protrusions (Shetty and Wehner, 2002). Cucumber varieties in Taiwan are mostly of the oriental trellis type, which was introduced by a Japanese seed company. Wen Nong 220, a green slicing cucumber, is currently the most popular variety in summer.

The most suitable temperature for cucumber growth is 20 to 30 °C, because temperatures higher than 35 °C can cause physiological disorders and seriously affect the fruit shape and quality (Yang et al., 2007).

Southern Taiwan has a *tropical climate* with high temperatures (26 to 28 °C) and humidity (70% to 80% in summer). However, global warming has caused a temperature rise in Taiwan, especially during the summer. According to news reports, the average temperature has risen ≈1.4 °C, which is twice the global average (Lu et al., 2012). As a result, summers in Southern Taiwan are not conducive to growing cucumbers. In Southern Taiwan, cucumbers are mainly cultivated in net houses to prevent pest infestations; however, if the indoor temperatures exceed 35 °C and moisture is increased because of restricted ventilation, then it results in the occurrence of downy mildew.

High temperatures and downy mildew not only interfere with the normal growth of cucumbers but also yield a bitter tasting fruit with a lower *quality*. Therefore, the Kaohsiung

District Agricultural Research and Extension Station (KDARES) has initiated the breeding of a new cucumber variety with tolerance to abnormally high temperatures and moisture. The new Kaohsiung No. 3 variety has the potential to flower early with vigorous growth and strong adaptation to the summer temperatures of Southern Taiwan. It is suitable for fresh slicing, with a crisp texture and no bitter taste.

F<sub>1</sub> hybrid is commonly practiced in breeding of the gourd family. The inbred lines are obtained from the monoclonal selection of several F<sub>2</sub> generations (Brim, 1966). The parents of Kaohsiung No. 3 were selected by adopting the pedigree method at early stages (F<sub>2</sub>–F<sub>4</sub>), the bulk-population method at F<sub>5</sub>–F<sub>6</sub>, and then selfed for five generations as inbreds (S<sub>5</sub>). The crosses between inbred lines were conducted and followed by observation

and line trials, as well as regional trials. A new, high-quality F<sub>1</sub> hybrid with heat tolerance was identified.

## Origin

The breeding program was initiated during the autumn of 2005 with the inclusion of germplasm collections, observation, selection, and inbred line-breeding.

The parents (KSL009 and KSL017) of Kaohsiung No. 3 were selected inbreds from a group of 40 commercial lines. After hybridization, a single plant from the F<sub>2</sub> to F<sub>3</sub> generations was selected for self-pollination, and breeding was conducted using the pedigree method. In the F<sub>4</sub>(S<sub>3</sub>) to F<sub>6</sub>(S<sub>5</sub>) generations, self-pollination was performed, and breeding was conducted by the bulk-population method. The female came from inbred line KSL009, which has a short internode, a dark green leaf, a long fruit (length:width = 6:1) with a dark green color, and white spines. The average marketable fruit weight is 100–120 g. The male came from inbred line KSL017, which has the characteristics of early flowering, strong vigor during summer, and a short fruit (length:width = 2:1) with white skin and a weight of 60–75 g.

The crossing between the inbreds was performed in the net house of KDARES (Kaohsiung, Taiwan) in the autumn of 2008. Line trials were conducted in both the spring and autumn of 2011. KSF110 (the original breeding code for Kaohsiung No. 3) was selected for its early fruit maturity, appetizing flavor, and heat tolerance. Regional trials were conducted in three areas of Southern Taiwan in the summer of 2012. The characteristic variety examinations (distinctness, uniformity, and stability testing) were carried out in both the spring and



Fig. 1. Fruit of the new cucumber variety, Kaohsiung No. 3.

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autumn of 2013. The variety was named Kaohsiung No. 3 (Fig. 1) in 2014.

### Description

The Kaohsiung No. 3 cucumber is a monoecious sex type F1 hybrid, with vigorous growth in the hot season and early maturity (Fig. 2). The skin color is emerald green with



Fig. 2. Kaohsiung No. 3 (left) has better heat tolerance than the control variety Wen Nong 220 (right) at 50 d after planting.

light-colored stripes. At the green-flesh stage (4–5 d after flowering), it is crisp and juicy. The average fruit length and width are  $12 \pm 1.0$  cm and  $3 \pm 0.8$  cm, respectively, with a length:width ratio of 4:1. The average fruit weight is  $85 \pm 7.5$  g.

Kaohsiung No. 3 and Wen Nong 220, along with the cross combinations KSF005, KSF058, KSF135, and KSF182, were planted for line trials in a net house at KDARES on 18 Apr. and 20 Oct. 2011, as well as 17 June 2012. The temperature ranges at these times were 22 to 36 °C, 18 to 35 °C, and 26 to 39 °C, respectively. A randomized complete block design with four replicates was applied for each trial, and standard production practices were followed. There were 22 plants per plot, each with an area of 12.1 m<sup>2</sup>, with 1.1 m between rows and 0.5 m between plants. Ten plants from each plot were randomly selected, and the days to female flowering, fruit length, fruit weight, and marketable yield were recorded for a month. The marketable yield was calculated by weighing the fruit in each plot and extrapolating the plot size to 1 ha.

Table 1. Days to first female flower, fruit length and weight, and the marketable yield of Kaohsiung No. 3 and Wen Nong 220 grown in the net house in the 2011–12 trials at Kaohsiung District Agricultural Research and Extension Station.

Cultivar line	Days to first female flower (days after planting)	Fruit length (cm)	Fruit wt (g)	Marketable yield <sup>2</sup> (Mg/ha)
Trial 1. Apr. 2011				
Kaohsiung No. 3	28 <sup>y</sup>	13.0*	89.3*	4.2 <sup>ns</sup>
Wen Nong 220	38	20.2	108.9	3.0
Trial 2. Oct. 2011				
Kaohsiung No. 3	29 <sup>y</sup>	12.7*	69.1*	2.8 <sup>ns</sup>
Wen Nong 220	35	21.7	93.2	2.7
Trial 3. June 2012				
Kaohsiung No. 3	29 <sup>y</sup>	12.5*	85.6*	1.38 <sup>ns</sup>
Wen Nong 220	39	20.3	98.9	1.2

<sup>2</sup>Yield is calculated for 1 mo.

<sup>y</sup>Significant at  $P \leq 0.05$ ,  $t$  test; ns = nonsignificant.

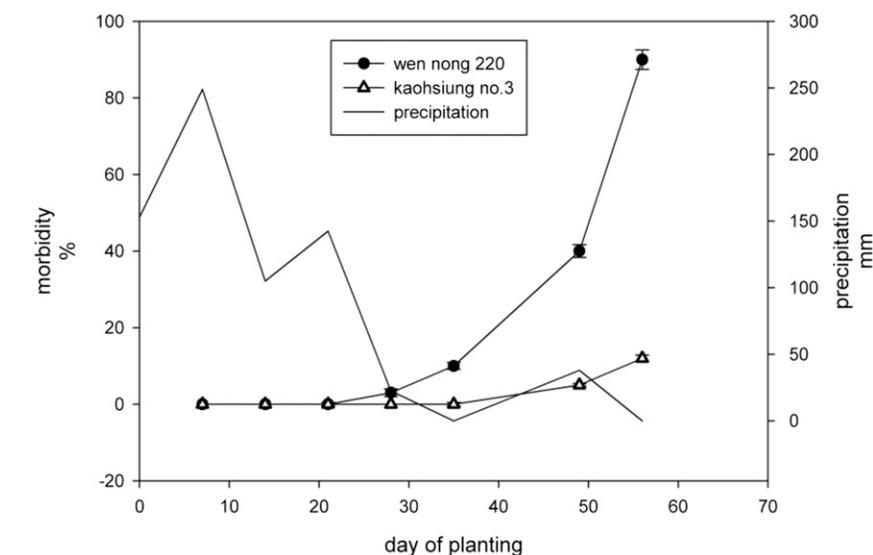


Fig. 3. Morbidity of downy mildew for Kaohsiung No. 3 and Wen Nong 220 planted on 11 June 2012. Data in the graph were quoted as mean  $\pm$  SE of the four replicates.

The data collected on these traits were analyzed using the SAS general linear model procedure (SAS Institute, Cary, NC). The means were separated using a protected least significant difference test at  $P \leq 0.05$ . A Student's unpaired  $t$  test was used to compare the performance of Kaohsiung No. 3 and Wen Nong 220 in these trials. The results showed that Kaohsiung No. 3 developed a female flower significantly earlier than Wen Nong 220, although the fruit length and weight of Kaohsiung No. 3 were significantly smaller than Wen Nong 220. No significant difference was found between the marketable yields of the two varieties (Table 1).

### Evaluation of Biotic and Abiotic Stresses

Cucurbit downy mildew [*Pseudoperonospora cubensis* (Berk. and Curt.) Rostov.] is characterized by angular chlorotic foliar lesions that quickly turn necrotic, often leading to rapid plant death (Savory et al., 2011). Cucurbit downy mildew is a devastating disease, which spreads particularly easily under humid conditions (Oerke et al., 2006). At the beginning of downy mildew disease, the symptoms on the lower leaf are small, slight chlorotic to bright yellow spot. Obviously, the lesion quickly becomes necrotic and chlorotic under high temperature. Kaohsiung No. 3 has not only less necrotic and chlorotic area but also lesion has been suppressed on the leaf (Fig. 2). Although the genetic basis of downy mildew resistance is unclear (Cohen et al., 2015), the breeding of disease resistance continues to be a high priority in cucumber improvement programs. Kaohsiung No. 3 and Wen Nong 220 seedlings at the two true leaf stage were planted on 11 June 2012, at KDARES in a net house. During the summer growth period, the daily precipitation varied from 0 to 249 mm. A randomized complete block design with four replicates was adopted for disease resistance testing. Each plot was 25 m long with 50 cm between plants and 1.2 m between rows on a single bed. Each week, 10 plants were investigated for the natural morbidity of downy mildew from each plot.

Graph preparation was performed with Sigmaplot 10 (Systat Software, San Jose, CA). The morbidity of Kaohsiung No. 3 was consistently lower than that of Wen Nong 220 at 28–56 d after planting (DAP). At 49 DAP, the morbidity of downy mildew of Wen Nong 220 exceeded 40%, whereas that of Kaohsiung No. 3 was only 5% (Fig. 3). Kaohsiung No. 3 matured earlier and was better adapted to the humid, hot weather than was Wen Nong 220.

Antioxidant enzyme activity can be used as an indicator of stress tolerance in cucumbers (Qian et al., 2013; Zhang et al., 2014). In this study, the fruit harvested from each replicate were used for the antioxidant enzyme activity analysis in a trial conducted in Oct. 2016. Superoxide dismutase (SOD) activity analysis was determined according to Paoletti et al. (1986); catalase (CAT),